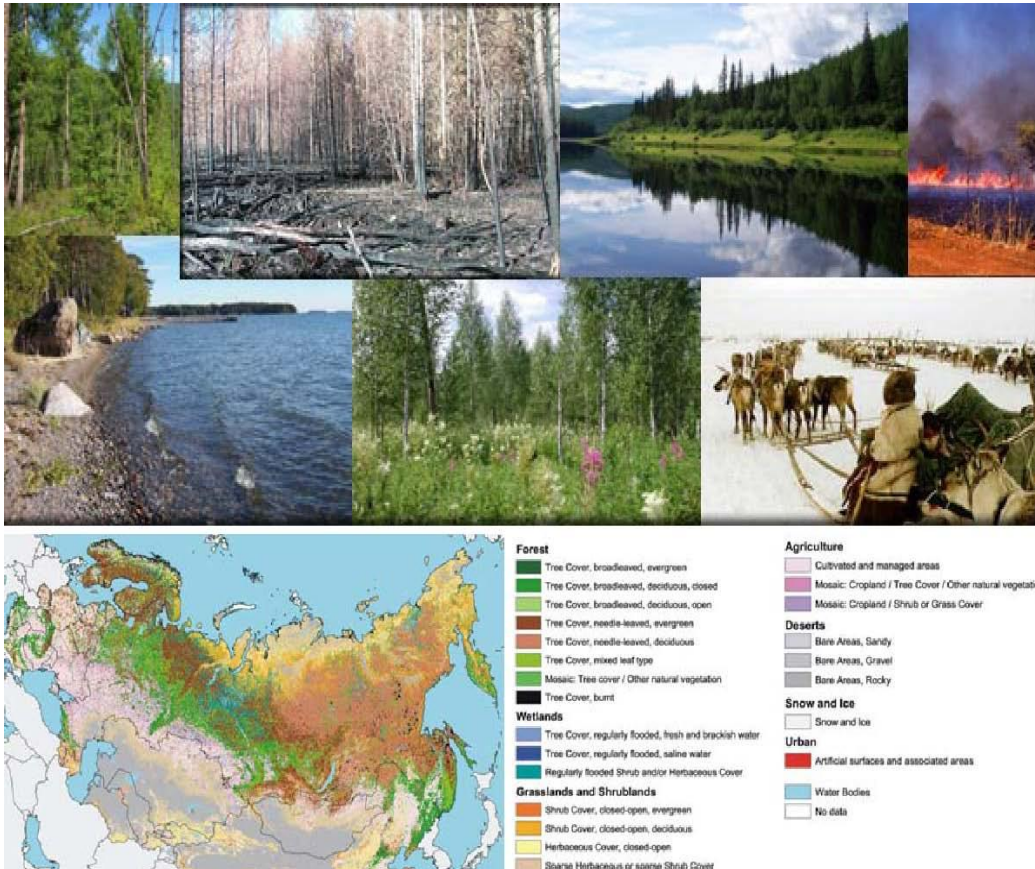
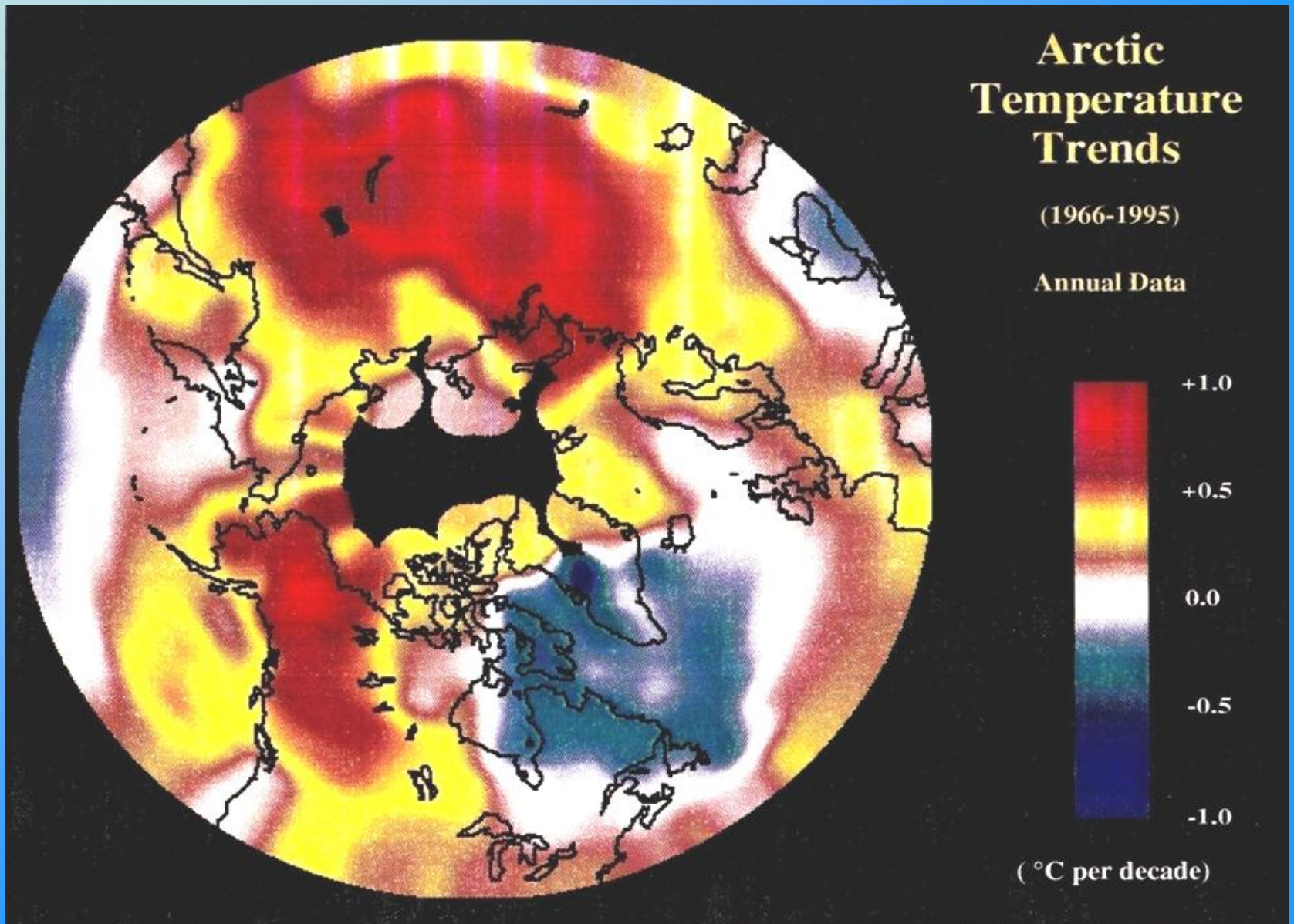


# Changes of Land Cover and Land Use and Greenhouse Gas Emissions in Northern Eurasia



(Source: NEESPI Executive Overview, December 2004)

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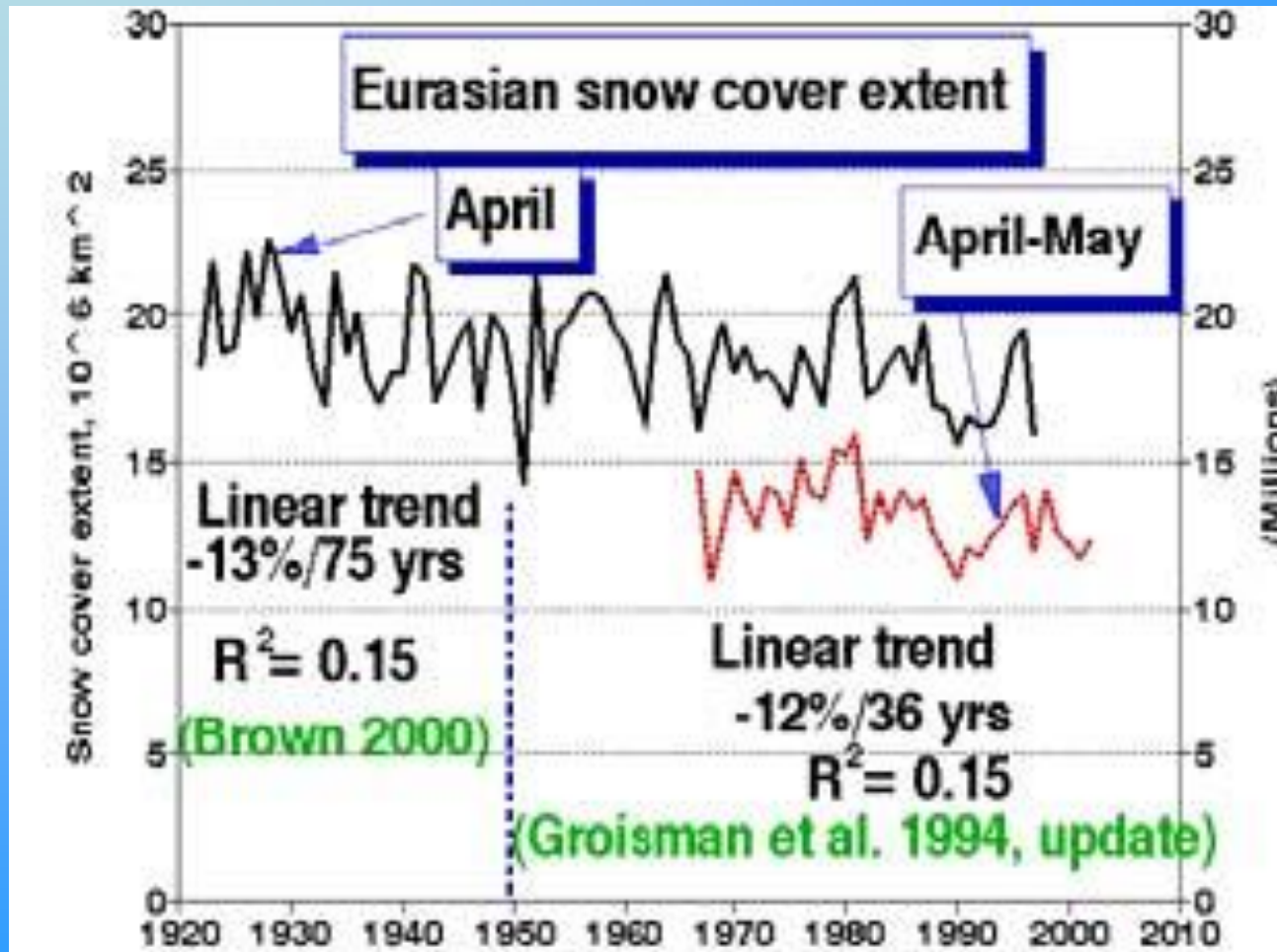
*Serreze et al., 2000, Climatic Change*

# Half of the Terrain Has Permafrost

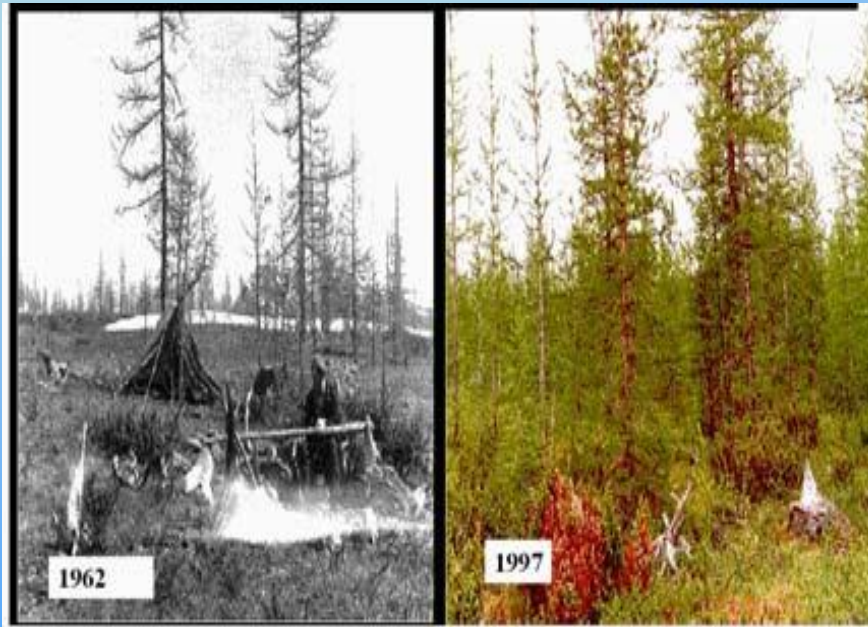


Circumpolar permafrost extent (Brown et al. 1997). Glaciers (dark blue) and areas of continuous, discontinuous, sporadic, isolated, and relict permafrost are shown. Shelf permafrost limit is depicted by the red line.

# Changes of Snow Cover



# Changes of Vegetation Distribution



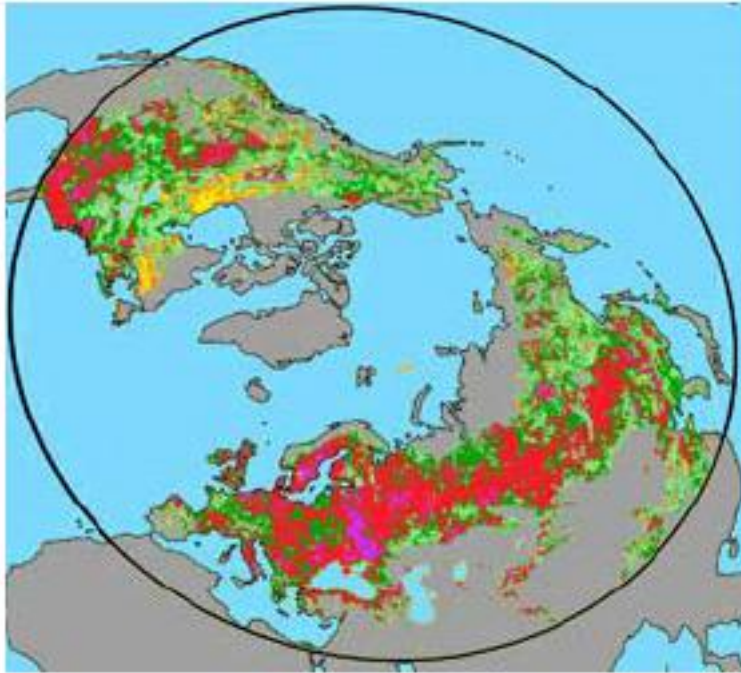
Advance/retreat of the forest line, increase/decrease of conditions conducive for forest fires, wind-throw, bogging, and logging may lead to global biogeochemical, energy, and water cycle changes.



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

(Source: NEESPI Executive Overview, *December 2004*)

# Changes of Vegetation Greenness



Low

High



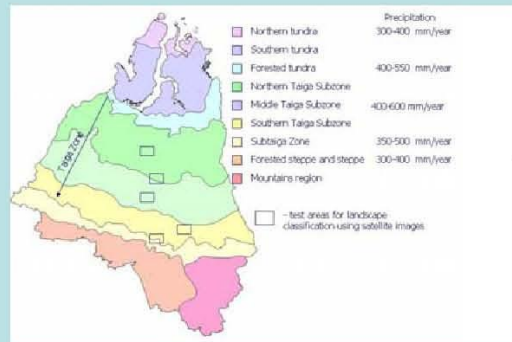
Persistence of greening

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

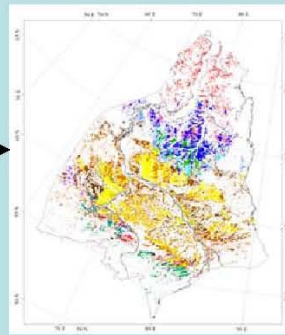
(Source: NEESPI Executive Overview, December 2004)

# Complex Land-Cover

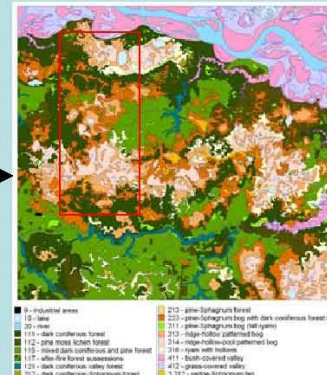
Climatic gradient of WS and location of test areas



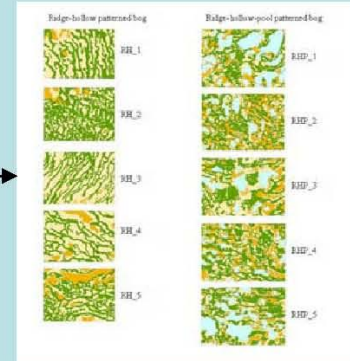
Wetland typology map, 2.5K scale, 20 classes and complexes



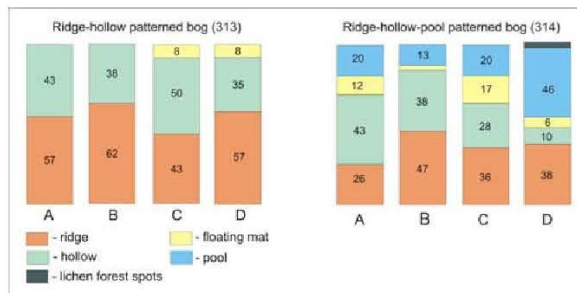
Classification of LANDSAT imagery by 30 classes (in a boreal region)



Classification of QuickBird imagery, 0.6 m/pixel



Areal fractions by micro-landscape and climatic gradient from classification of the QuickBird imagery



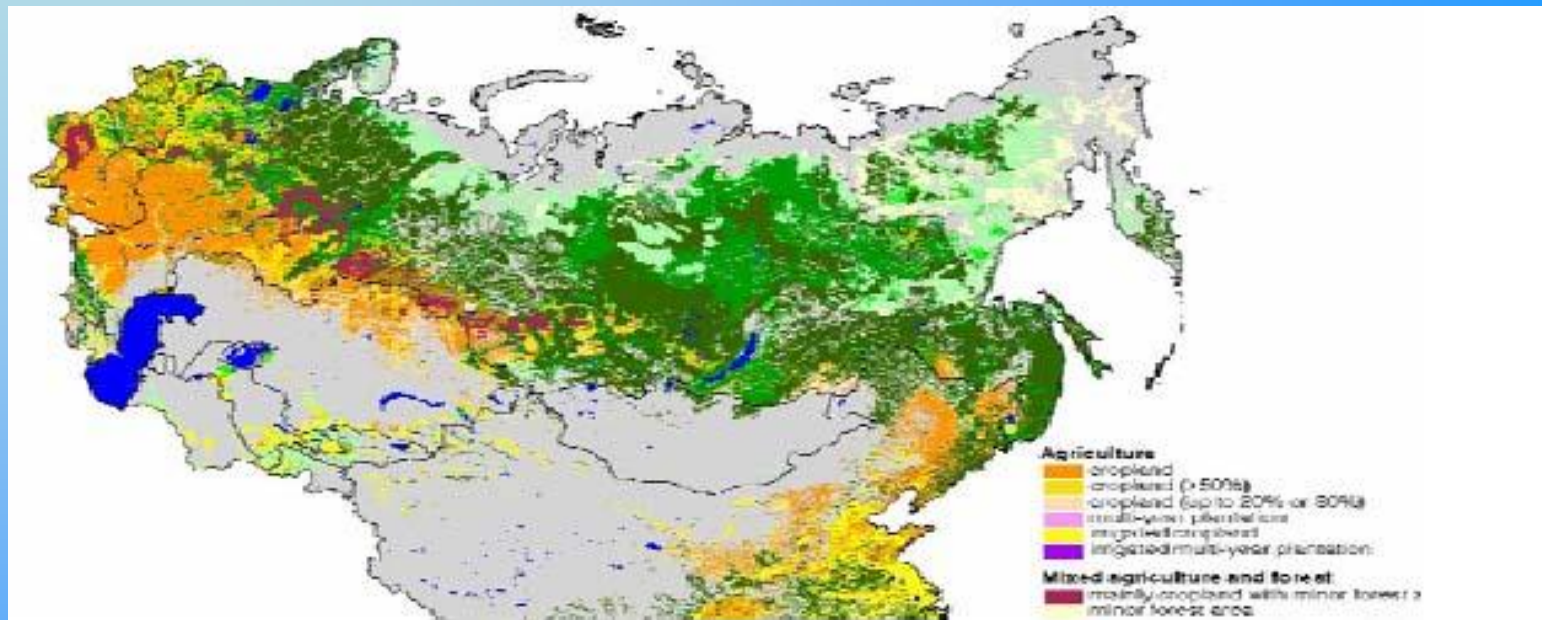
A, B, C, and D: test areas are mentioned from south to north in the boreal region, WS. Test areas: A – Kedrovyy, B – Tomsk Obl., C – Langeepas, D – Polesye.

Typical values of methane flux in boreal regions of western Siberia (as compiled by M. Glagolev)

Zone or subzone	Ecosystem <sup>1)</sup>	CH <sub>4</sub> flux, mgC·m <sup>-2</sup> ·h <sup>-1</sup>		Source of information
		F <sup>2)</sup>	Err <sup>3)</sup>	
Northern Taiga	Palsa	0.00 <sup>m</sup> (10)	-0.13/0.01 <sup>K</sup>	[Naumov, 2001]
	Unforested bog	0.62 <sup>m</sup> , 0.62 <sup>s</sup> (9)	0.42/0.83 <sup>K</sup> , 0.35 <sup>o</sup>	
	Hollow of RHC	0.86 <sup>m</sup> (11)	0.58/1.05 <sup>K</sup>	
Middle Taiga	Ridge of RHC	0.00 <sup>m</sup> (8)	0.00/0.27 <sup>K</sup>	[Naumov, 2001] and own data (2007)
	Fen	3.58 <sup>m</sup> , 3.59 <sup>s</sup> (43)	2.03/5.25 <sup>K</sup> , 2.12 <sup>o</sup>	
	Hollow of RHC	1.83 <sup>m</sup> (60)	0.78/7.25 <sup>K</sup>	
	Ridge of RHC	0.45 <sup>m</sup> , 0.40 <sup>d</sup> (8)	0.23/0.65 <sup>K</sup> , 0.27 <sup>z</sup>	
	Ryam	0.31 <sup>m</sup> (34)	0.09/0.87 <sup>K</sup>	
Southern Taiga	Pond	1.28 <sup>s</sup> (6)	1.28 <sup>o</sup>	[Tolhima et al., 1995; Naumov et al., 2007], own data (2006-2007)
	Lake	0.25 <sup>s</sup> (7)	0.28 <sup>o</sup>	
	Eutrophic hollow	3.55 <sup>m</sup> (84)	2.46/6.35 <sup>K</sup>	
	Fen	4.16 <sup>m</sup> (180)	2.59/7.91 <sup>K</sup>	
	Hollow of RHC	2.74 <sup>m</sup> (47)	1.01/4.44 <sup>K</sup>	
	Ridge of RHC	1.70 <sup>m</sup> (37)	1.05/2.77 <sup>K</sup>	
	Ryam	1.26 <sup>m</sup> (109)	0.28/2.94 <sup>K</sup>	
Lake	3.1 <sup>m</sup> (11)	0.06/17.94 <sup>K</sup>		
Waterlogged Forest	0.21 <sup>m</sup> (7)	0.05/0.61 <sup>K</sup>		

(Source: Anna Peregon)

# Regional Cropland Distribution



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

(Source: NEESPI Executive Overview, *December 2004*)

# Unique Features of This Region

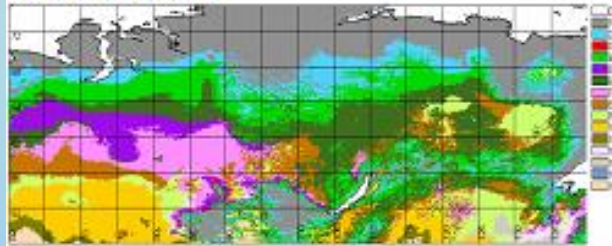
- Northern Eurasia is a major host of the boreal forest and bog ecosystems, which may exercise control over the global biogeochemical cycle affecting the atmospheric composition of such greenhouse gases as  $\text{CH}_4$  and  $\text{CO}_2$
- This is the world's largest cold region with 2/3 of the permafrost area, 2/3 of the area with seasonal snow cover, and more than a 1/3 of the mountain glaciers in the Northern Hemisphere. Cold land processes define, control, and put a unique signature on the Northern Eurasian climate, hydrology, and environment
- This is the region where the most continental climate is observed that affects the intensity of the Eurasian monsoon circulation, which is vital for the densely populated southern half of Eurasia
- This is the region with the largest river, lake, and reservoir systems on Earth, the largest closed drainage basins, and the most extensive coastal zone exposed to permafrost thaw

# Research Questions

- How have land cover and land use been affected by climate variability and change over the region during the past three decades?
- How much  $CO_2$  and  $CH_4$  have been emitted or taken up by terrestrial ecosystems in the region during the last three decades?
- How will the region's land cover and land use change in the next 50 to 100 years as a result of climate change and permafrost degradation as well as human activities and economic development?
- How will regional  $CO_2$  and  $CH_4$  fluxes change over the next 50 to 100 years in response to climate changes alone?
- How will regional  $CO_2$  and  $CH_4$  fluxes change over the next 50 to 100 years in response to changes of climate, atmospheric chemistry, land cover, and land use?
- What are climate impacts of regional changes in  $CO_2$  and  $CH_4$  fluxes, land use and land cover?
- Are conditions in Northern Eurasia becoming more suitable or less suitable to human habitation?

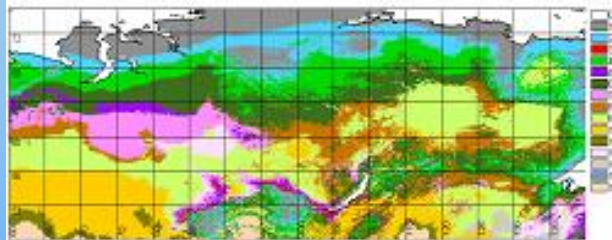
# Vegetation change from current climate to 2080 in Siberia

Current climate

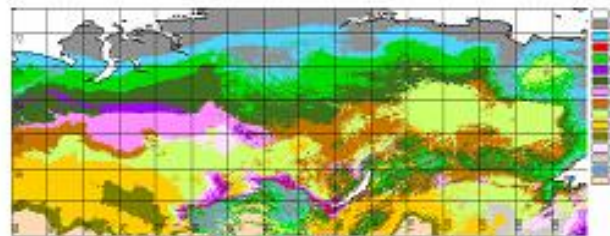


Vegetation classes: BOREAL: 1 – Tundra; 2 – Forest-Tundra; Northern Taiga: 3 – darkleaf, 4 – lightleaf; Middle taiga: 5 – darkleaf, 6 – lightleaf; Southern Taiga: 7 – darkleaf, 8 – lightleaf; 9 – Subtaiga, Forest-Steppe; 10– Steppe; 11 – Semidesert; TEMPERATE: 12 – Broadleaf; 13 – Forest-Steppe; 14 – Steppe, 15 – Desert, 0- Water

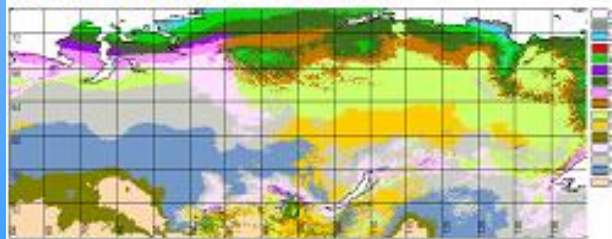
Scenario HadCM3 A1FI 2020



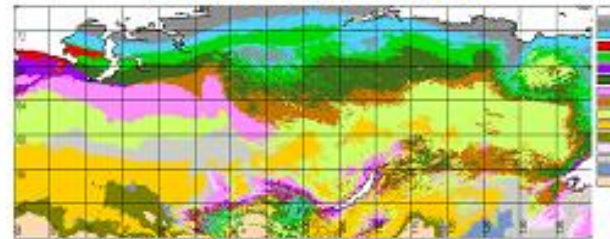
Scenario HadCM3 B1 2020



Scenario HadCM3 A1FI 2080



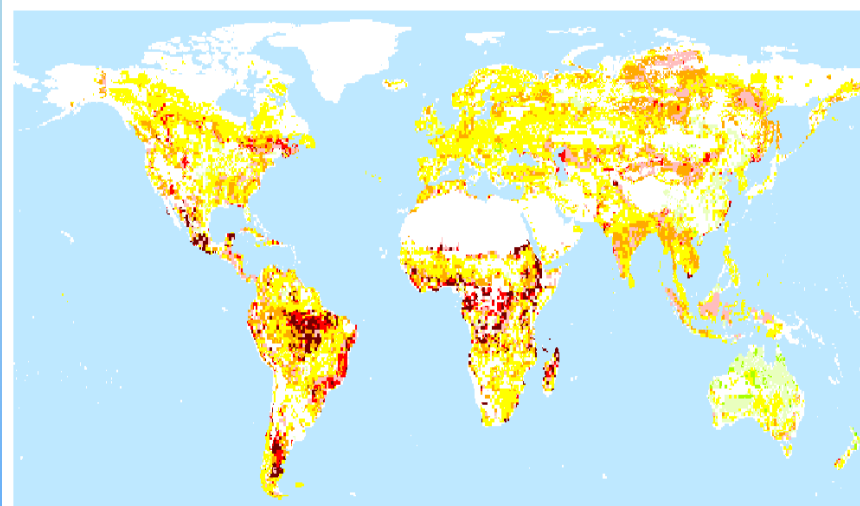
Scenario HadCM3 B1 2080



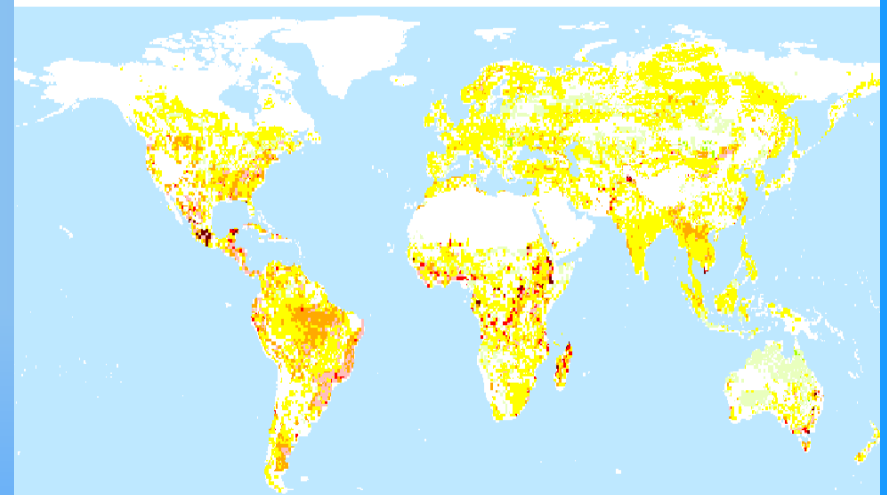
Vegetation change from current climate to 2080 in Siberia was mapped by coupling our bioclimatic vegetation model with maps of bioclimatic indices and of the permafrost which drive the model for different time slices and two climate change scenarios (Tchebakova et al., 2008).

# Loss of natural areas due to their conversion to crop and pasture cellulosic biofuels between 2000 and 2050

a. Deforestation.



b. Intensification.

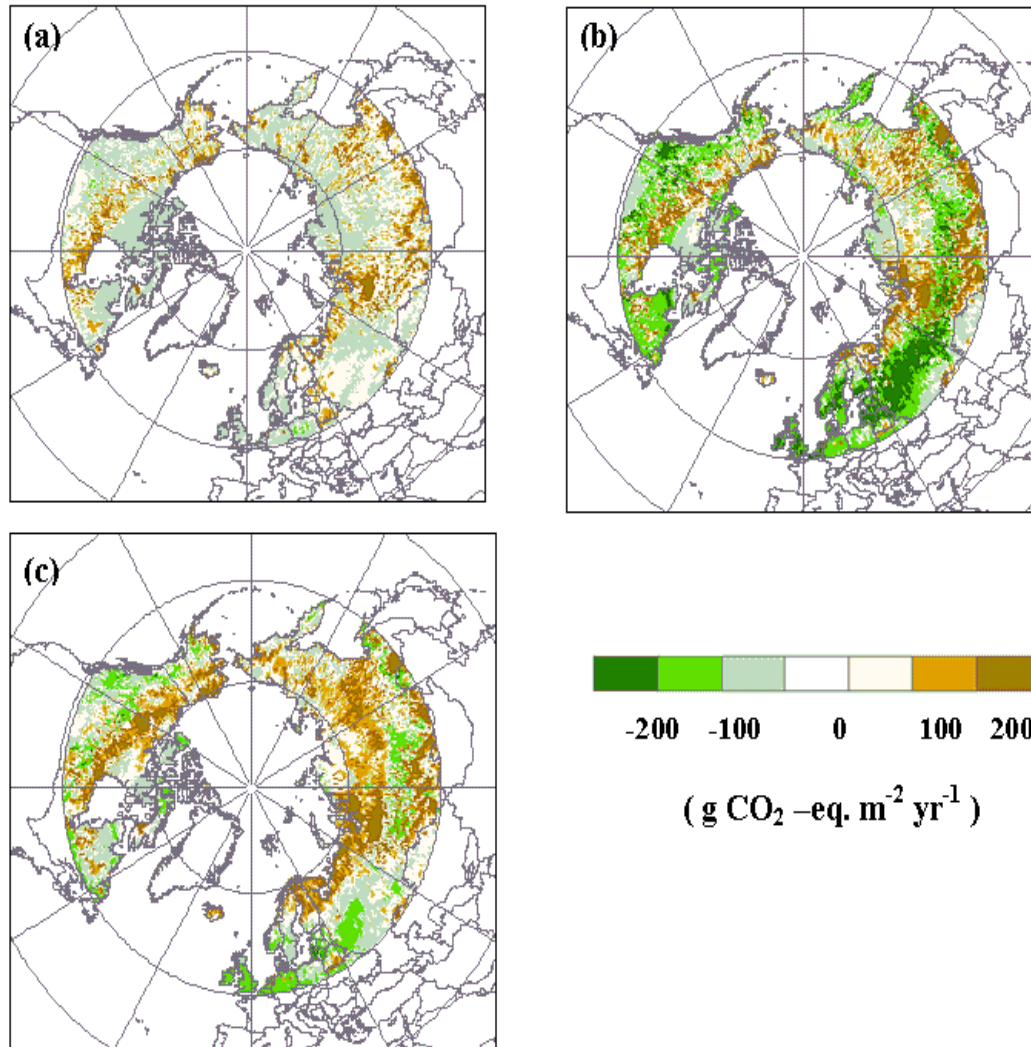


-60 -40 -20 -1 1 20 40 60 80 100

Percent

Loss of natural areas due to their conversion to crop and pasture agriculture and cellulosic biofuels between 2000 and 2050 as simulated by the deforestation (a) and intensification (b) scenarios. Data expressed as the percentage of each  $\frac{1}{2}$  by  $\frac{1}{2}$  degree grid cell devoted to agricultural and cellulosic biofuels production (Melillo et al., 2008).

# Net Greenhouse Gas Exchanges of CO<sub>2</sub> and CH<sub>4</sub>



Spatial distribution of net greenhouse gas exchanges simulated with TEM (a) in the 1990s, (b) in the 2090s with  $\text{CO}_2$  fertilization effects, and (c) in the 2090s without  $\text{CO}_2$  fertilization effects. The MIT Integrated Global Systems Model (IGSM) is used to develop monthly estimates of surface air temperature, precipitation, and vapour pressure for three future climate and atmospheric  $\text{CO}_2$  concentration scenarios for input into TEM. In these maps, the effects of fire disturbances have also been considered (Zhuang et al., 2009).

# Research Tasks

**Task 1:** Refine land-cover and land-use data in the region using satellite and remote sensing products.

**Task 2:** Evaluate how climate change and human activities may influence land-cover and land-use change in Northern Eurasia over the next 50 to 100 years.

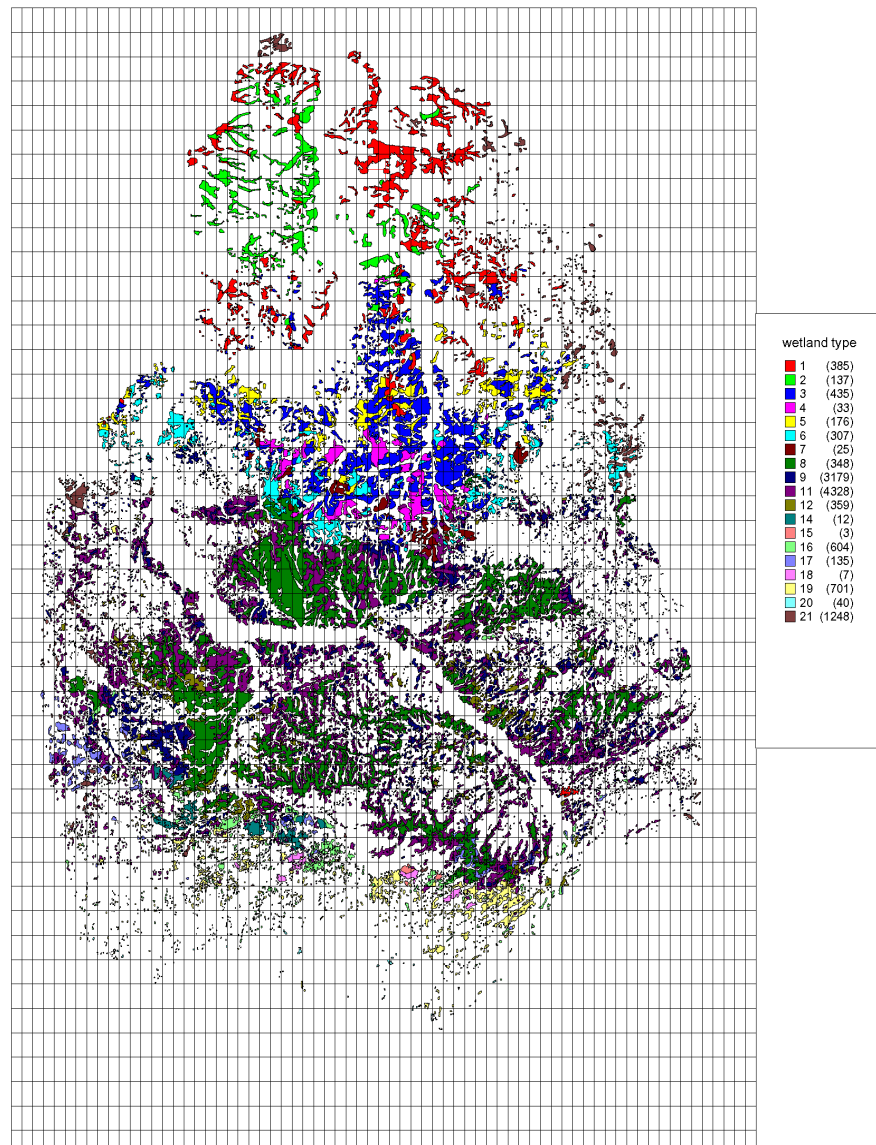
**Task 3:** Evaluate how  $CO_2$  and  $CH_4$  fluxes and carbon pools in Northern Eurasia have changed over the last three decades.

**Task 4:** Evaluate how  $CO_2$  and  $CH_4$  fluxes in Northern Eurasia may change over the next 50 to 100 years in response to changes of climate, atmospheric chemistry, land cover, and land use.

**Task 5:** Evaluate the impacts of changes in terrestrial biogeochemistry and land-use and land-cover on regional and global climate.

**Task 6:** Assess human adaptation and quality of life to changes in climate, atmospheric chemistry, land cover and land use in Northern Eurasia.

# Land-Cover Data Development with Multi-Scale Approaches



## A. Humid zone.

### I. Oligotrophic and meso-eutrophic lowland polygon mires:

- 1 - Polygonal-roller and polygonal-fissure mires,
- 2 - Polygonal mires combined with grass- and moss-dominated mires.

### II. Oligotrophic and mesotrophic flat-palsa mires:

- 3 - Patterned (hollow and hollow-pool) flat-palsa bogs,
- 4 - Flat-palsa and high-palsa bogs,
- 5 - Shrub-dominated tussock mires.

### III. High-palsa oligo-mesotrophic and oligo-eutrophic mires:

- 6 - High palsa-hollow and pool-hollow patterned mires,
- 7 - High-palsa and flat-palsa mires.

### IV. Oligotrophic (*Sphagnum* dominated) domed bogs:

- 8 - *Sphagnum*-dominated bogs with pools and open stand of trees,
- 9-10-Ridge-hollow, ridge-hollow-pool and ridge-pool patterned bogs,
- 11 - Forested (treed) shrubs- and moss-dominated mires,
- 12 - Moss-dominated treed (*Pinus*) mires.

## B. Semi-arid zone.

### V. Eutrophic and mesotrophic (sedge-brown mosses treed) flat mires:

- 14 - Ridge-hollow patterned bogs,
- 15 - Grass-mossy mires and oligotrophic pine-dwarf shrub-*Sphagnum* raised bogs - ryams,
- 16 - Grass- and grass-moss-dominated mires,
- 17 - Grass-sedge and *Sphagnum*-sedge hardwood swamps.

## C. Arid zone.

### VI. Eutrophic reed and grass-dominated salt marches:

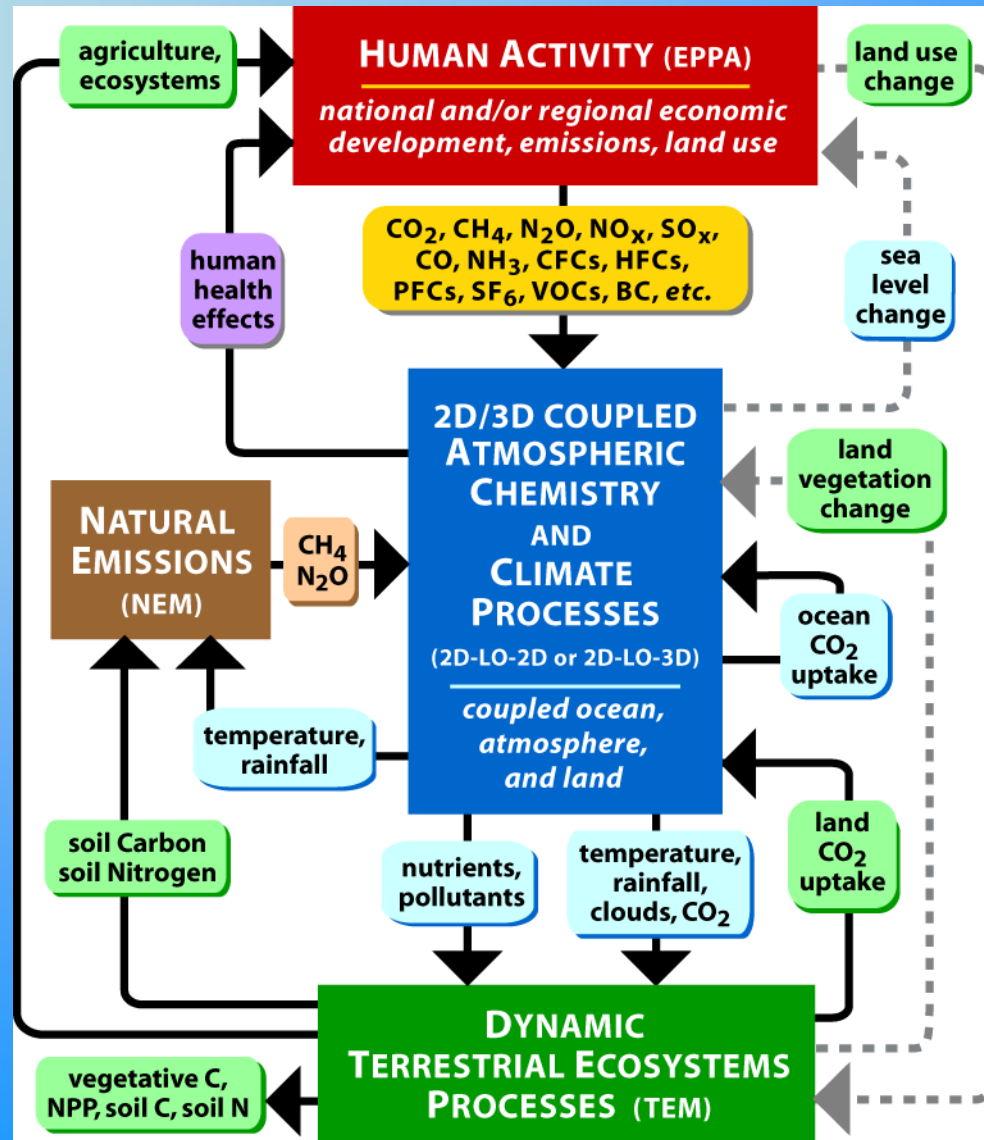
- 18 - Reed and sedge-reed mires concerning oligotrophic raised bogs (ryam),
- 19 - Reed-sedge and grassy mires,
- 20 - Grass-dominated mires on salted soils,
- 21 - Unidentified mire type.

(Peregon et al., 2008)

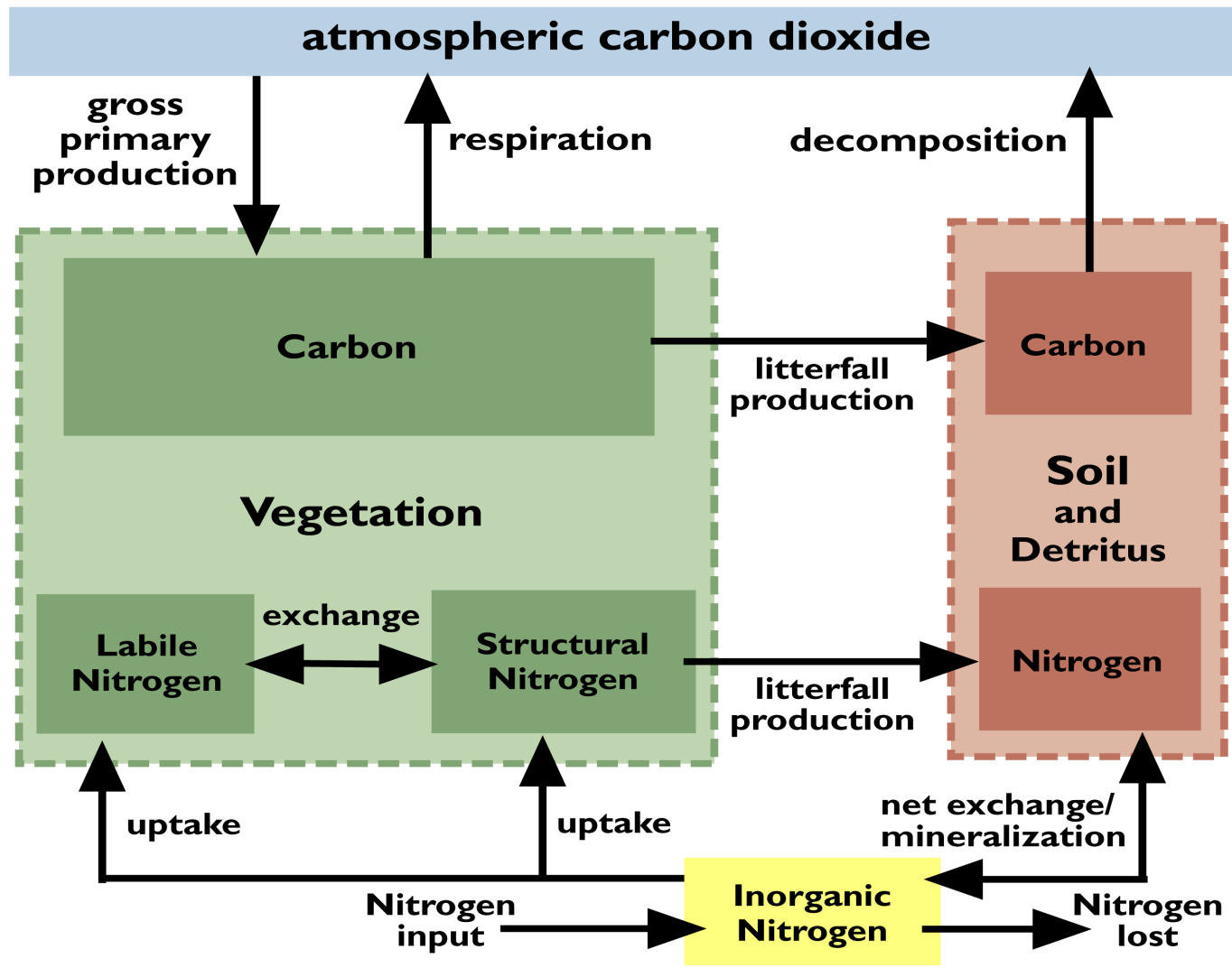
# Future Land-Cover and Land-Use Data Development

1. Bioclimatic vegetation modeling approach with consideration of the permafrost dynamics (Tchebakova et al., 2008)
2. Economic modeling approach that considers the world economy, population, and climate policy using a coupled system of TEM, EPPA and the MIT-IGSM

# MIT Integrated Global System Model



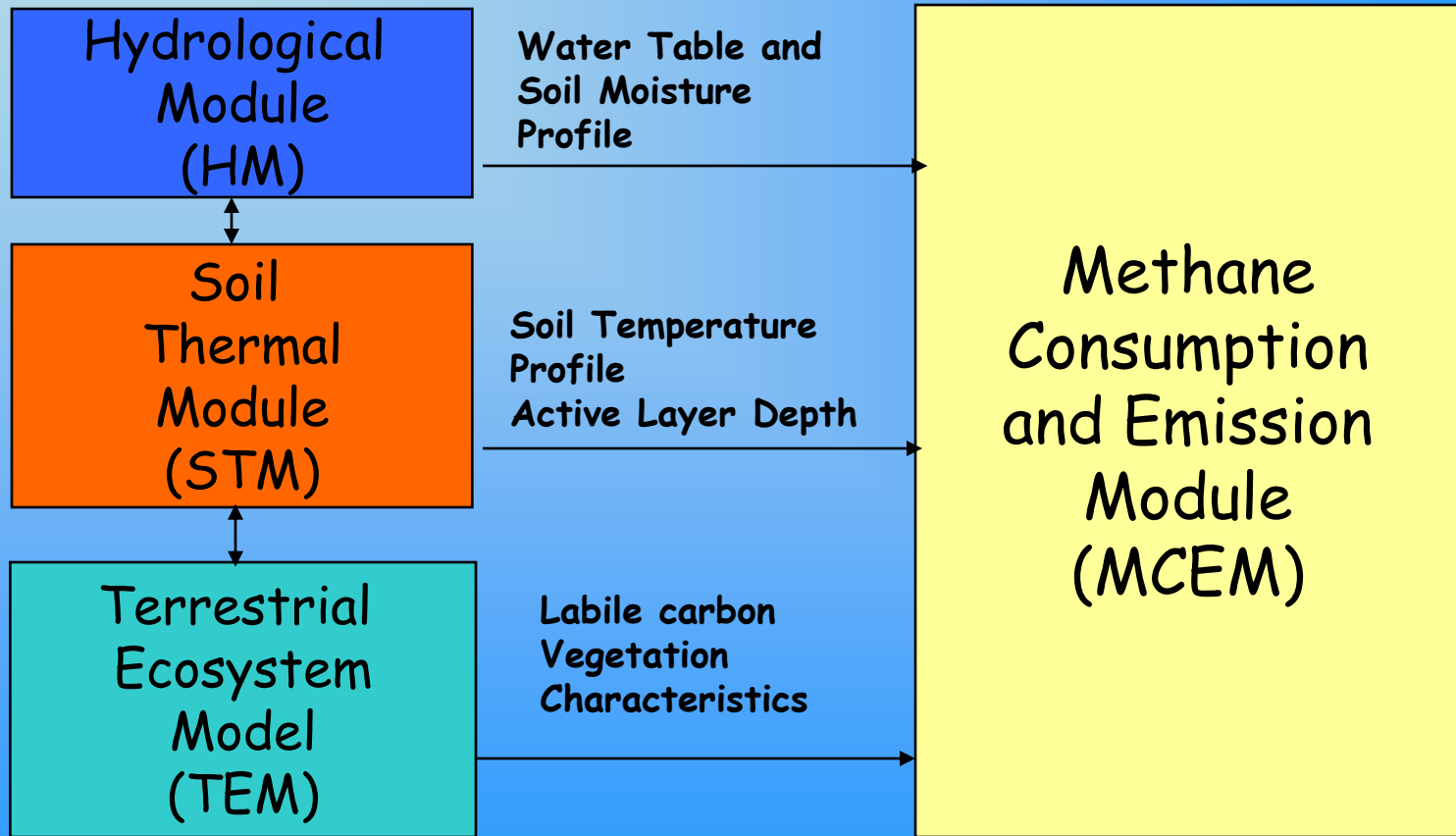
# The Terrestrial Ecosystem Model



## **Terrestrial Ecosystem Model (TEM)**

*The Ecosystems Center, Marine Biological Laboratory (Woods Hole, Massachusetts)*

# The Coupled Permafrost, Carbon and Water Modeling System



# Acknowledgment

1. NASA Land-Use and Land-Cover Change Program
2. NSF Carbon and Water in the Earth System
3. National and international collaborators