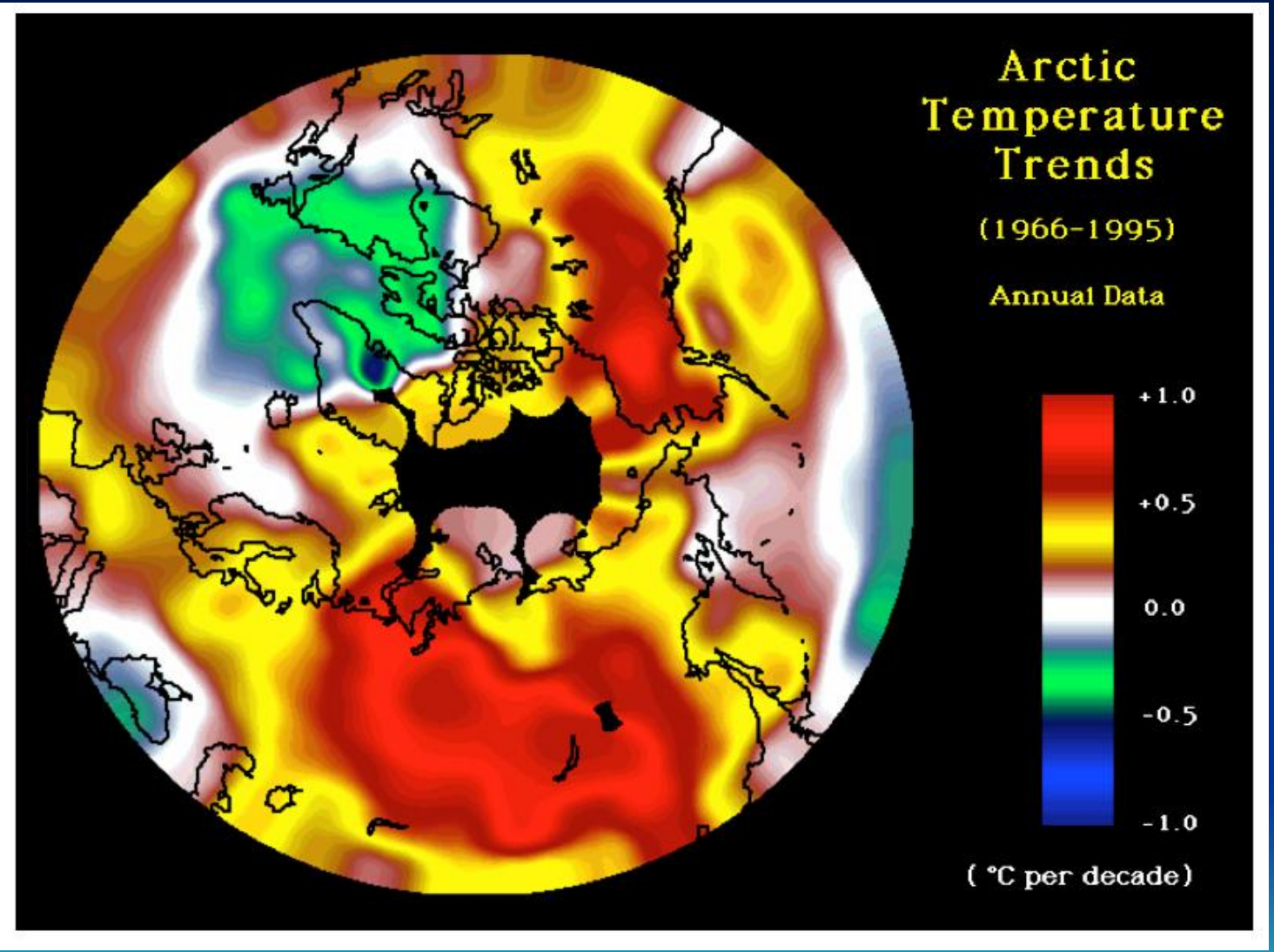
Land-Cover/Land-Use Interactions with Climate in the Boreal Zone

Garik Gutman, NASA Headquarters,
Washington, DC, USA

Outline

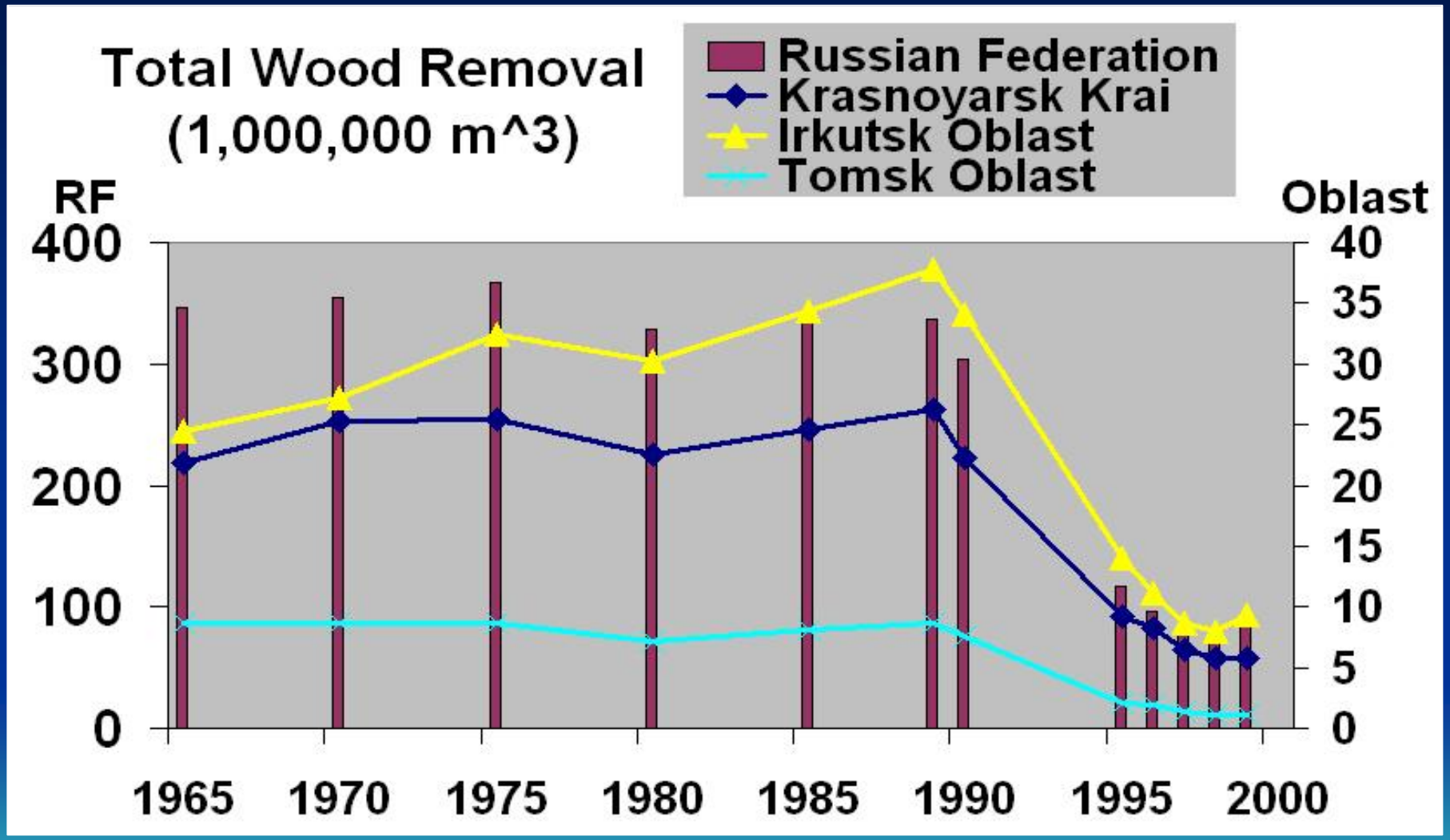
- Climate-Land Cover Interactions
- Potential of Remote Sensing
- NEESPI (Northern Eurasia Earth Science Partnership Initiative) – only briefly, more on July 8 at the NELDA workshop

Climate Change and Variability



Observed Warming Trend From: Serreze, MC, et al. 2000. Observational Evidence of Recent Change in the Northern High-latitude Environment. Climatic Change 46:159-207.

Land Use


Total Wood Removal
(1,000,000 m^3)
Russian Federation
Krasnoyarsk Krai
Irkutsk Oblast
Tomsk Oblast
RF
Oblast
400
300
200
100
0
40
35
30
25
20
15
10
5
0
1965
1970
1975
1980
1985
1990
1995
2000

The Basic Science Question

What are the consequences of such changes and are there significant feedbacks to the atmosphere from terrestrial ecosystems?

Implications of Change

- Carbon Cycle change (release/uptake)
- Hydrologic change (drainage/transpiration)
- Land-cover and land-use change (both climate- and human-induced)

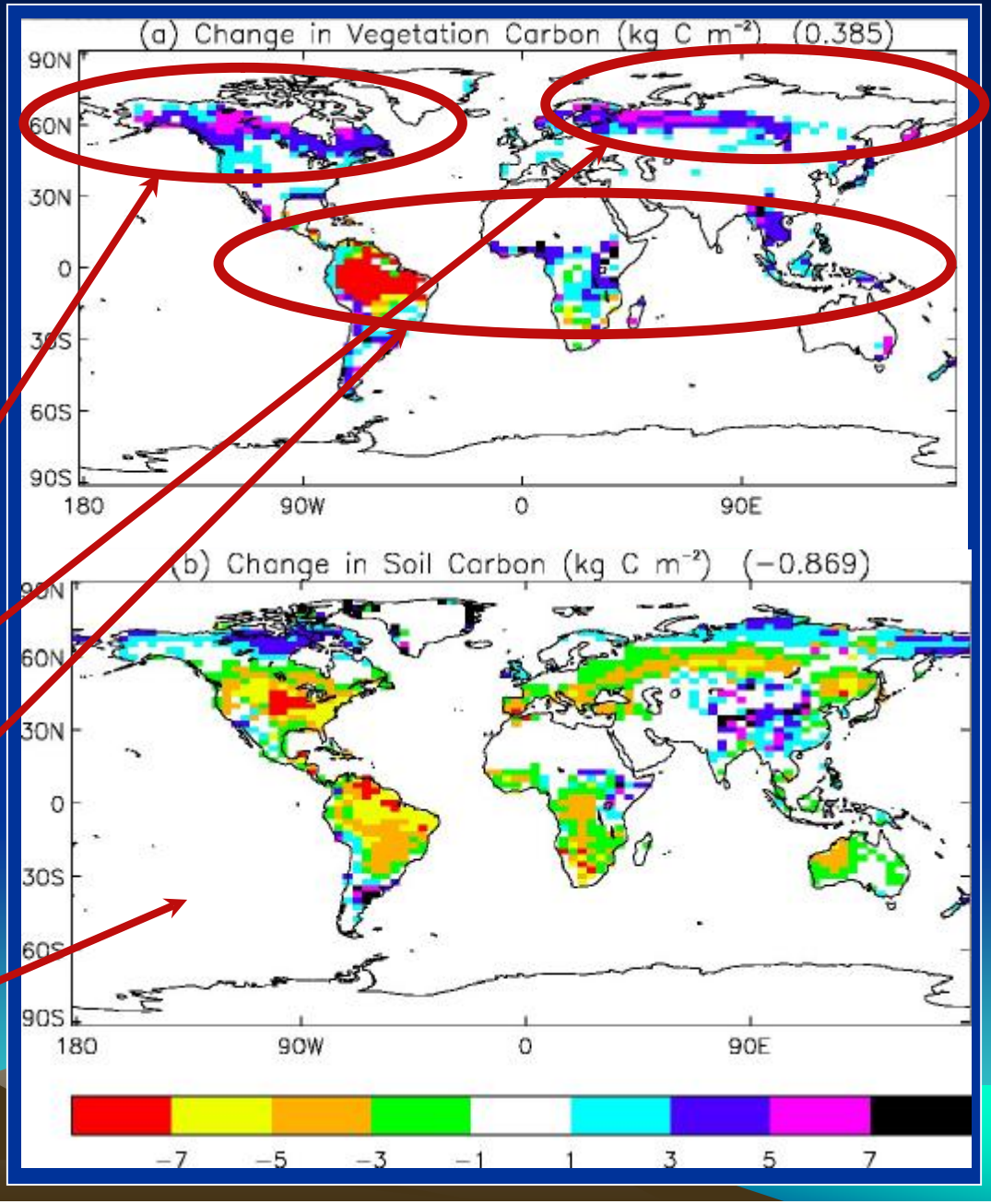
Simulated Changes in Carbon Storage Hadley Center Model 1860-2100

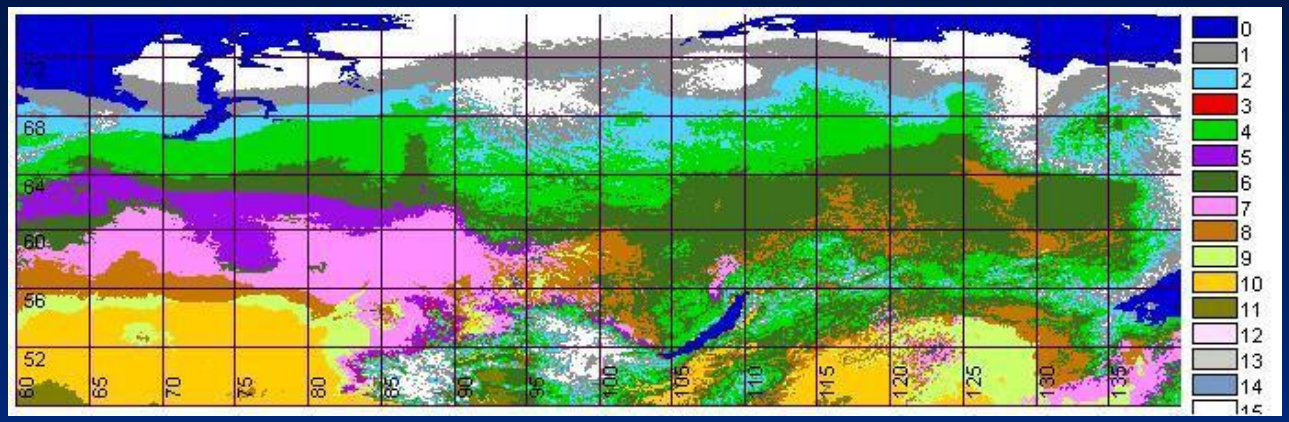
Carbon Cycle "Hotspots":

Boreal Forests, Tundra (Permafrost)

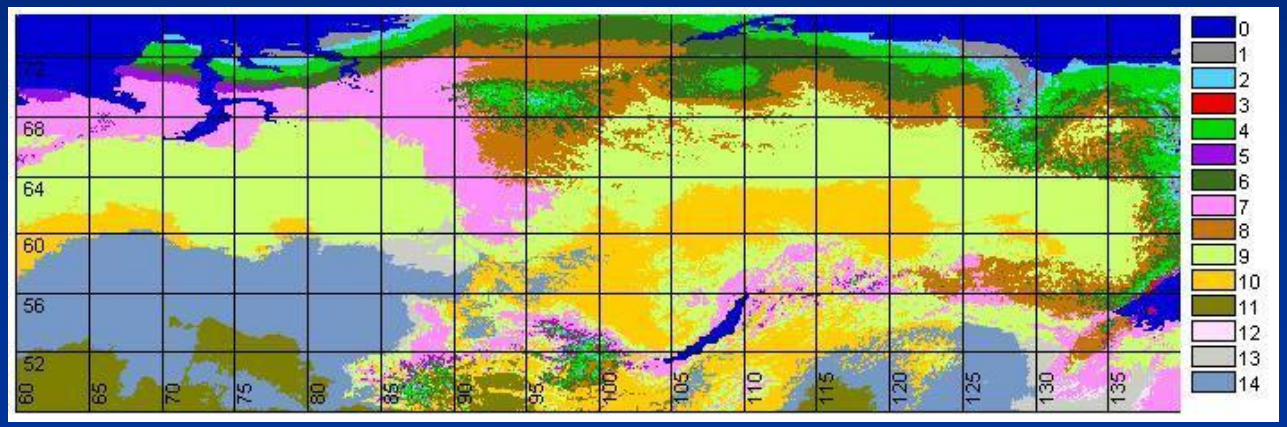
Tropical Ecosystems

Soils





Current distribution of Siberian vegetation



100-yr prediction of Siberian vegetation based on climate change

Water (0)
Tundra (1)
Forest-tundra (2)
Northern dark taiga (3)
Light taiga (4)
Middle dark taiga (5)
Light taiga (6)
Southern dark taiga (7)
Light taiga (8)
Forest-steppe (9)
Steppe (10)
Semi-desert (11)
Broadleaved (12)
Temperate forest-steppe (13)
Temperate steppe (14)

Tchebakova, N., and E. Parfenova (2004), Possible vegetation changes in Arctic and Boreal regions due to climate warming, in *Feasibility Workshop for Circumpolar LIDAR Mapping for Biomass Carbon Assessment and Vegetation Change Monitoring*, pp. in press, Waseda University, Tokyo.

Results of GCM Simulations

Clearing the boreal forest has a strong cooling effect in GCM climate simulations

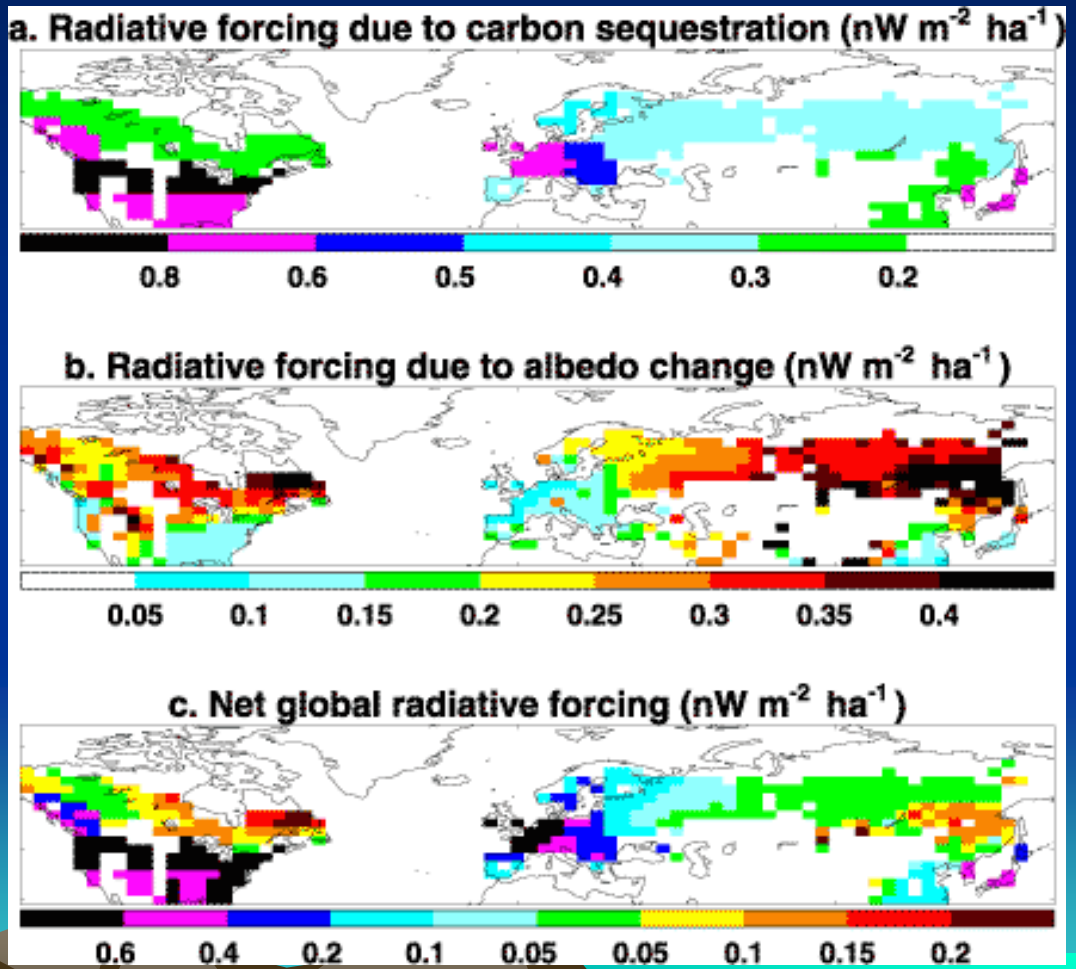
Bonan, G.B., D. Pollard and S.L. Thompson, 1992. Effects of boreal forest vegetation on global climate. *Nature* 359:716-718

Growing Eurasian forests has a warming effect in GCM climate simulations

Betts, R.A., 2000. Offset of the potential carbon sink from boreal forestation by decreases in surface albedo. *Nature* 408:187-190.

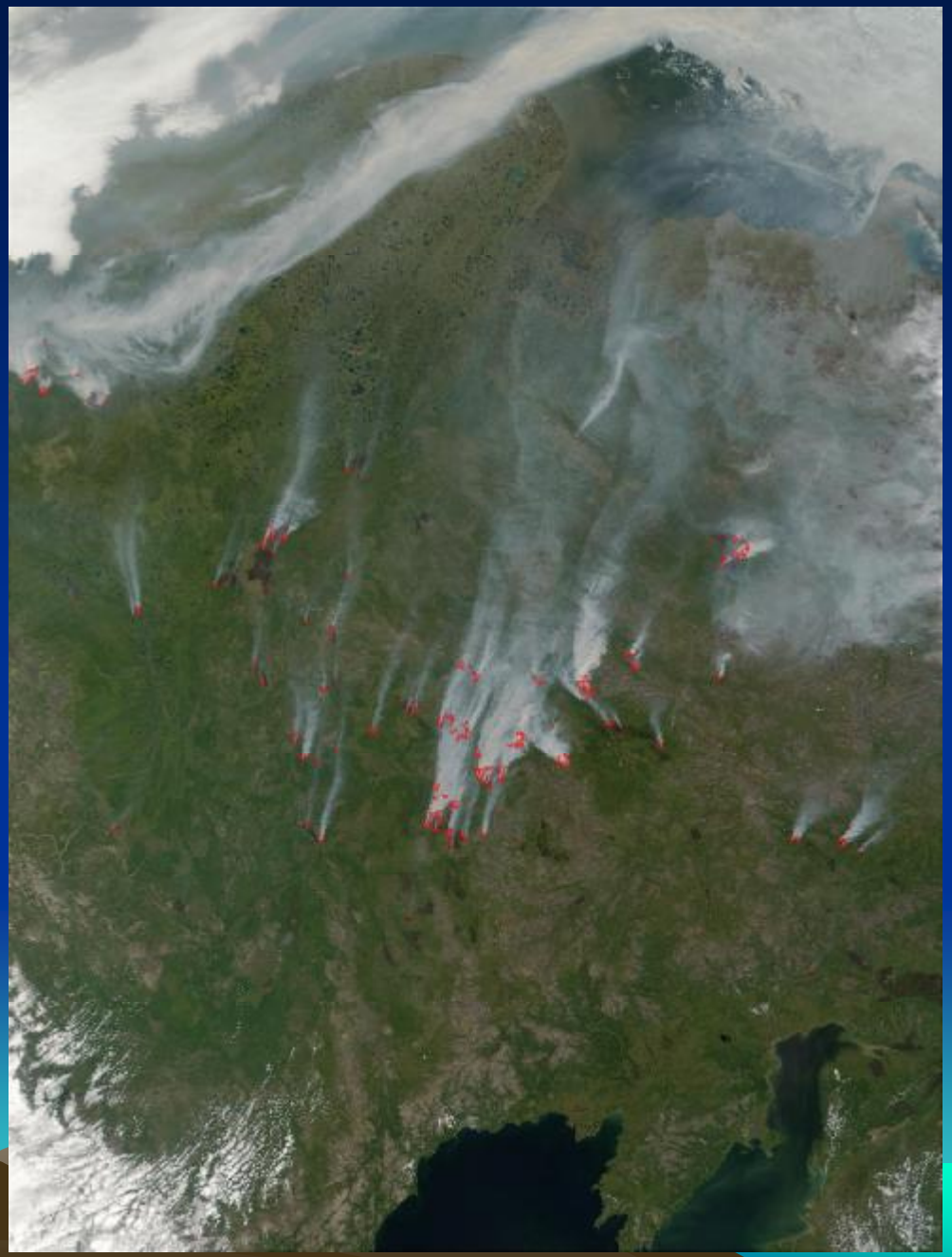
Radiative Forcing

- in large parts of the temperate and boreal forest areas, the decrease in surface albedo by forestation is as important as carbon sequestration in its forcing of climate. As a result, forest carbon sinks in these regions could exert a much smaller cooling influence than expected, or even exert an overall warming influence

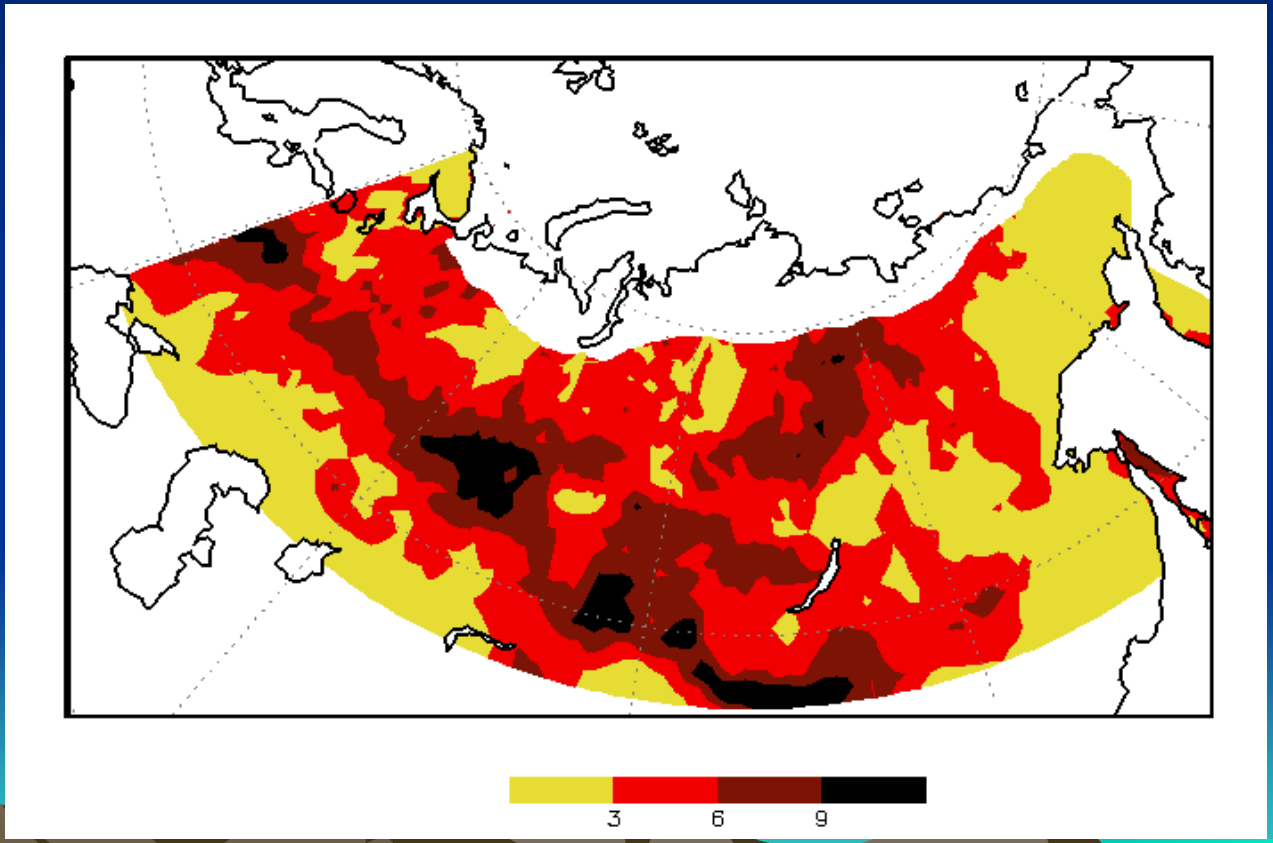


Estimating Disturbances

Fire, under the control of climate, is a major driving force of land cover change in remote boreal regions.



Projected change of the number of days with highest probability of forest fire by the end of the 21st century: 9-member ensemble of IPCC AR3 AOGCMs, B2 emission scenario.



Nadyozhina et al., 2005

Estimating Disturbances

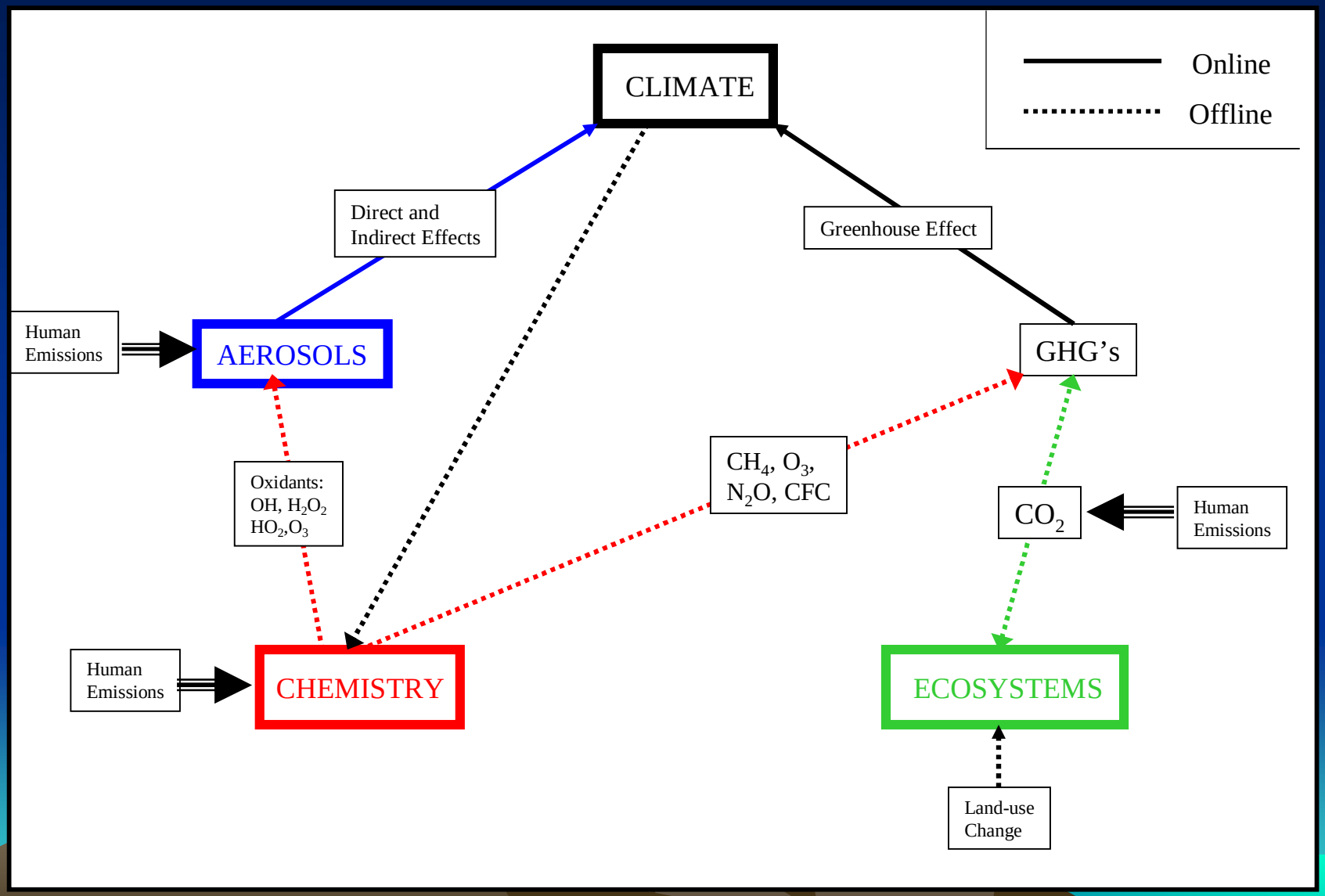
Insect outbreaks have always been a major factor initiating change in the boreal zone.

Can our models provide an operational interface between ground and remote sensing data for data assimilation ?

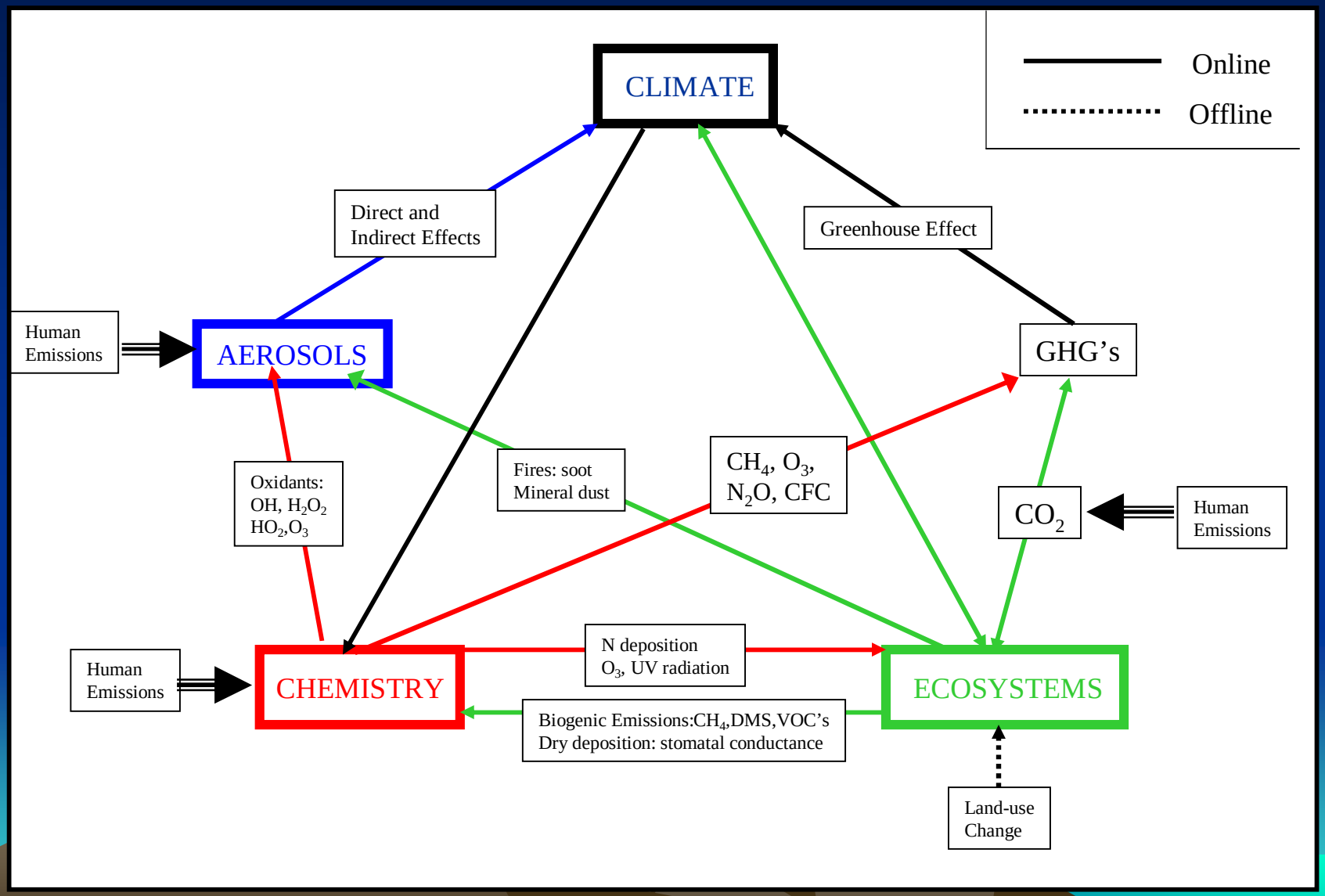
How to enhance the capability of our models to simulate the past and project future environmental and societal changes both in Northern Eurasia and globally?

Hadley Centre Global Environment Model 2 (HadGEM2) – prototype of an Earth System model

Hadley Centre's Climate System – Uncoupled Model



Climate System – Earth System Coupled Model



Example: Human- and Lightning-Induced fires

- Natural and anthropogenic fires affect atmospheric chemistry and climate by injection of large amounts of aerosols and greenhouse gases (Andreae et.al., 1988)
- Totally fires consume 5% of terrestrial net primary production, resulting in emiting 2-3 PgC/year (Randerson, et.al., 2002). This constitutes a half to 2/3 of current fossil fuel emissions.
- Majority of fires are human-induced – 97% in Spain (Vasques, et.al, 2002), **60-80% in Russia** (Shvidenko and Nilsson, 2002)
- Lightning fires account for disproportionally large area burnt in boreal zone – 38% of 10000 fires that occur each year in Canada result in 82% of area burned nationwide (Stocks et.al., 2002)

FRIDAY'S RESULTS

Do you think human activity is causing global warming?

24% Yes

67% No

2% I don't know

7% There is no global warming

CAST YOUR VOTE ON TODAY'S POLL QUESTION AND CHECK OUT LINE-BY-LINE AND STATION-BY-STATION RESULTS FROM YOUR FELLOW METRORAIL COMMUTERS. READEXPRESS.COM/POLLCENTER.PHP

Integrated Assessment of Global Fires in the GCM HADCM3LC: A Prototype of an Earth System model

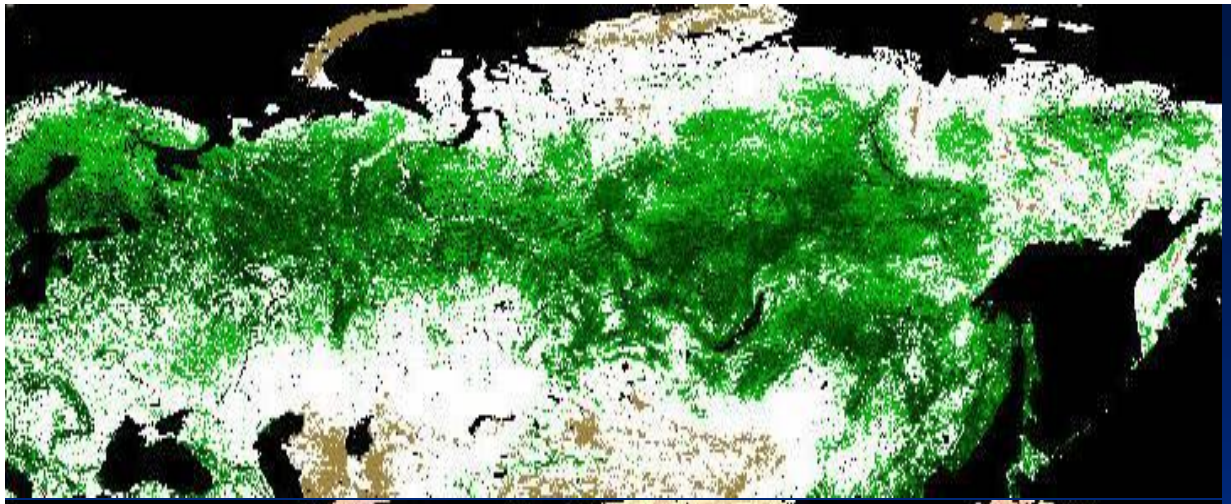
- Implementation of fire risk (fire weather) functions into GCM
- Simplification of human ignitions functions, accounting for urban and agricultural tiles in GCM
- Simplification and re-parameterization of area burnt functions for simplified vegetation types. Design of fuel functions from vegetation carbon and soil carbon.
- Developing interaction between land-surface scheme and the fire model (providing disturbance rate for vegetation model, getting moisture and fuel)

Tools

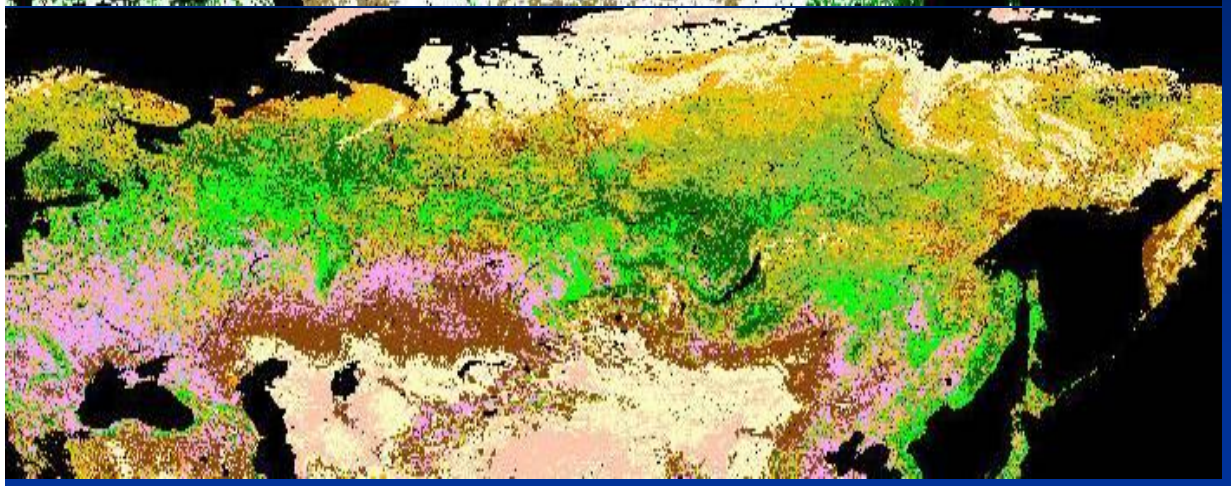
- Remote sensing satellite observations
  - Optical
    - High resolution multispectral (Landsat)
    - Moderate resolution multispectral (AVHRR, MODIS)
    - Lidars
  - Microwave
    - Passive
    - Radars
- Airborne and in situ observations
- Intensive field campaigns
- Basic process studies and case studies
- Modeling and integrative data analysis
- Data and information systems

Earth Observation Systems in Space

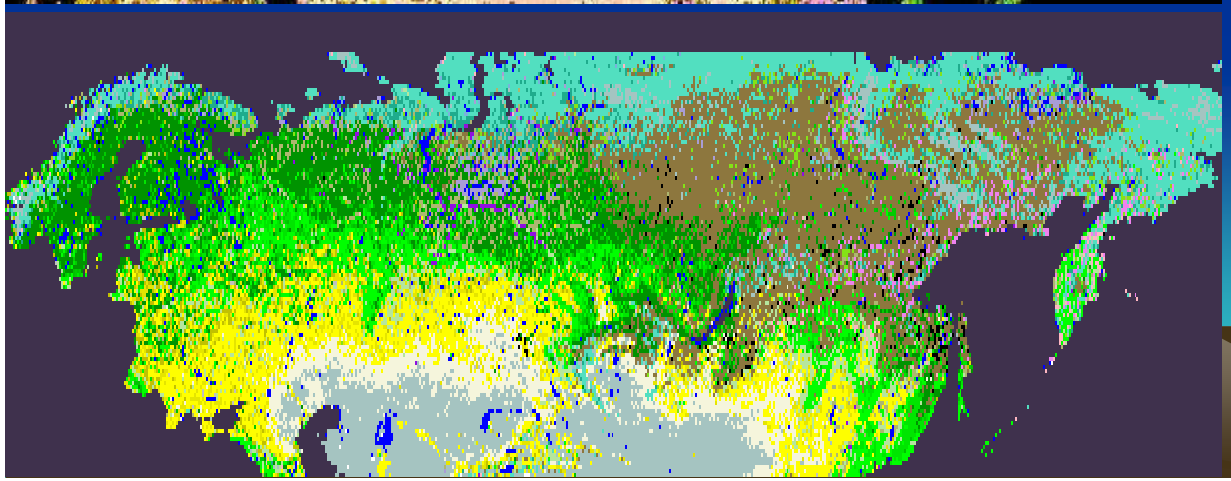
- Optical
  - Coarse resolution 1-2 km:
    AVHRR, SeaWiFS, OLS, Vegetation, ATSR, Geostationary
  - Moderate resolution 0.2-1 km:
    MODIS, MISR, MERIS
  - High resolution 5-30m:
    Landsat(s), ASTER, ALI, Hyperion, CIBRS, IRS
  - Hyper-spatial resolution 1-4 m:
    IKONOS, ORBVIEW
- Microwave
  - Passive: DMSP/SSMI, AMSU
  - Active: Radars



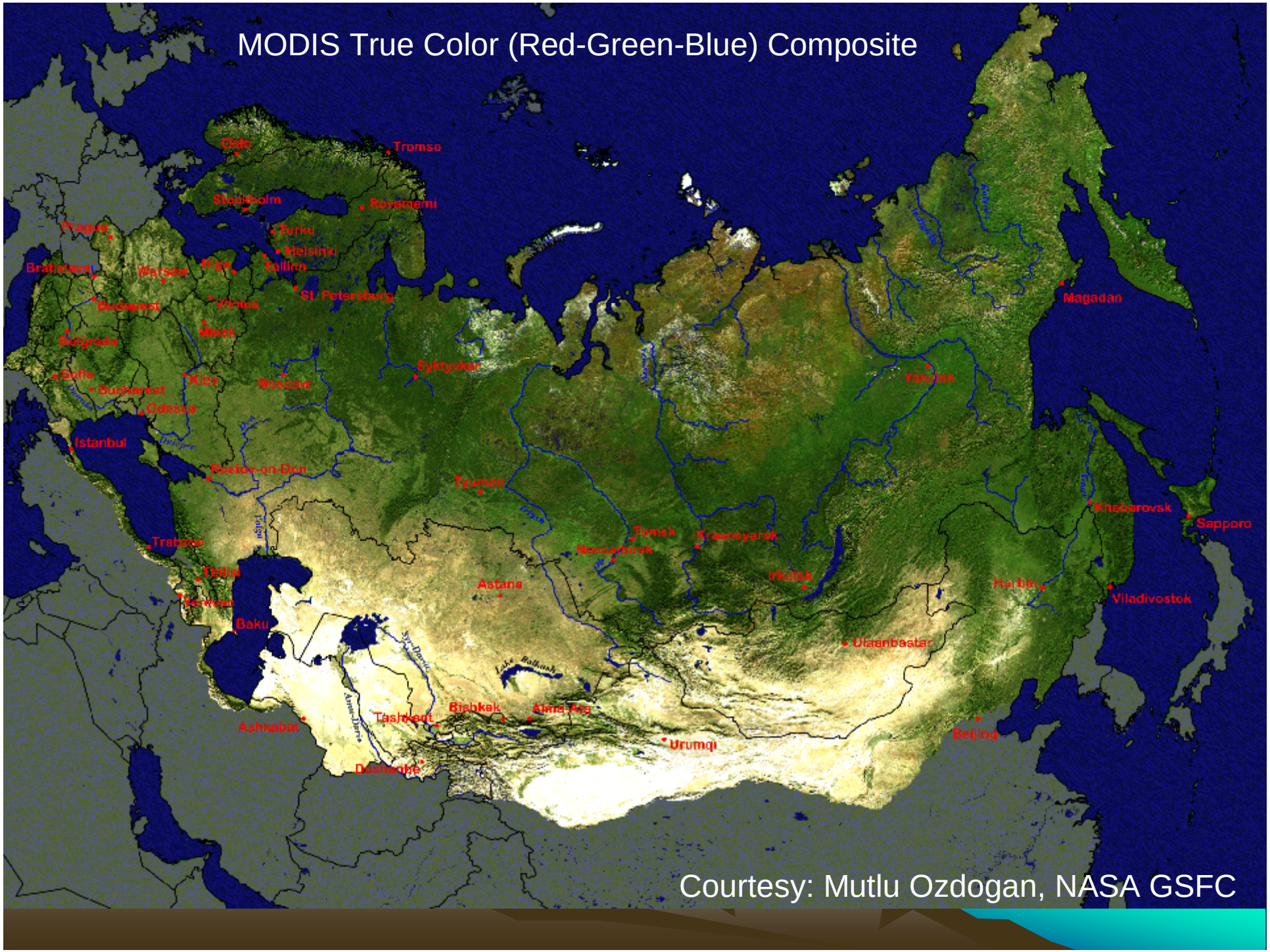
AVHRR Continuous Fields Tree Cover Product
1992-04-01 - 1993-04-01

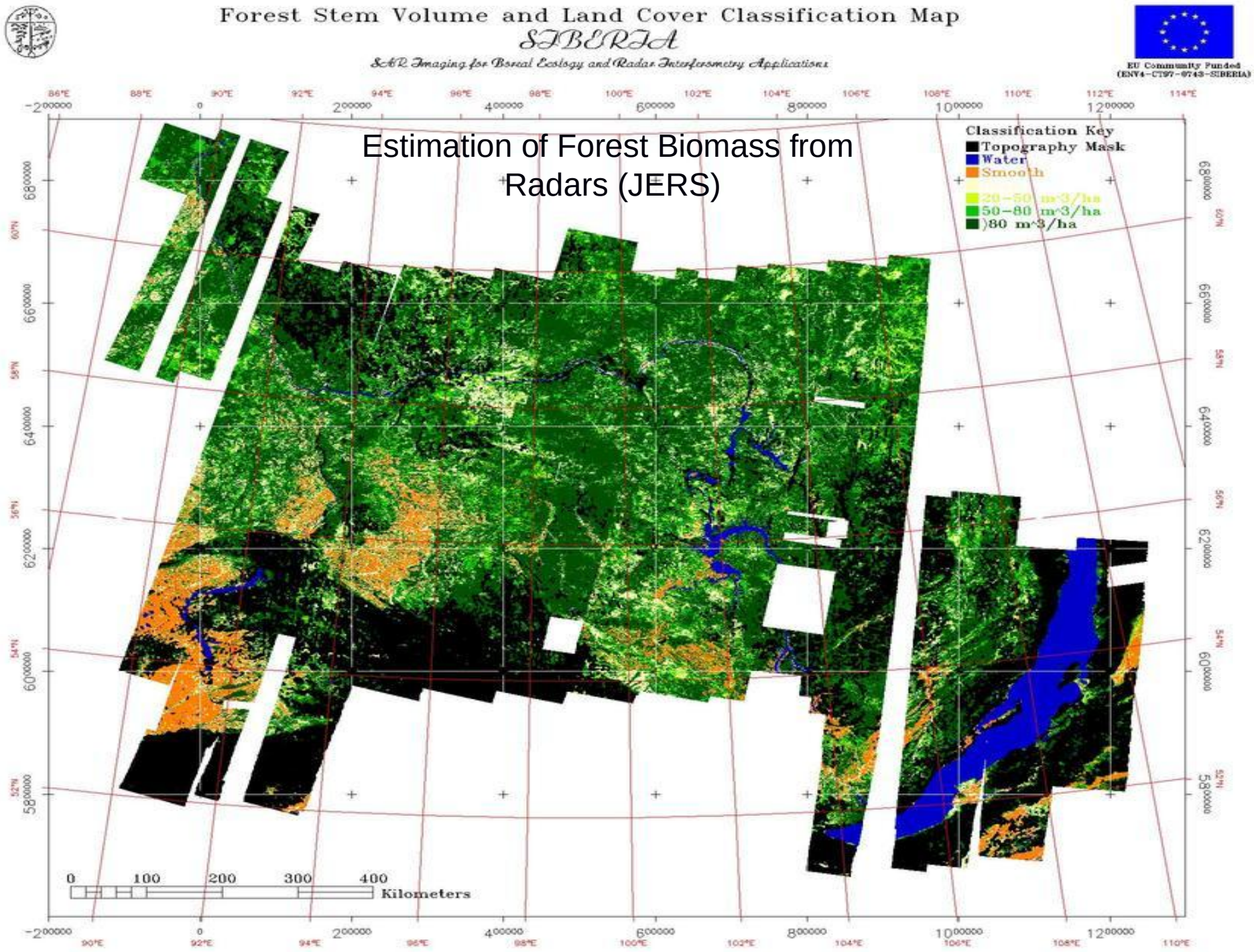


AVHRR Global Land Cover Product
1981-01-01 - 1994-12-31

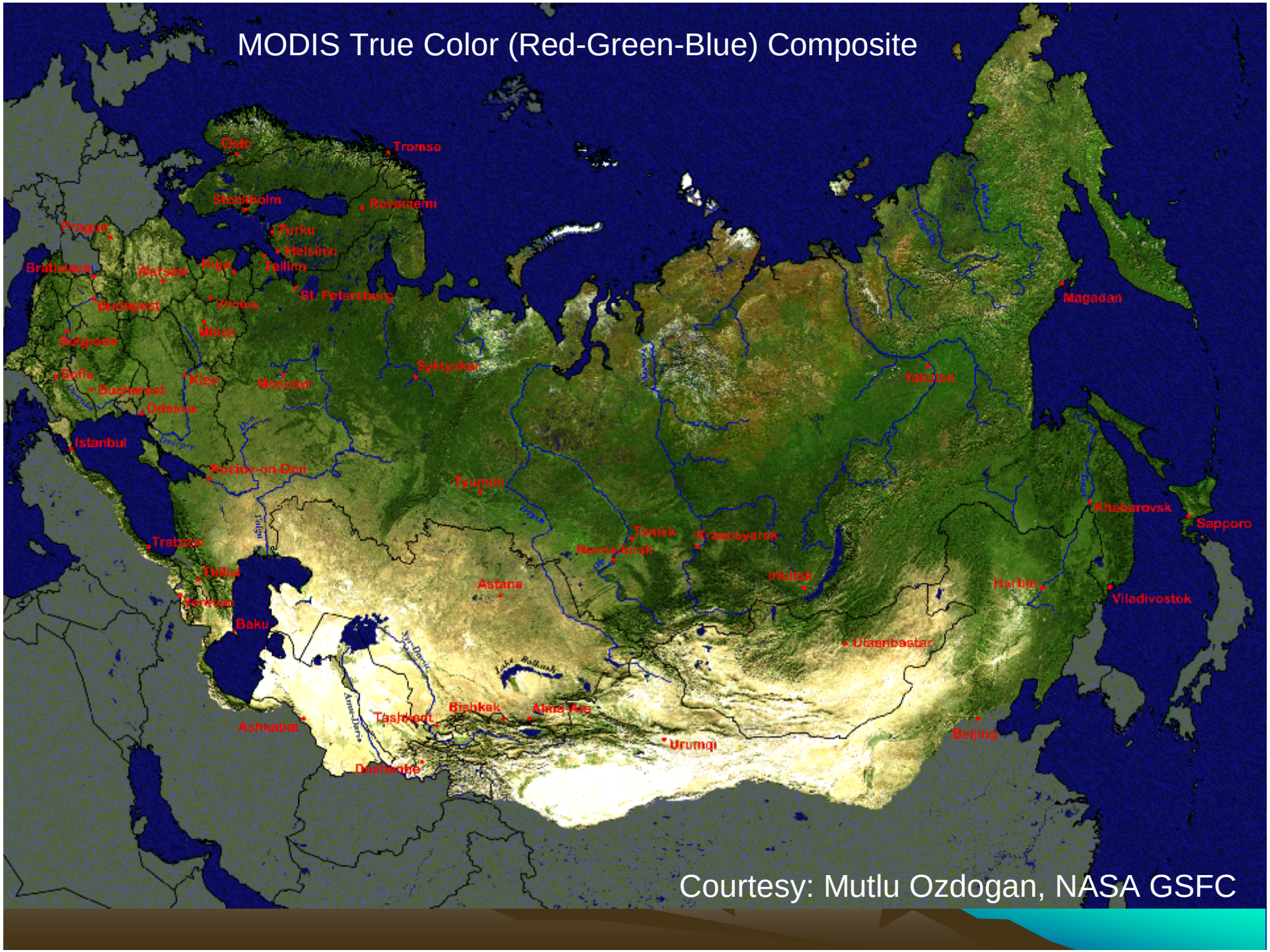


VEGETATION Land Cover Product


MODIS True Color (Red-Green-Blue) Composite
Oslo
Tromso
Stockholm
Rovaniemi
Prague
Turku
Helsinki
Bratislava
Warsaw
Riga
Tallinn
St. Petersburg
Budapest
Vilnius
Minsk
Belgrade
Sofia
Bucharest
Kiev
Moscow
Syktyvkar
Odessa
Istanbul
Rostov-on-Don
Tyumen
Trabzon
Tbilisi
Yerevan
Baku
Astana
Tomsk
Krasnoyarsk
Novosibirsk
Irkutsk
Yakutsk
Magadan
Khabarovsk
Sapporo
Harbin
Vladivostok
Ulaanbaatar
Lake Balkash
Bishkek
Alma-Ata
Tashkent
Ashkhabat
Urumqi
Beijing
Dushanbe
Courtesy: Mutlu Ozdogan, NASA GSFC


Forest Stem Volume and Land Cover Classification Map
SIBERIA
SAR Imaging for Boreal Ecology and Radar Interferometry Applications
EU Community Funded
(ENV4-CT97-0743-SIBERIA)
Estimation of Forest Biomass from Radars (JERS)
Classification Key
Topography Mask
Water
Smooth
20-50 m^3/ha
50-80 m^3/ha
)80 m^3/ha
0 100 200 300 400
Kilometers

NEESPI


MODIS True Color (Red-Green-Blue) Composite
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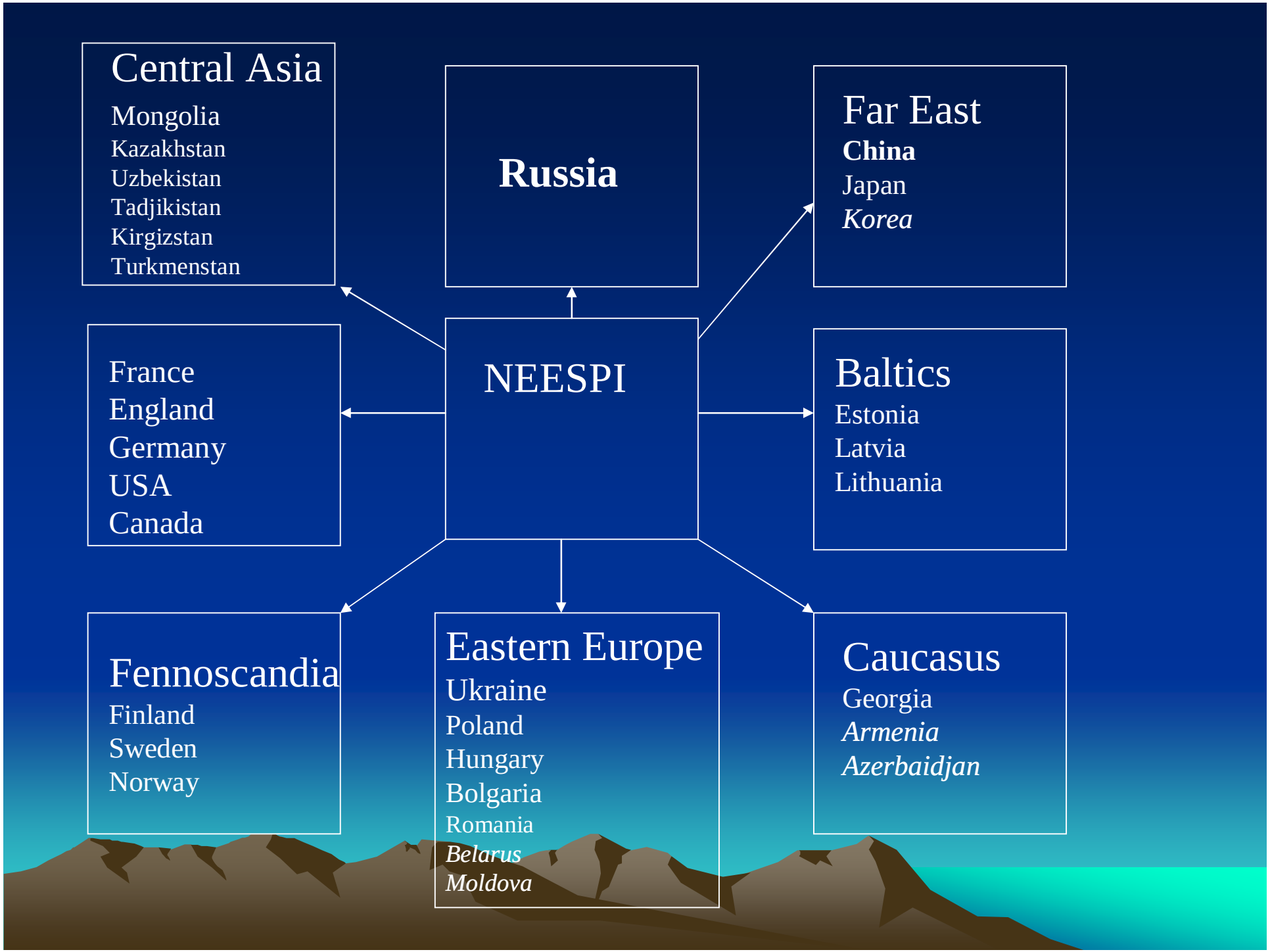
St. Petersburg
Budapest
Vilnius
Minsk
Belgrade
Sofia
Bucharest
Kiev
Moscow
Syktyvkar
Odessa
Istanbul
Rostov-on-Don
Tyumen
Trabzon
Tbilisi
Yerevan
Baku
Astana
Tomsk
Krasnoyarsk
Novosibirsk
Irkutsk
Yakutsk
Magadan
Khabarovsk
Sapporo
Harbin
Vladivostok
Ulaanbaatar
Lake Balkash
Bishkek
Alma-Ata
Tashkent
Ashkhabat
Urumqi
Beijing
Dushanbe
Courtesy: Mutlu Ozdogan, NASA GSFC

Northern Eurasia Earth Science Partnership Initiative (NEESPI)

- International, multi-agency program for Earth science research in northern Eurasia focused on ecosystem-climate interactions
- Comprehensive: Almost a quarter of the global land, representing most of the existing geo-botanic zones except for tropical; multi-disciplinary program covering basic terrestrial, environmental disciplines
- Important: An area of the globe with early indications of the global climate change
- Challenging: many countries, many languages, different mentalities, remote locations
- Advantageous: plenty of data, talents; existing infrastructure

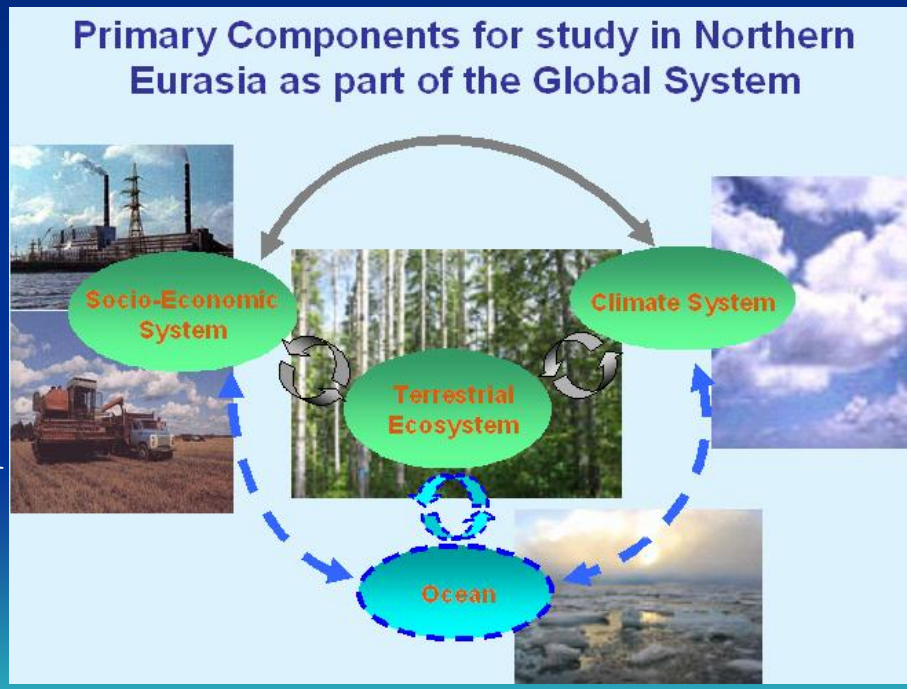

Central Asia
Mongolia
Kazakhstan
Uzbekistan
Tadjikistan
Kirgizstan
Turkmenstan
Russia
Far East
China
Japan
Korea
France
England
Germany
USA
Canada
NEESPI
Baltics
Estonia
Latvia
Lithuania
Fennoscandia
Finland
Sweden
Norway
Eastern Europe
Ukraine
Poland
Hungary
Bolgaria
Romania
Belarus
Moldova
Caucasus
Georgia
Armenia
Azerbaidjan

NEESPI Science Agenda

Focus on climate-ecosystem interactions and societal impacts in boreal and non-boreal zones of Northern Eurasia

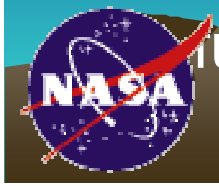
Goal:

- To evaluate the role of anthropogenic impacts on the regional ecosystems and climate and how it may affect the global climate
- To evaluate the consequences of global changes for regional environment, the economy and the quality of life in the region



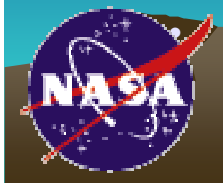
NASA Role in NEESPI

- Lead the NEESPI remote sensing component
  - Develop and maintain a regional satellite data base with raw data and products
  - Develop and distribute special remote-sensing based datasets useful for climate modeling
  - Facilitate access to satellite data and products by NEESPI investigators
  - Support regional calibration/validation activities
- Contribute to the support of Focus Research Centers, Science Data Centers, NEESPI logistics
- Support regional network activities
- Support NEESPI projects with a remote sensing component that were peer-reviewed and selected for funding by NASA

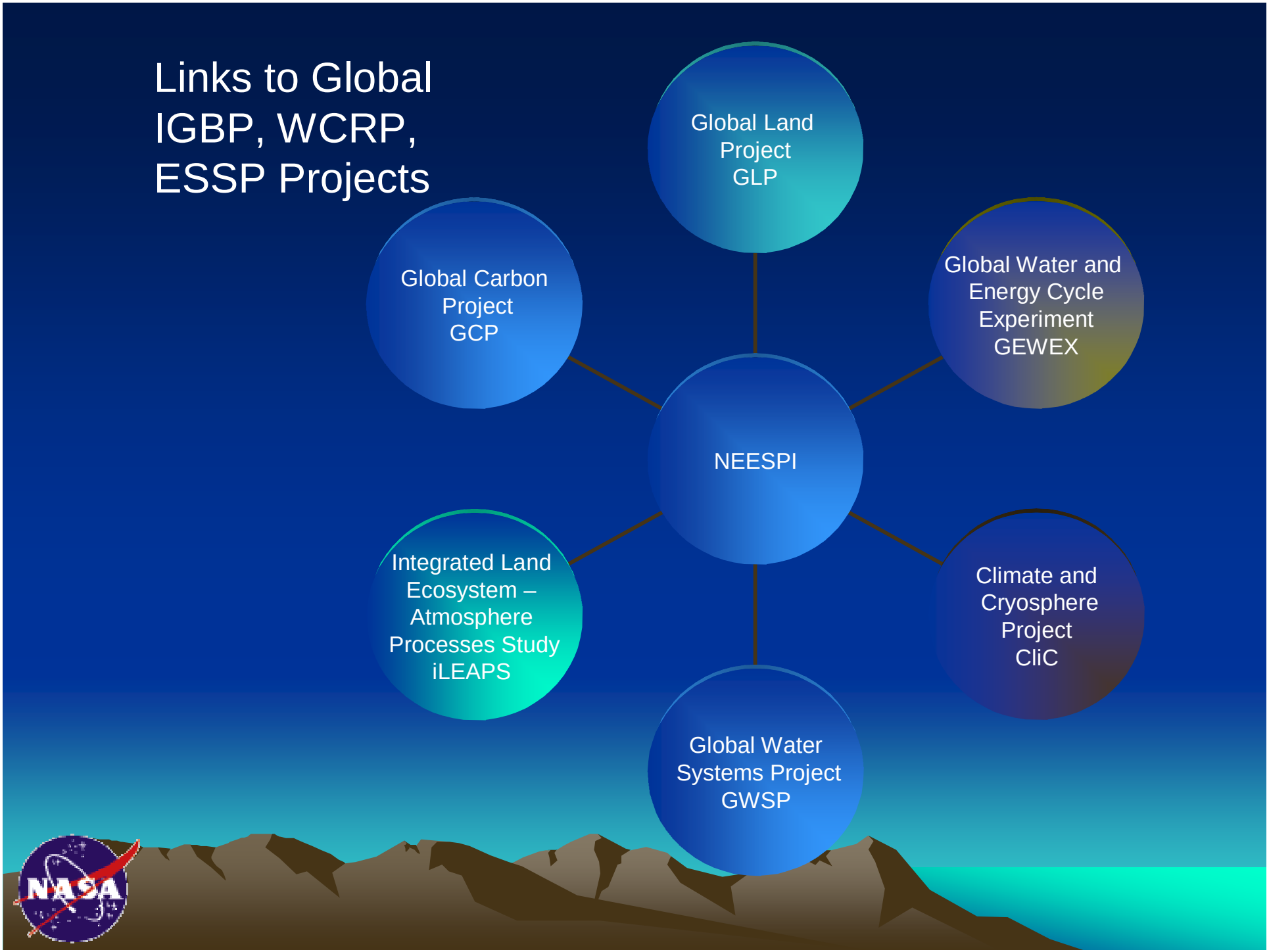


NEESPI Boreal Projects (~ $3.5 M/yr for 3 years)

- **Modeling the Carbon Dynamics of the Eurasian Boreal Forest**
- **An Integrated Analysis of Flux Tower Data, Remote Sensing Data and Biogeochemical Modeling**
- **Comparative Studies on Carbon Dynamics in Disturbed Forest Ecosystems**
- **Quantifying Effects of Fire Intensity/ Severity/ Burning Conditions on Carbon Stocks and Exchanges**
- **Impacts of Lake and Wetland Extent on the Regional Carbon Balance**
- **Land-Use and Land-Cover Dynamics of China**
- **Role of LCLUC in Eurasian pan-Arctic hydrology**
- **Monitoring/Validating the Distribution and Change in NEESPI Land Cover**
- **LCLUC in Yamal Peninsula and Novaya Zemlya**
- **Weather-Extreme Fire Events-LCLUC relationships in the Changing Climate of Siberia**
- **Current climate changes over Eastern Siberia and their impact on permafrost landscapes, ecosystem dynamics, and hydrological regime**
- **Permafrost Dynamics within the Northern Eurasia Region and Related Impacts on Surface and Sub-Surface Hydrology**
- **An integrated understanding of the terrestrial water and energy cycles across the NEESPI domain through observations and modeling**
- **The Eurasian freshwater cycle from GRACE and in-situ hydrologic networks: distinguishing water cycle behavior in permafrost and non-permafrost regions**
- **Area-stage relationships in rivers and wetlands: Tracking the high-latitude water cycle and provision of core knowledge requirements for a Surface Water satellite mission**
- **Continuous fields of snow cover characteristics derived through coupling satellite data with snowpack model: Application in the river runoff modeling over NEESPI domain.**

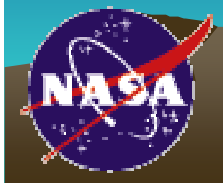


Links to Global IGBP, WCRP, ESSP Projects



Focus Research Centers

- Max Planck Institute, Germany
  - Carbon Cycle
- University of New Hampshire
  - Water Resources
- Colorado State University
  - LCLUC
- Georgia Technological Inst
  - Climate-Aerosol
- University of Alaska Fairbanks
  - Climate- Permafrost
- Hadley Center for Climate Prediction and Research
  - Climate-Land Ecosystems-Atmosphere



Science Data Support Centers

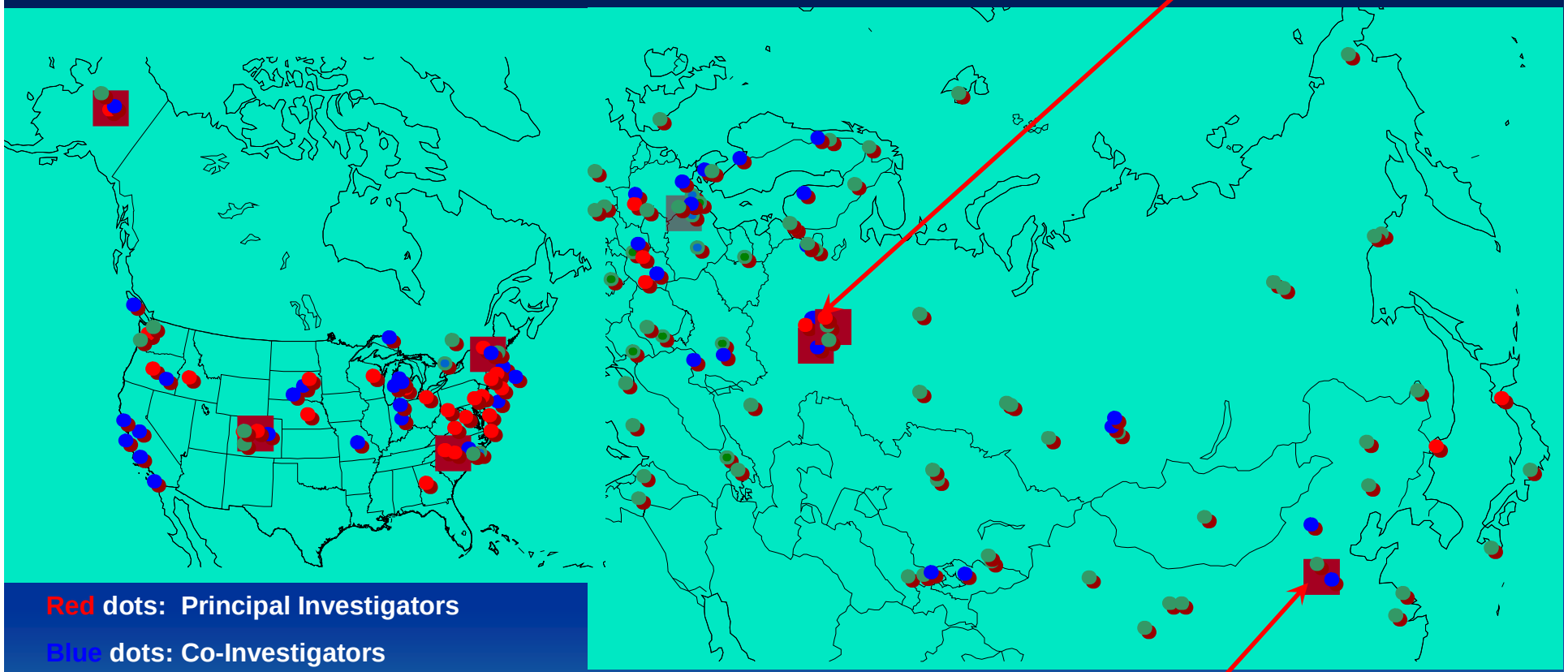
- ScanEx, Moscow, Russia
- Goddard Space Flight Center, Greenbelt, MD
- Beijing Climate Center for East Asia
- National Climatic Data Center, Asheville, NC
- Regional Hydromet Center, Obninsk, Russia

NEESPI Senior Scientists by country
(~300 scientists from 170 institutions; ~50 projects)

- Russia 84 scientists 36 institutions
  - including Moscow 50 scientists 18 institutions
  - most active Institution: RAS Sukachev Institute of Forest Research (6sci. in 7 projects)
- China 26 scientists 15 institutions
  - most active Institution: Institute of Botany, Chinese Acad. Sci. (5 scientists)
- United States 99 scientists 46 institutions
  - most active institution: University of Maryland (9 scientists in 9 projects)
- European Union 37 scientists 26 institutions 10 countries
  - including Finland 10 scientists 5 institutions
  - including Germany 10 scientists 8 institutions
- Japan **International Arctic Research Center + 3 institutions**
- Canada 4 scientists 4 institutions
- NIS countries, Mongolia, Korea, Syria, and Eastern Europe
  37 scientists 33 institutions 14 countries

NEESPI Distribution

18 institutions in Moscow participate in 21 projects



Red dots: Principal Investigators

Blue dots: Co-Investigators

Green dots: Collaborators

Squares: Focus Research Centers and Science Data Support Centers

6 institutions in Beijing participate in 5 projects

NASA NEESPI Support

- Carbon Cycle/LCLUC
  - 9 projects funded (started Jan ’05)
- New Investigator Program
  - 2 biodiversity projects (Jan ’05)
- LCLUC (Hydrology)
  - 7 projects funded (started October ’06)
- LCLUC (Climate, Monitoring, Impacts)
  - 6 projects funded (start Jan ’06)
- Terrestrial Hydrology
  - 6 projects funded (start Jan ’06)
- ACCESS (Data Systems Program)
  - 1 project (starts in Jan ’06)

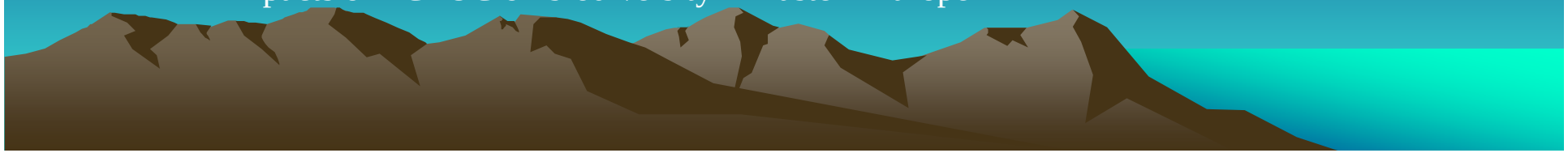
Total about $7.5 M per year

NEESPI Projects

- >30 NASA projects
- >15 non-NASA projects
- The first NEESPI Science Team meeting in February 2006

NASA Boreal NEESPI Projects: Carbon/Ecosystems/LCLUC

- Carbon dynamics modeling
  - Modeling the Carbon Dynamics of the Eurasian Boreal Forest
  - An Integrated Analysis of Flux Tower Data, Remote Sensing Data and Biogeochemical Modeling
  - Comparative Studies on Carbon Dynamics in Disturbed Forest Ecosystems
- Land-cover change monitoring
  - Land-Use and Land-Cover Dynamics of China
  - Monitoring/Validating the Distribution and Change in NEESPI Land Cover
  - LCLUC in Yamal Peninsula and Novaya Zemlya
  - Forest structure derived from EOS data
- Fires
  - Biomass Burning in Northern Eurasia
  - Quantifying Effects of Fire Intensity/ Severity/ Burning Conditions on Carbon Stocks and Exchanges
  - Weather-Extreme Fire Events-LCLUC relationships in the Changing Climate of Siberia
- Ecosystems and Biodiversity
  - Impact of LCLUC on Siberian tigers
  - Impacts of LCLUC on biodiversity in Eastern Europe



NASA Boreal NEESPI Projects: LCLUC/Hydrology

- LCLUC
  - Impacts of Lake and Wetland Extent on the Regional Carbon Balance
  - Role of LCLUC in Eurasian pan-Arctic hydrology
  - **Exacerbation of Flooding Responses Due to LCLUC in Carpathian region**
- Permafrost
  - Current climate changes over Eastern Siberia and their impact on permafrost landscapes, ecosystem dynamics, and hydrological regime
  - Permafrost Dynamics within the Northern Eurasia Region and Related Impacts on Surface and Sub-Surface Hydrology
- Suface Water
  - An integrated understanding of the terrestrial water and energy cycles across the NEESPI domain through observations and modeling
  - The Eurasian freshwater cycle from GRACE and in-situ hydrologic networks: distinguishing water cycle behavior in permafrost and non-permafrost regions
  - Area-stage relationships in rivers and wetlands: Tracking the high-latitude water cycle and provision of core knowledge requirements for a Surface Water satellite mission
- Snow
  - Continuous fields of snow cover characteristics derived through coupling satellite data with snowpack model: Application in the river runoff modeling over NEESPI domain.

Young NEESPI

- Education component is important
- Several NEESPI projects include young scientists from Northern Eurasia (Russia, China, etc.)
- A structure for NEESPI-Education is being established (Georgia Tech., U.Michigan, AEROCOSMOS, CERT)

Getting Involved

- Ask your adviser/boss/chief to contact NEESPI Project Scientist (Pasha Groisman)
- Make a potential US/EU partner interested in using your expertise/model/data in their own activities
- Prepare together with your US/EU partner a proposal to your future potential sponsor (e.g. NASA – the proposal is submitted by the US partner)
- Pray and hope that your proposal will get good reviews and selected in the competition, which is usually tough
- Become a NEESPIan
- Decent knowledge of English is required

Benefits to NEESPI members

- 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 through the Science Data Support Centers. In many cases they will be provided free of charge.
- **Education: student exchange, doctoral and post-doc positions**

Join the NEESPI family!

Website: http://neespi.org

谢谢

спасибо

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Thank you!

BACKUP SLIDES

LCLUC and Hydrology

Funded NEESPI Projects (started in October, 2005)

Arid (Partners: Russia, Kazakhstan, Uzbekistan, China)

- **Impacts of Glacial Area Changes in Central Asia During on LCLUC**
- **Role of LCLUC in Water Budget and Water Use Across Central Asia**
- **Assessing the vulnerability of the Eurasian semi-arid grain belt**
- **Ecological Monitoring in Semi-Arid Central and West Asia**
- **Effects of Land Use Change on the Energy and Water Balance of the Semi-Arid Region of Inner Mongolia**
- **Linking Biophysics and Socio-economics for Addressing Water Vulnerability in Central Asia**

NON-Arid (Partners: Ukraine)

- **Exacerbation of Flooding Responses Due to LCLUC in Carpathian region**

About $1.1 M per year for 3 years

Carbon Cycle Science and LCLUC

Funded NEESPI Projects (started in January, 2005)

BOREAL (Partners: Russia, China and Germany)

- Modeling the Carbon Dynamics of the Eurasian Boreal Forest
- An Integrated Analysis of Flux Tower Data, Remote Sensing Data and Biogeochemical Modeling
- Comparative Studies on Carbon Dynamics in Disturbed Forest Ecosystems
- Quantifying Effects of Fire Intensity/ Severity/ Burning Conditions on Carbon Stocks and Exchanges
- Impacts of Lake and Wetland Extent on the Regional Carbon Balance
- Land-Use and Land-Cover Dynamics of China

NON-BOREAL (Partners: Ukraine, IIASA, Kazakhstan, Uzbekistan, Mongolia)

- Carbon, Climate and Managed Land in Ukraine: Integrating Data and Models of Land Use
- Quantifying the Effects of Land Use Change on Carbon Budgets in the Black Sea Region
- Northern Eurasian Carbon-Land Use-Climate Interaction in the Semi-Arid Regions

About $1.9 M per year for 3 years

LCLUC

Funded NEESPI Projects (start in January, 2006)

Boreal (Russia)

- Role of LCLUC in Eurasian pan-Arctic hydrology
- Monitoring/Validating the Distribution and Change in NEESPI Land Cover
- LCLUC in Yamal Peninsula and Novaya Zemlya
- Weather-Extreme Fire Events-LCLUC relationships in the Changing Climate of Siberia

Non-boreal (Central Asian countries, Ukraine)

- Role of LCLUC and atmospheric dust loading and their coupling on climate change in dry-lands
- LCLUC effects on surface water quality in Dnieper and Don river basins

About $1.1 M per year for 3 years

Terrestrial Hydrology

Funded NEESPI Projects (start in January, 2006)

Permafrost

- **Current climate changes over Eastern Siberia and their impact on permafrost landscapes, ecosystem dynamics, and hydrological regime**
- **Permafrost Dynamics within the Northern Eurasia Region and Related Impacts on Surface and Sub-Surface Hydrology**

Suface Water

- **An integrated understanding of the terrestrial water and energy cycles across the NEESPI domain through observations and modeling**
- **The Eurasian freshwater cycle from GRACE and in-situ hydrologic networks: distinguishing water cycle behavior in permafrost and non-permafrost regions**
- **Area-stage relationships in rivers and wetlands: Tracking the high-latitude water cycle and provision of core knowledge requirements for a Surface Water satellite mission**

Snow

- **Continuous fields of snow cover characteristics derived through coupling satellite data with snowpack model: Application in the river runoff modeling over NEESPI domain.**

About $1 M per year for 3 years

NASA-Funded Integrative Boreal Projects

- Modeling the carbon dynamics of the Eurasian Boreal Forest
- Current climate changes over Eastern Siberia and their impact on permafrost landscapes, ecosystem dynamics, and hydrological regime
- Diagnosis and Prognosis of Changes in Lake and Wetland Extent on the Regional Carbon Balance of Northern Eurasia
- Quantifying CO_2 fluxes from boreal forests in Northern Eurasia: An integrated analysis of flux tower data, remote sensing data and biogeochemical modeling
- Permafrost dynamics within the Northern Eurasia region and related impacts on surface and sub-surface hydrology
- Role of land cover and land use change in hydrology of Eurasian Pan-Arctic
- An integrated understanding of the terrestrial water and energy cycles across the NEESPI domain through observations and modeling