

2. SCIENTIFIC QUESTIONS AND MOTIVATION

This chapter addresses two major topics. First, the scientific questions are presented. Next we explain why studying Northern Eurasia is a crucial opportunity to help answer these questions.

2.1. Scientific Questions

The overarching NEESPI science question is:

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

This question can be reformulated in a more 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, we must conduct the same scientific investigations. We need to specifically answer the following questions:

- *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, atmospheric composition and circulation, and Arctic Ocean and sea ice dynamics? For example, do the properties of the land system affect the Arctic Oscillation, and how does the Arctic Oscillation affect the patterns of the Northern Eurasia ecosystem? How do the changing precipitation, land use, forest cover, and permafrost affect runoff into the Arctic Ocean, and subsequent salinity and ocean circulation?*
- *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 and global ecosystems? For example, for different scenarios of future greenhouse gas and aerosol inputs, and for different forest clearing, water and agricultural land management, urban, industrial, and oil development projects, how will the ecosystem be changed? 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 regional environment, the economy, and the quality of life in Northern Eurasia? And how can science contribute to decision making on environmental issues in the region?*

The last question above, while addressing local regional problems, is in fact the most important for the nations of Northern Eurasia. This part of the world has proven to be prone to extraordinary climatic and environmental changes in the past. Sometimes, only the

remnants of these changes impact the outside world. The possible consequences of global changes in Northern Eurasia are many and we can expect others will arise as we learn more about the system.

The major uncertainty which justifies our science questions is that during the past, we have evidence of significant and rapid changes in the atmosphere, hydrosphere, cryosphere, and land cover in Northern Eurasia, but still need to accurately quantify these changes and the particular processes that caused them. Taking into account the scale and rate of changes, this situation is unacceptable. We need to develop the ability to measure, monitor, and model the processes that will provide for us future projections of climatic and environmental changes in the region because these changes may impact the Global Earth System and the human society.

Topical scientific questions that are further elaborated in Chapters 3 to 5 are structured differently for several reasons. These are briefly explained here.

Study of **Biogeochemical Cycles** is relatively young and our topical scientific questions start from climatology:

- What are the current geographical and temporal distributions of the major stores and fluxes of carbon and other elements in Northern Eurasia?

Thereafter we want to know their major processes and impacts. This leads to the next two questions.

- 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 climate system and human societies?

The answer to the second of these questions already assumes the ability to model the major processes that define the dynamics of biogeochemical cycles. Finally, we need to know our ability to control the situation. This requirement leads to the last question:

- What points of intervention and windows of opportunity exist for society to manage biogeochemical cycles in order to mitigate adverse effects in them?

For the **Surface Energy and Water Cycles** the major topical scientific question is:

- 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?

The scientific community is already at work on this question. We need a suite of calibrated land surface models that are well fed by in-situ and remote sensing observations and seamlessly interact with regional and global earth system models. But, this does not mean that this question is already answered (3.3, 3.5, 3.6, 4, and 5). In fact, the rich set of observational data available in this region (e.g., Robock et al. 2000, Schlosser et al. 2000) will go a long way toward helping us to understand these processes on a global basis). A significant part of the NEESPI Research Strategy (8) is devoted to working on this problem. We still may need to clarify the answer on another topical question for the 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?

Land Use and Society. Society affects and is being affected by the environment. Its wellbeing has been affected and will be affected by environmental changes. Thus, it can now be considered as an active and conscious part of the Earth environment. This generates a set of “societal feedback” questions that will also be a focus of the NEESPI studies:

- What land use changes are taking place in Northern Eurasia and what are their impacts on the environment and society?
- What lessons can be learned from the responses to dramatic land-use modifications during the “planned” economy period for future sustainable natural resource management?
- What will be the consequences of socio-economic changes in Northern Eurasia on the environment?
- How can science contribute to development of environmental strategies for society (societies)?

We have emphasized these questions separately because the ability to answer them intelligently provides the best and likely the only chance for correct future policy decisions related to environmental issues in the region.

Northern Eurasia is one of the regions where **Ecosystem and Climate Interactions** play a particular role. These interactions strongly control the state of the Earth system in the region and must be understood first, if we plan to properly describe and model both these components of the global Earth system. This requirement leads to a topical question:

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

Cold Regions, Coastal Zone, and Atmospheric Aerosols and Pollution were identified as cross-cutting topics of special interest. In 2.2 below, the reasons for this special interest are spelled out and the topical scientific questions are:

- **Cold Regions and Coastal Zone:** How do the changes here affect regional and global biogeochemical, surface energy and water cycles, and human society?
- **Atmospheric Aerosols and Pollution:** How do their changes affect regional and global biogeochemical, surface energy and water cycles, and human society?

Remote Sensing, Data, Information Technology, and Modeling are among the major tools of the future NEESPI studies and the topical scientific questions 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 remote sensing systems as well as in-situ observations 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?

2.2. Why 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 a nutshell, the answers are:

- The changes in this region have the potential to affect the entire Earth System 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 them, description and modeling of the entire Earth system is not possible.
- The study will have benefits to the societies of the region.
- This region possesses a wealth of scientific talent that can be utilized in this study.
- This region has been studied in detail for more than a century by Soviet and Russian research projects, yet the abundance of data that has been collected has not been utilized enough to study these problems and is in danger of being lost.

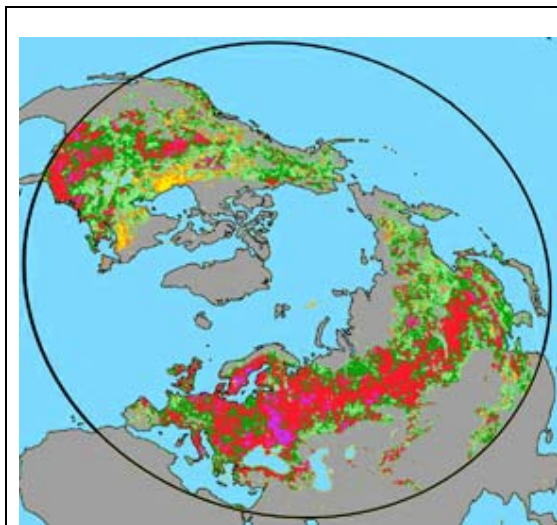
2.2.1. The Role of Changes in Northern Eurasia in the Global Earth System

Climate changes will affect Northern Eurasia to a greater degree than the rest of the planet, and this has been shown in studies of past climate change and virtually all of the simulation models of the Earth's climate system under global warming scenarios. These changes will cause and interact with changes in terrestrial ecosystems that, in turn, will feed back to regional and global climate. Society will continue changing the environment, be affected by these changes, and react to them. Therefore, it is crucial to understand Northern Eurasia as a fundamental component of the global climate and ecological system.

Being the largest land mass in the extratropics, the largest terrestrial reservoir of carbon in the biosphere, one of the regions with the largest 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 region¹.

¹ At present, Northern Eurasia accounts for more than half of the total pool of terrestrial carbon in soil, wetlands, and above-the-ground biomass. A single country in Eurasia, Russia, holds most of the Eurasian forest resources. At present, it appears that during the last decade of the 20th century, boreal forests were a net sink of atmospheric carbon, with most (around 70%) of this sink (0.4 Gt of carbon per year) located in Siberian taiga (Figure 2.1). Whether or not this region will continue to remain a carbon sink in the future is not known (3.1, 3.2, 3.5, 3.6.1).



Persistence of greening

Figure 2.1a. 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 $0.68 \pm 0.34 \text{ Gt of C yr}^{-1}$ of which nearly 70% is in Northern Eurasia.

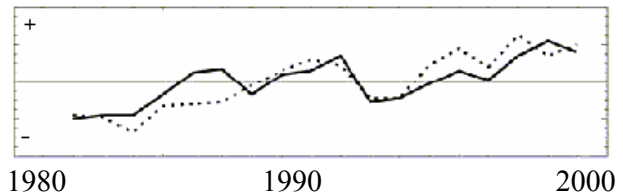


Figure 2.1b. Spatial average of NDVI from the Global Inventory Monitoring and Modeling Studies for vegetated pixels between 40°N and 70°N from 1982 to 1999 in North America (solid line) and Eurasia (dashed line). The scale of NDVI changes is from -0.04 to $+0.04$. It was suggested that observed trends in NDVI reflect on trends in atmospheric temperature, precipitation or atmospheric concentration of carbon dioxide. According to Zhou et al. (2003), air temperature changes between the early 1980s and the late 1990s were responsible for much of the observed increase in satellite measures of northern forest greenness.

- Accelerated climatic changes across Northern Eurasia may cause changes in global atmospheric circulation and meridional heat transfer (3.3; Figure 2.2).

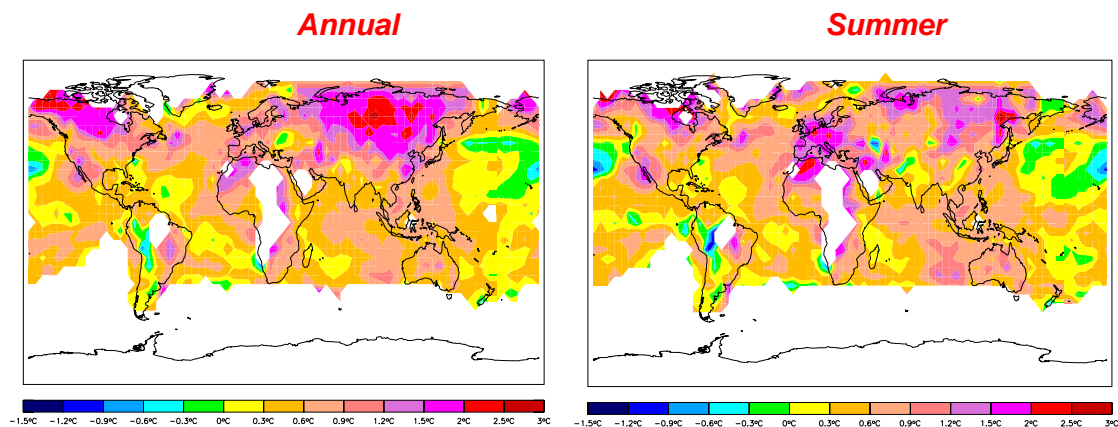


Figure 2.2. Mean Temperature Change 1965 to 2003 over the globe. Data source: <http://www.cru.uea.ac.uk/cru/data/temperature/> (Jones and Moberg 2003). Processed by the U.S. NCDC Global Climate at the Glance Mapping System.

- Changes in surface albedo (snow/ice cover, shifts in vegetation, land use change) and atmospheric humidity may change the Earth heat and water balances (3.3, 3.4, 3.5).

About half of the Northern Eurasian terrain has permafrost (Figure 2.3). Its presence 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 will produce major changes in land cover and in surface and subsurface hydrology² (3.6.1).

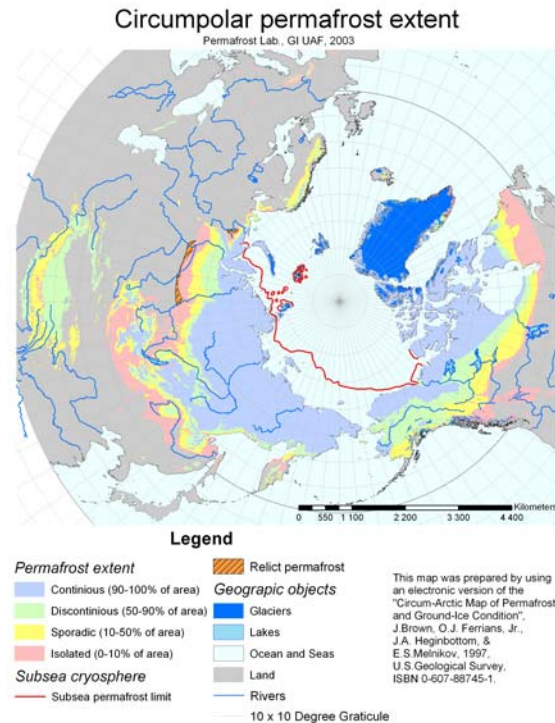


Figure 2.3. Circumpolar permafrost extent map based on the electronic version of the "Circum-Arctic Map of Permafrost and Ground-Ice Condition", J. Brown, O. J. Ferrains, Jr., J. A. Heginbottom, and E. S. Melnikov, 1997, U.S. Geological Survey. In the continuous permafrost zone, permafrost occupies the entire area (except beneath large rivers and deep lakes). In the discontinuous permafrost zone, including the sporadic zone, anywhere from 10 to 90 percent of the surface is underlain by permafrost. In the southernmost isolated permafrost zone, permafrost occupies less than 10% in a form of isolated masses within the generally permafrost-free area.

² A significant amount of potentially decomposable organic material, methane (CH₄), and carbon dioxide (CO₂) are now sequestered in permafrost and ground ice. Climate warming can potentially thaw the permafrost and greatly enhance the microbial activities in the formerly frozen soils. Thawing permafrost and melting ground ice would release the greenhouse gases into the atmosphere. If this occurs, the vast storage in the arctic and sub-arctic ecosystems of Northern Eurasia could become strong sources of CO₂. Also, in the areas of the active thermokarst lakes development, new and significant production of CH₄ will occur. Permafrost is already thawing in many areas and its degradation is expected to accelerate with future climate warming. This can significantly affect the biogeochemical cycle in the cold regions of Northern Eurasia and may create an amplifying feedback loop in the greenhouse gases composition in the atmosphere and, thus, cause a further warming. Dramatic damage to the infrastructure and changes in vegetation can be also associated with the permafrost degradation. Precipitation on a large part of permafrost area corresponds to semi-desert, however permafrost results in a perched water table and keeps the water in the root zone. Loss of permafrost is expected to increase soil drainage and may result in desertification in these areas. This also would affect, and even reverse, the tendency of increased carbon sequestration in the taiga regions of Northern Eurasia observed in the last decade (3.6.1).

- Changes in the hydrological cycle over the continent will affect the fresh water transport to the Arctic Ocean and, thus, may influence the shelf seas and the ocean thermohaline circulation (3.3).
- Deglaciation in the mountain systems of Central Asia, increasing water withdrawal, and increasing dryness of steppe and semi-arid zones will affect surface albedo, water resources, and their quality of the interior areas of the continent and, thus, the global climate and society (3.3, 3.4, 3.6.1).
- Advance/retreat of the forest line³, increase/decrease of conditions conducive for forest fires, wind-throw, and logging may lead to global biogeochemical, energy and water cycle changes (3.2, 3.3, 3.5).
- Drying of bogs over expansive areas in West Siberia and the Great Russian Plain may result in their degradation, will affect the global carbon cycle⁴, and runoff formation.

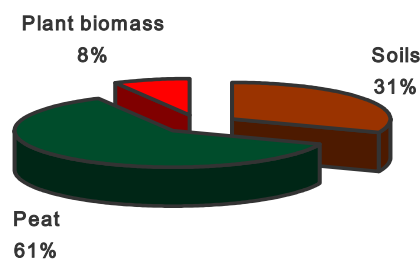


Figure 2.4. Peat is responsible for 61% of carbon storage in boreal ecosystems. Estimates of peat stores in Russia range from 45 to 138 PgC.

- Boundary exchange of fresh water, organic and non-organic matter across the extensive coastal zone may affect the world ocean circulation (3.3) and biochemical processes in the shelf seas and interior lakes (3.6.2). Intensive erosion (up to 10 m yr⁻¹ in some areas) and other coastal line changes may affect life conditions and cause enormous economic damage⁵ (3.6.2).
- Ongoing aridization of the continental interior may cause a massive aeolian aerosol input into the troposphere⁶ that can affect the Earth's heat balance and generate direct

³ The northward expansion of the forest line into the tundra zone will cause a decrease in surface albedo. However, if at the same time the southern border of the forest zone shifts northward, giving the room for forest-steppe and steppe environment, the increase in surface albedo will occur in the south. Furthermore, the surface albedo is affected by interactions in the forest - snow cover – thaw – soil and vegetation wetness system. This makes definite projections of its changes very difficult (3.5).

⁴ Much of the soil carbon in the region is stored in peatlands (Figure 2.4), which occupy an estimated 273 million ha and contain about 118 PgC in Russia alone (Vompersky et al. 1994, Alexeyev and Birdsey 1998), out of the total estimate for Northern peatlands of 358 million ha and 455 PgC (Gorham, 1991).

⁵ The coastal zone in Northern Eurasia is extensive (Figure 2.5). It contains over 40% of the entire population of Northern Eurasia and more than half of its economic resources. Capitals of several countries of the region and major industrial centers are also located in this zone. In the coastal zone, tendencies of increasing population, economic activity (especially prospecting and exploitation of oil and gas fields), sea level rise, degradation of sea coast due to wave and thermal erosion, denudation, slope processes, and pollution of the coastal bays (especially in the river deltas near large cities) are intensifying.

⁶ Atmospheric aerosols have several direct and indirect impacts on the environment and climate. Changes in the emission of these aerosols can trigger several complex feedbacks in the Earth System that are poorly quantified (IPCC 2001; 3.6.3). Atmospheric aerosols come from a wide variety of natural and anthropogenic sources and are produced via direct emission of particles (e.g., wind-blown dust from natural deserts and carbonaceous particles from natural fires) or formed via chemical reactions of gaseous precursors emitted into the atmosphere

biospheric and societal impacts thousands of kilometers away from the origin of these dust storms (3.3, 3.6.3).

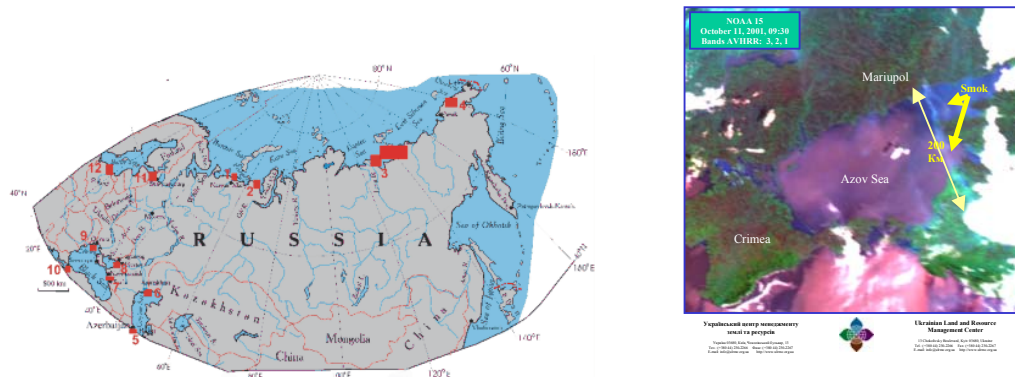


Figure 2.5. (Left) Coastal zone of Northern Eurasia with the regions most affected by past, present and projected changes (Right) Example of pollution in the coastal zone of the Sea of Azov: Smoke distribution from Mariupol Metallurgical Factory (Donbass) , October 11, 2001 (09:30).

- Human activity has changed ecosystem types over most of the steppe and forest-steppe zones and over part of the forest zone (3.1, 3.4) causing numerous biogeochemical and biogeophysical feedbacks (3.5), near-global environmental changes (box inserts A.1 and A.2 cf. Scientific Background Appendix), and affecting environmental health and quality of life⁶ (Figure 2.6; 3.4, 3.6.3).

Each of these aspects of global impact of Northern Eurasia will be discussed in Chapter 3 and in Chapters 4 through 8, where major directions of the proposed initiative are outlined.

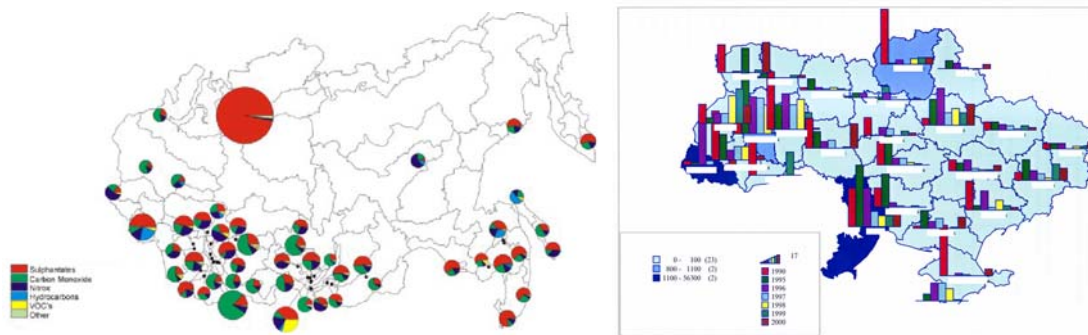


Figure 2.6. Examples that characterize the environmental health in two regions of Northern Eurasia, Siberia and The Ukraine: (Left) Volume emissions of gaseous and particulate air pollutants in Siberia (IIASA, 2003) and (Right) Emergency Contamination of Environment and Hazardous Situations in the Ukraine (Environment of Ukraine, 2001)

2.2.2 Unique features of Northern Eurasia

(e.g., sulfates formed by gas-to-particle conversion of SO_2). There is a compelling body of evidence that human activities result in increasing concentrations of lower atmospheric (tropospheric) aerosols. The lifecycle of all aerosols is closely related to the cycles of energy and water, including biogeochemical cycles. Aerosols constitute an important component of air and water pollution. For example, currently, deserts in Northern Eurasia are the second largest in the world. Varying desert area (now affected also by human activity) controls the lower tropospheric aerosol loading because deserts are the main natural source of mineral dust in the atmosphere. This loading, in turn, affects climate, environment, and human health.

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 of the global biogeochemical cycle. One of the largest storages of organic carbon is located here, which indicates that for a long period of time the region was a carbon sink, thus affecting the atmospheric composition of such greenhouse gases as methane and carbon dioxide. (3.1, 3.2, and 3.5).
- This is the world's largest cold region (more than twice as large as Antarctica) where the coldest recorded temperature has been reported in human settlement (Verhoyansk, -71°C). 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 are in Northern Eurasia. This is the region the most extensive coastal zone exposed to the permafrost thaw. Snow cover variations, effects of permafrost, and seasonal freeze/thaw/refreeze processes define, control, and put a unique signature on the Northern Eurasian climate, hydrology, and environment during most of the year (and in the permafrost areas, year round).
- This is the region where the most continental climate is observed with seasonal temperature amplitudes of ~60°C. In winter, this is a heat sink and in summer (although short in the far north), it is a source of heat for the regions east-, west-, and northward. This peculiarity of the continental surface heat balance affects the intensity of the Eurasian monsoon circulation, which is vital for the densely populated southern half of Eurasia.
- 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 not. Northern Eurasia is relatively dry, being mostly cut off from the humid tropical air masses. This is the area of the western air transfer contrary to monsoon Asia. It receives most of its moisture from extratropical cyclones coming from the west (Kuznetsova 1983), and its interiors heavily depend upon the intensity of zonal water vapor transport. Thus, the precipitation here comes with extratropical cyclones that by no means can be considered a stable source. Consequently, this is the region where the highest levels of climate and weather variability are observed and the Northern Eurasian surface modulated and probably will modulate any future external forcing imposed on the Earth Global System.
- Extensive variable dry land areas in Northern Eurasia are the largest source of dust in the extratropics due to a predominantly zonal circulation spread over mid- and high latitudes polluting areas far away from the source (Darmeneva and Sokolik 2002). Furthermore, these regions host highly vulnerable natural and man-made (e.g., agricultural) ecosystems that depend upon scarce and highly variable water resources (Vörösmarty et al. 2000).
- This is the region with the largest river, lake, and reservoir systems on the Earth. Furthermore, Northern Eurasia hosts the largest closed drainage basins on Earth (the largest of them are the Aral, Caspian, and Tarim River basins) with a total area of more than 5×10^6 km². These basins have been trapping atmospheric moisture for a long period of time (Aizen and Aizen, 1998).

Comparison with North America. There are two major continents in the northern extratropics. Thus a legitimate question is: Why would it not be enough to study environmental processes in one of them and just extrapolate the findings to the second one? The answer to this question is because in many aspects North America and Northern Eurasia

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 while they commonly do this in North America; mountain ranges and plateaus that isolate its northern part from the tropics; and different roles of extratropical oceans (Atlantic and Pacific) in the formation of climates of both continents. Furthermore, the major part of the freshwater runoff into the Arctic Ocean comes from Northern Eurasia. The geographical differences produce unique ecosystems with different reactions to external forcing and different history throughout the geological past, and unique combinations of atmospheric circulation conditions and controls that vary differently with global Earth system changes. Human activity added a new and distinctively different feature to each of the continents. Finally, synergy of all the above generated, and will generate in the future, different feedbacks and patterns of environmental changes. The bottom line here is: 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. The annual surface radiative balance is usually a positive value and, in Northern Eurasia, these values are lower than in the southern regions. Low air temperatures and soil moisture deficit are associated with low values of latent heat fluxes and low precipitation. This together with a long cold season and extensive desert areas suppress the intensity of the water cycle in Northern Eurasia. At the same time, variations in the energy budget (e.g., disturbances due to greenhouse gases increase or vary meridional heat transport controlled by the North Atlantic Oscillation) or in the water cycle (e.g., reduction in storm activity or depletion of the water storage due to deglaciation) do not need to be huge to cause significant relative perturbations in the regional weather conditions and terrestrial hydrology. This low intensity but high variability of processes in Northern Eurasia creates a twofold problem. It is difficult both to monitor these processes and to study them. On the other hand, this raises the importance of information about energy and water cycles in Northern Eurasia. 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. Numerous unresolved problems are listed at the end of Sections 3.2, 3.3, and 3.5.

Box insert. Some historical considerations that separate the Northern Eurasia.

“Northern Eurasia” with its suggested borders (Figure 1.1) is very close to the “Eurasian geographical world” of Eurasists – political and scientific school in the first (“white”) Russian emigration (Savitsky, 1927). The school considered most of old Russia as a specific geographical world, “Eurasia”, which together with two others worlds - “Europe” (Western Europe in common use) and “Asia” (the rest of common Asia) form the Eurasian continent. Savitsky insisted that these geographical features determine the past and future history, economy, culture, etc. Just follow his predictions we associate now with Northern Eurasia “regions in transition”, i.e., those with societal, land use, and economic changes.

According to the Eurasists’ school, the first unique peculiarity of Northern Eurasia is the broad geographical horizontal zonality. From the coast of the Arctic Ocean to the coast of the Black Sea, not only the climate changes in the direction of increasing aridity, but even the water table has a single slope from near the surface in tundra to around or above 50 meters at the Black Sea shores. The second unique peculiarity is the existence of the Central Latitudinal Axis along the border of the forest and forest – steppe zones or inside the latter zone. Along the Axis, the soils are most fertile and the biodiversity reaches its maximum. The third unique peculiarity is the north-south symmetry on both sides of this Axis – many features are changing to the north and south of it in a similar manner – the biodiversity and bio-productivity diminish, the color of soils (and animals!) becomes whiter (e.g., white wolves in tundra and deserts), the soil became thinner, there are many analogues in the soil

chemistry between swamps in the north and solonchaks in the south. We observe a cycle of biomes: desert, tundra, forest, steppe, desert (special case: Far East). This gave Savitzky the reason to formulate the periodical law of zonality –the term that 20 years later was developed further by Grigoriev (1954). Finally, the fourth peculiarity is the two possible ways of evolution – expansion or thinning the central zones in both directions from the Axis simultaneously. The details of geology and topography too may cause the Axis-ward and Axis-away processes. Savitzky stressed that biota not only depends on soils and climate but also feed back to them, just like we all believe now (e.g., Kabat et al. 2004).

2.3. 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 the society (early warning / management / mitigation of floods, fire, droughts, and other natural disasters)*

2.4. Specific objective for remote sensing in Northern Eurasia

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. When these processes are poorly understood or they change, remote sensing is difficult. Avoiding this situation is a key objective of world space agencies. *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.* Chapter 4 specifically addresses the tools available and research objectives of remote sensing for Northern Eurasia.

Remote sensing in Northern Eurasia is of particular importance, because vast areas of the region (e.g., Arctic, Siberia, and Central Asia) are not well covered by in-situ observations. Therefore, reliable assessment of the state of present climate and environment and their changes is not doable without integration of high-quality remote sensing products and in situ observations within a suite of global, regional, and process-based models. However, some of present and planned remote sensing products in the region (e.g., precipitation, net ecosystem exchange, surface energy budget, cloudiness, and water vapor) need substantial improvements. Efforts to provide these improvements by *development of better regional retrieval algorithms and establishment of a network for their validation will be one of important objectives of the NEESPI studies.*

2.5. Rationale for the synthesis approach and linkages

Terrestrial ecosystems, being an integrating component at the land surface and, in some sense, one of the major forms 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 the societal sustainability, are closely and substantially interconnected to each other and should be studied together in an interdisciplinary fashion. This approach is further justified in Chapter 3.5. The global role of Northern Eurasia and its response to global change are shaped by complex interactions among many processes, including climatic change, land cover and land use change, ecophysiological and successional processes in ecosystems, wildfire and other disturbances, changes in permafrost, snow, and ice, hydrologic processes in rivers and wetlands, social, and technological changes. Traditionally, studies of these processes were segregated by discipline and geographic zone or ecosystem type. However, many of the important processes that define the environmental role of Northern Eurasia occur at the boundary between zones and ecosystems as the balance between forest and tundra, wetlands and agriculture, forest and wetland, in the coastal zone, shifts with changing climate and land use. *Interdisciplinary studies are critical for understanding these changes.*

The NEESPI science plan includes **education, satellite monitoring, data acquisition and information technology, and modeling components**. The rationale for the education component is the anticipation that a network of students will gain expertise in this area while working on the Initiative. This is especially important for the newly independent countries of the Commonwealth of Independent States and Mongolia, where a significant reduction of investment in environmental sciences has been observed in the past decade. By outlining the modeling, monitoring, and information technology aspects of the study, we want to emphasize the role of new tools (primarily remote sensing, new modern field observation techniques, and modeling) that will be widely employed while working on the Initiative. Four core countries involved in the Initiative (Russia, China, Japan, and the United States), as well as the European Union, have space study capabilities that can be further developed, enhanced, and employed for the Initiative objectives. Within the integrative framework of the Northern Eurasian partnership, the NEESPI studies will include learning from and contribute to other relevant regional and global programs existing and/or projected under umbrella of the World Climate Research Programme (*WCRP*), International Geosphere-Biosphere Programme (*IGBP*), and others. In particular, close collaboration and intertwining of efforts are anticipated with two integrated regional projects *NORTH* (NORTHERN Latitudes Observing System that is currently under development by the European Union Research Community) and *SEARCH* (Study of Environmental ARctic CHange, a U.S. Interagency Research Program; <http://psc.apl.washington.edu/search/>).