

# Northern Eurasia Terrestrial Processes, their Change and Role in the Global Earth System: Northern Eurasia Earth Science Partnership Initiative (NEESPI) Pilot Results.

## I. Introduction.

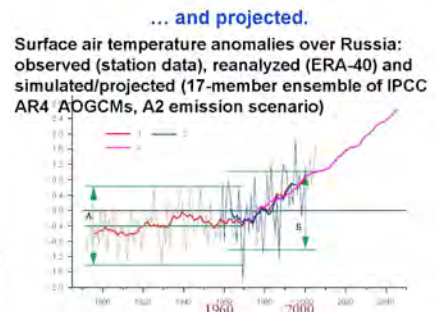
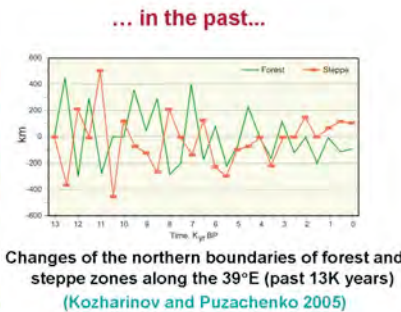
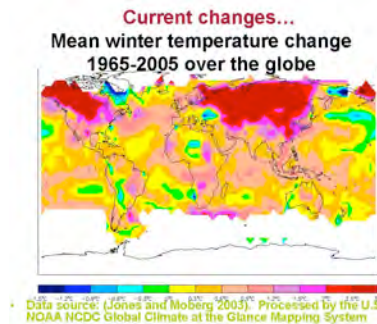
### 1.1. Region of Study.

NEESPI study area includes: Former Soviet Union, Northern China, Mongolia, Fennoscandia, & Eastern Europe



**Northern Eurasia as defined in the NEESPI Program.** Moderate Resolution Imaging Spectroradiometer (MODIS) 1km true color composite from August 20-28 2004 data. Shaded relief adjustment using the Shuttle Radar Topography Mission (SRTM) GTOPO30 elevation dataset. Shades of green correspond to vegetated land. Light brown and yellow indicate sparse vegetation and arid areas. Produced by Dr. Mutlu Ozdogan (NASA GSFC).

### 1.2. Rationale.

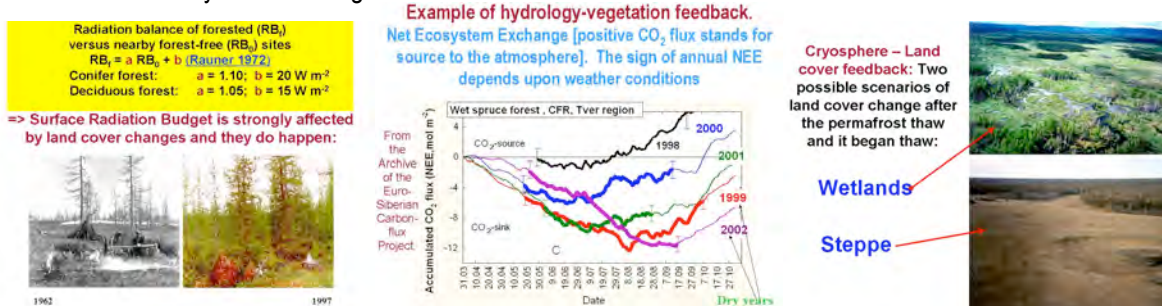


Northern Eurasia is undergoing rapid and significant changes associated with warming climate and with socio-economic changes during the entire 20<sup>th</sup> century. Climatic changes over this largest landmass in the northern extratropics (and ~ 20% of the global land mass) interact and affect the rate of the global change through atmospheric circulation and through strong biogeophysical and biogeochemical feedbacks. These feedbacks arise from changes in surface energy, water, and carbon budgets of the continent. How *this carbon-rich, cold region component of the Earth system* functions as a regional entity and interacts with and feeds back to the greater global system is to a large extent unknown. Thus, the capability to predict future changes that may be expected to occur

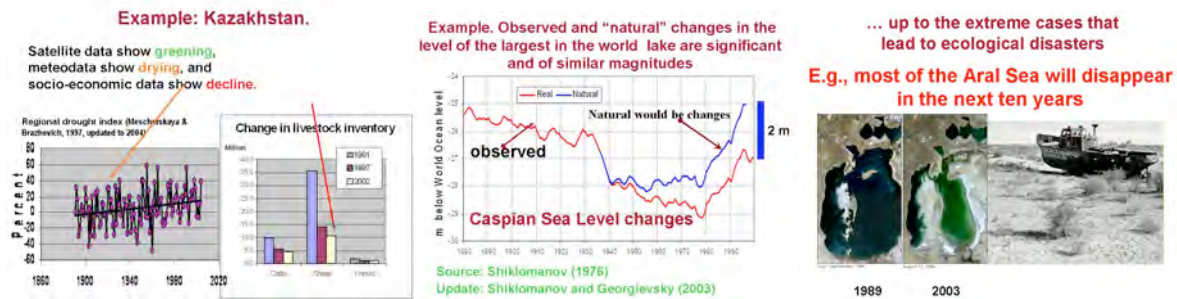
within this region and the consequences of those changes with any acceptable accuracy is currently uncertain and hampers projections of the Global Change rates which are among the WCRP major objectives. One of the primary reasons for this lack of regional Earth system understanding is the relative paucity of well-coordinated, multidisciplinary and integrating studies of the critical physical and biological systems. Furthermore, the critical measurements needed to monitor changes in the area are not available.

Introduction of the biosphere and socioeconomic changes into the framework of Global Change is among the most challenging problems for society as well as for the Earth Science community. In the Northern Eurasian domain we have both challenges:

- strong hydrology-biosphere feedbacks that may (and do) affect sign of changes in surface energy budget and/or net ecosystem exchange and



- socioeconomic changes that several times during the past century dramatically affected land use and water management practices causing changes that far exceeded (in some cases) climate variability and affected the societal well-being and environmental health.



Lack of concise efforts to deliver both understanding and information for Northern Eurasia makes studies of climatic changes in this region an important contribution to reduction of uncertainties in our understanding of the Global Change far beyond the Northern Eurasia domain.

## II. NEESP Initiative Objective in a nutshell.

The Northern Eurasia Earth Science Partnership Initiative (NEESPI), an interdisciplinary program of internationally-supported Earth systems and science research, was established to address large-scale and long-term manifestations of climate and environmental change. NEESPI considers all Northern Eurasian ecosystems and needs to draw on all environmental scientific disciplines during the coming decade. *NEESPI strives to understand how the land ecosystems and continental water dynamics in Northern Eurasia interact with and alter the climatic system, biosphere, atmosphere, and hydrosphere of the Earth.* Its overarching Science Question is: 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? The foci of the NEESPI research strategy are the deliverables, which support both national (e.g., the National Climate Change Science Programs) and international science (e.g. IGBP) programs. A synergetic approach to projections of the future changes is a core of the NEESPI. Major NEESPI-related research deliverables, in approximately ten years, will be a suite of process-oriented models for each major terrestrial process in all its interactions; a suite of global and regional models that seamlessly incorporate all major regionally specific feedbacks associated with terrestrial processes; an integrated observational knowledge data base for environmental studies; and an environmental

hazards warning system in place that can serve the emergency needs of the society. A synergetic approach to projections of the future changes is a core of the NEESPI. NEESPI Science Plan Preparation Team (that worked in 2003-2004) included more than 90 scientists from 11 countries with the majority of them being from the United States and Russia. After external review and extensive editing the NEESPI Science Plan (~260 pages) has been published on the web at <http://neespi.org> in December 2004. An Executive Overview of the Science Plan (18 pages) is available at the same web site in three languages (English, Russian, and Chinese) and has been published in *Global and Planetary Change Journal* (Groisman, Bartalev, and The NEESPI Science Plan Development Team 2007, available at <http://neespi.org>). The NEESPI Science Plan structure is presented in Appendix 1.

The NEESPI Science Plan (SP) 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. Assuming that the functioning of the Global Earth System can be considered as an interaction of three major types of processes (cycles):

**Energy and Water Cycles**, which affect the transfer of energy, water, aerosols, and trace gases between the atmosphere, land surface, hydrosphere, and cryosphere; **Biogeochemical Cycles**, which affect the composition of the atmosphere and ocean, the formation of soils, and the evolution of biomes; and **Human Activity**, which began to strongly affect the planetary system on the regional level (first of all land processes) with the establishment of the first agricultural civilizations,

now includes effects on the Global Earth System. The SP states that 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.

**NEESPI developers indicated that 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 insert 1) 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

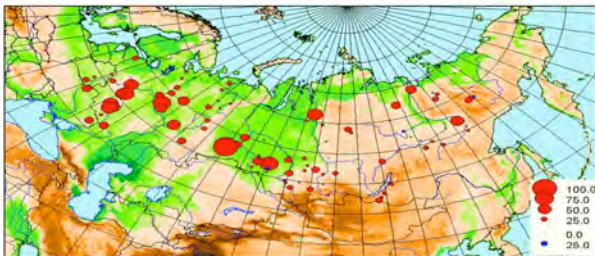
#### Insert 1. Importance of studying Northern Eurasia from the Global Change perspective

- 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's heat and water balances.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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<sup>-1</sup> in some areas) and other coastal line changes may affect life conditions and cause enormous economic damage.
- 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
- 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.

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.

### An issue of global concern: The Arctic fresh water budget

Fresh water transport to the Arctic is increasing



Winter runoff deviations for the 1978-2000 period compared to the long-term mean for ~ previous 55 years (Georgievsky et al. 2003)

### Coastal zone processes

•Inundation; Land-ocean exchange; Impact on biota; Eutrophication; Impact on quality of life; and Coastal erosion

Coastal erosion in the Arctic is rampaging



20 years ago these oil tanks were 60 m away from the coast of The Pechora Sea (Ogorogov, 2003)

## III. Current NEESPI Status

From the beginning, three terms characterize the NEESPI: **Global, Interdisciplinary, and Active.**

- **Global** - Priorities were assigned to projects and topics that address regional changes that affect (or may affect) Global Earth System
- **Interdisciplinary** –It was early recognized and shown in examples, that strong interactions within the system terrestrial ecosystem, hydrosphere, cryosphere, atmosphere, and human society in the region require interdisciplinary studies
- **Active** - Preparation of the NEESPI Science plan (2003-2004) occurred simultaneously with pilot projects initiation and the writing of proposals (some of them have been already funded)

Since 2004, NEESPI participants were able to seed several waves of research proposals to the international (NATO, European Union, GEF) and national funding agencies and institutions (e.g., in the United States, Russia, Japan, UK, Germany, Finland, and Hungary), and to the International Polar Year (IPY). Some of these proposals have already been funded and officially joined NEESPI (more than 100 of them), other proposals have been funded (more than 20 of them) and a process of their recognition by NEESPI is on the way, but a large group of proposals is still under review. Generally, there are two modes of NEESPI expansion: dedicated calls for proposals and freely joined projects that benefit or anticipate benefits from the NEESPI membership such as:

- *Improved links to collaborators in Northern Eurasia and to US and EU scientists working on similar problems*
- *Exchange of ideas, datasets, and knowledge with other team members working on similar problems*
- *Synergistic approach in working on complex problems*
- *Priority access to remote sensing and in situ data collected over Northern Eurasia*
- *Student exchange, doctoral and post-doc positions sharing among the Team Institutions*

**Among the first NEESPI public steps were:**

- Presentations at the International Conferences, including Open Science Sessions at the American Geophysical Union Fall Meeting (San Francisco, USA, December 2004, 2006) and at the 31<sup>st</sup> International Symposium on Remote Sensing of Environment (St. Petersburg, Russia, June 2005),
- Several successful proposals to the International Polar Year,
- Preparation of the special NEESPI issue of “Global and Planetary Change” journal Establishment of the network of the NEESPI Focus Research and Science Support Centers in the United States, Russia, China, and Germany,
- The 1<sup>st</sup> NEESPI Science Team Meeting in IIASA, Laxenburg, Austria (February 22-24, 2006), and
- Several regional NEESPI Workshops (St. Petersburg, Russia; San Francisco, California; Fairbanks, Alaska; Odessa, Ukraine; and Beijing, China).

As a result of these steps, NEESPI is widely recognized and endorsed as being potentially valuable to the international scientific community for development of the scientific plan that fostered regional research and has already created scientific research partnerships around the world. During the past 18 months, the NEESPI program has been endorsed by several Earth System Science Partnership Program (ESSP) Programs and Projects: International Geosphere and Biosphere Programme (IGBP), World Climate Research Programme (WCRP) through the Climate and Cryosphere Project, Global Water System Project, Global Carbon Project, Global Land Project, and Integrated Land Ecosystem – Atmosphere Processes Study. Thereafter, the NEESPI program has requested from ESSP the status of an *ESSP Integrated Regional Study* in the northern part of Eurasia. The NEESPI Science Plan (260 pp.) and its Executive Summary (18 pp.) have been published at the NEESPI web site (<http://neespi.org>). Executive Summary is also dubbed in a refereed publication by the NEESPI SP Editors, Groisman and Bartalev in Special issue of “Global and Planetary Change” journal. The special NEESPI issue of “Global and Planetary Change” journal has been published in April 2007. The NEESPI scientists were quite productive during the past two years publishing more than 200 books, book chapters, and papers in refereed journals. List of NEESPI meetings, workshops, and conference sessions consist of 19 titles and the present Aspen Workshop was the 20<sup>th</sup> of them.

#### IV. Scientific Questions

Shugart

Lettenmaier

Ojima

Sokolik

Romanovsky

#### V. Strategy of further NEESPI development

While the NEESPI Science Plan is balanced, a quick growth and non-proportionate funding caused different paces of development of different NEESPI components. To mitigate this disproportionality in implementation, the NEESPI Leadership:

- structure the Initiative by Topical and Regional Focus Research Centers
- move the NEESPI data support to Permanent Science Data and Services Centers, and
- promote clustering (integration) among the NEESPI Projects into virtual Mega-Projects and/or inception of interdisciplinary internally-integrated projects

It is anticipated that these steps will: (a) secure the continuity of the research within the cluster (or FRC) when individual projects (usually 3 year-long) expire; (b) allow the data preservation; and (c) will gradually balance advances in different research directions Increase of the number of funded projects and their diversity creates a real

challenge with scientific coordination among the projects and access to their data. Clustering the NEESPI research (and researchers) around Thematic and Regional Focus Research Centers and Science and Data Support Centers (<http://neespi.org/team.html>) started in 2006. These Centers (14 of them (2 under construction), and 3 more projected) began gradually evolving around the lead scientists with funded NEESPI Projects who are linked to international Research Projects (GLP, GWSP, CliC, etc) and/or to major World Data Centers in Russia, the United States, and China. These Centers are securing scientific and informational support of NEESPI and it is anticipated that they will continue doing it in the future. Nevertheless, the NEESPI Science Advisory Panel is seriously concerned with the problem of integration across the diversity of the NEESPI projects and tasked the Leaders of NEESPI FRCs to address this issue. The Aspen Workshop held in August 12-17, 2007 at the Aspen Global Change Institute, Aspen, Colorado targeted these integration problems:

- **How to balance and coordinate various NEESPI activities? And, in particular,**
- **How to secure integration of NEESPI regional studies with global climate and Earth System modeling activities?**

## V. The objectives of the Aspen Workshop, 12-17 August, 2007

The Aspen Global Change Institute is an excellent forum to gather Earth system and regional modelers, experimentalists, and observationalists to address these major integration issues for the northern high latitudes, with a focus on the NEESPI domain. An overarching objective of the Aspen Workshop was to provide a venue for the NEESPI researchers and researchers from the interdisciplinary climate and Earth system modeling communities for the discussion and synthesis of the current knowledge of ongoing changes in Northern Eurasia and their linkages with global changes, regional and global modeling capabilities, and emerging problems and needs. The following three major objectives were set in front of the Workshop Participants.

- **Evaluation of the state of the art** of the modeling efforts in the region along three spatial scales: micro-scale (or at the process level), regional scale (or within major biomes of the region and in the transitional zones between them), and on the global scale.

In addition to evaluation of the level of current efforts, it is time to try to synthesize and quantify the major biogeochemical and biogeophysical feedbacks within the NEESPI domain important for Global Change and assess the existing tools to downscale global change signals into the NEESPI domain as well as tools to incorporate regional non-linearities (sub-scale processes) from the NEESPI domain into GCMs.

- **Development of recommendations for collaboration between the Global Earth Modeling Community and the NEESPI region researchers.**

This collaboration is mutually beneficial. NEESPI can provide invaluable insight into Earth system data initialization and parameter sets for the global models and advise how to tackle in global Earth models regional feedbacks emerging from the NEESPI expertise. In return, the global modeling community can provide insight into NEESPI with regard to important processes and mechanisms that contribute to the design of field observations and experimentation.

- **Identification of missing research topics critical for achievement of the NEESPI objectives and thus for global change research.**

During the past 3 years, the NEESP Initiative expanded substantially. But, not all its components were launched timely and some topics (while identified in the NEESPI Science Plan) have only cursory presence among the NEESPI ongoing projects.

## **VI. The Workshop Results**

**6.1. Synthesis of current state of knowledge of changes and modeling capabilities**

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**6.2. Recommendations for integration of NEESPI regional studies with global climate and Earth System modeling activities**

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**6.3. Recommendations on integration of land surface models in the NEESPI domain**

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**6.4. Identification of missing research topics critical for achievement of the NEESPI objectives and thus for global change research**

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**6.5. Outreach**

## Appendix 1. NEESPI Science Plan Structure.

1. INTRODUCTION
  2. SCIENTIFIC QUESTIONS AND MOTIVATION
  3. MAJOR SCIENTIFIC TOPICS
    - 3.1. Terrestrial ecosystem dynamics <http://neespi.org>
    - 3.2. Biogeochemical cycles
    - 3.3. Surface energy and water cycles
    - 3.4. Land use interactions: societal-ecosystem linkages
    - 3.5. Ecosystems and climate interactions
    - 3.6. Topics of special interest
      - 3.6.1. Cold land region processes
      - 3.6.2. Coastal zone processes
      - 3.6.3. Atmospheric aerosols and pollution
  4. REMOTE SENSING
  5. MODELING **TOOLS**
  6. DATA AND INFORMATION TECHNOLOGY
  7. EDUCATION
  8. RESEARCH STRATEGY
- Scientific Background Appendix

## Appendix 2.

Two examples of NEESPI Projects (clusters of Projects) are presented below:

### Example 1. Example of the NEESPI funded integrative project.

*Understanding the role of changes in land use/land cover and atmospheric dust loading and their coupling on climate change in the NEESPI study domain drylands (Funded by NASA, PI, I.N. Sokolik)*

This integrative project brought together 12 senior scientists from 8 countries to address the land-atmospheric interaction processes over the southern half of the NEESPI domain. Regional atmospheric modeling, modeling of the land cover transformation under the natural and human-induced desertification processes, modeling of the dust storm formation and transport (including transcontinental transport), and finally, modeling of the climatic change resulting from the interaction of all these processes

### Example 2. Example of the NASA-NSF funded cluster of NEESPI projects that are ready for integration

1. PI: Dennis Lettenmaier. *Diagnosis and Prognosis of Changes in Lake and Wetland Extent on the Regional Carbon Balance of Northern Eurasia*
2. PI: Dennis Lettenmaier. *Use of International Polar Year data to improve attribution of long-term hydrologic changes in Arctic Eurasian land areas*
3. PI: Eric Wood. *An integrated understanding of the terrestrial water and energy cycles across the NEESPI domain through observations and modeling*
4. PI: Eric Wood. *Collaborative Research: Understanding Change in the Climate and Hydrology of the Arctic Land Region: Synthesizing the Results of the ARCSS Fresh Water Initiative Projects*
5. PI: Charles Vörösmarty. *Role of land cover and land use change in hydrology of Eurasian Pan-Arctic*
6. PI: Alexander Shiklomanov. *Study of Dam/Reservoir-Induced Hydrologic Changes in Large Siberian Watersheds: Regional Analysis to Pan-Arctic Synthesis*
7. PI: Larry Hinzman. *Current climate changes over Eastern Siberia and their impact on permafrost landscapes, ecosystem dynamics, and hydrological regime*
8. PI: Vladimir Romanovsky. *Permafrost dynamics within the Northern Eurasia region and related impacts on surface and sub-surface hydrology*
9. PI: Vladimir Romanovsky. *Thermal State of Permafrost (TSP): The U.S. contribution to the International Permafrost Observatory Network*
10. PI: Vladimir Romanovsky. *Development of a Network of Permafrost Observatories in North America and Russia: The US Contribution to the IPY*

These ten projects funded individually to four US Institutions jointly address a significant fraction of large-scale hydrological studies in the boreal zone of Northern Eurasia and its relation to the cryospheric changes.