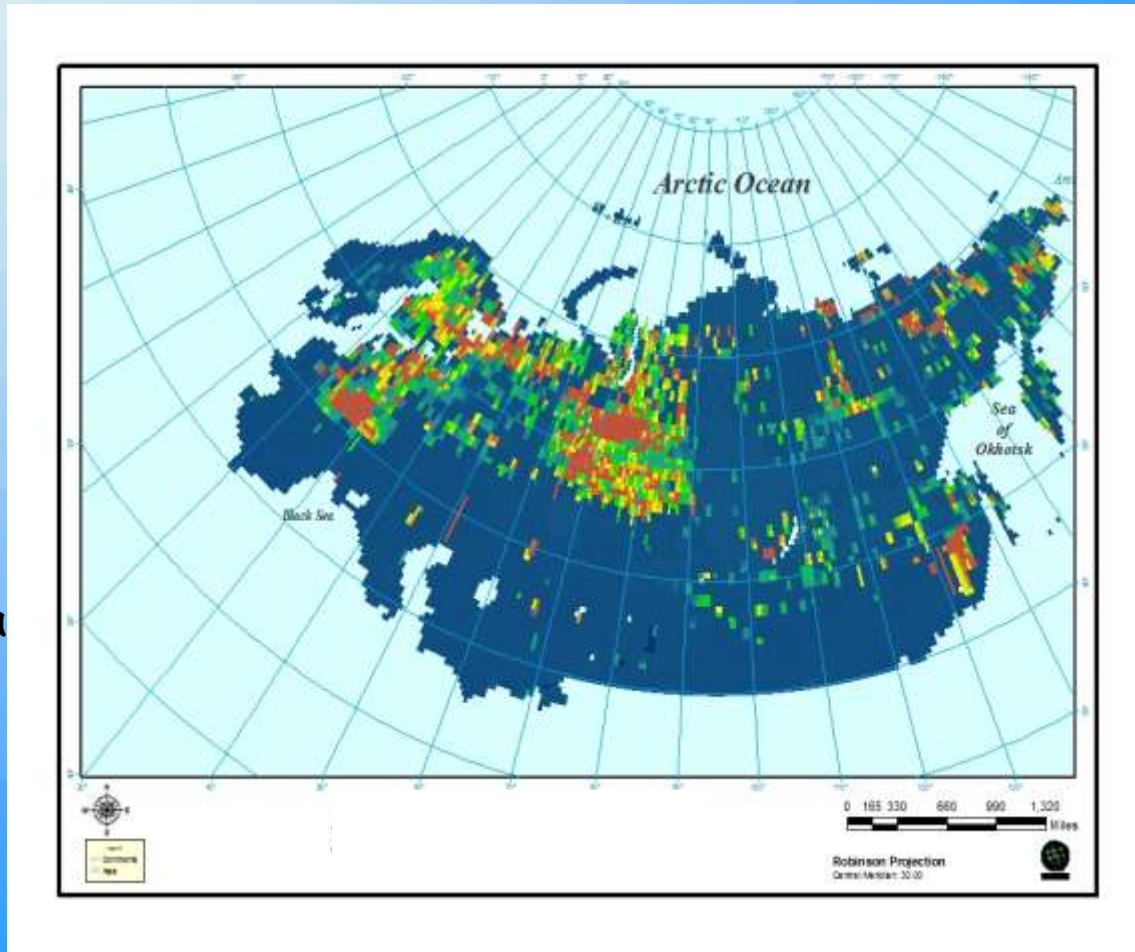


Land Use and Land Cover Change and Greenhouse Gas Emissions in Northern Eurasia

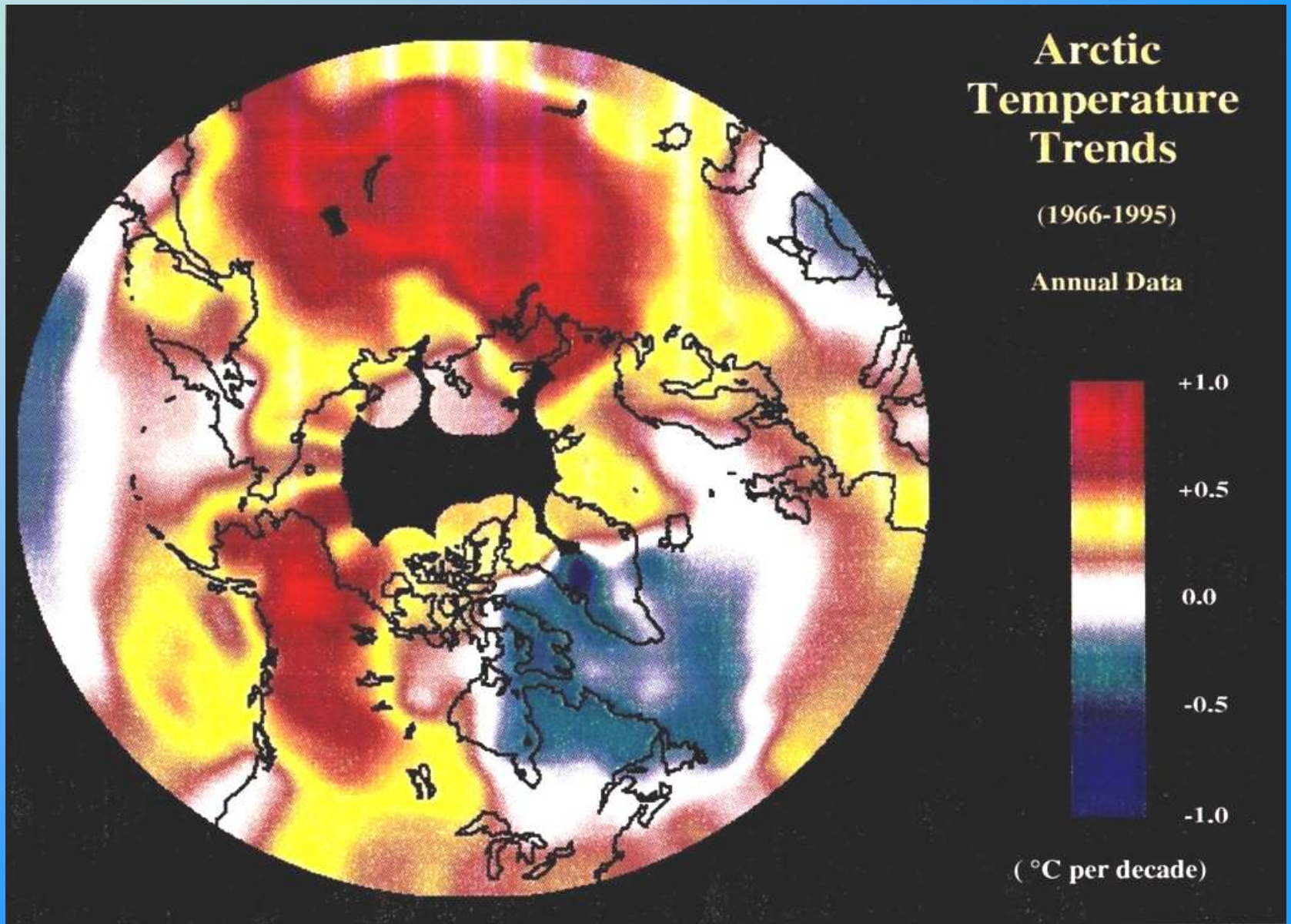
Participants:

Zhuang, Q.
Z. Zhang
M. Chen
X. Lu
J. Melillo
D. Kicklighter
J. Reilly
A. Sokolov
N. Tchebakova
A. Peregon
A. Shvidenko
A. Sirin
G. Zhou
S. Maksyutov



Institutions:

Purdue
MBL
MIT
IIASA
RAS
NIES
CAS



Serreze et al., 2000, Climatic Change

Ecosystems in Northern High Latitudes

- Large vulnerable carbon pool (~1/3 of world soil C) - Majority in NE
- Large wetland distribution (~1/2 of world wetlands) - Majority in NE
- Longer growing season (1-4 days /decade)
- Changing vegetation (e.g., moving treeline)

Large-scale processes in the region

- Permafrost thawing
(~1/4 of areas underlain
by permafrost) - higher in
NE

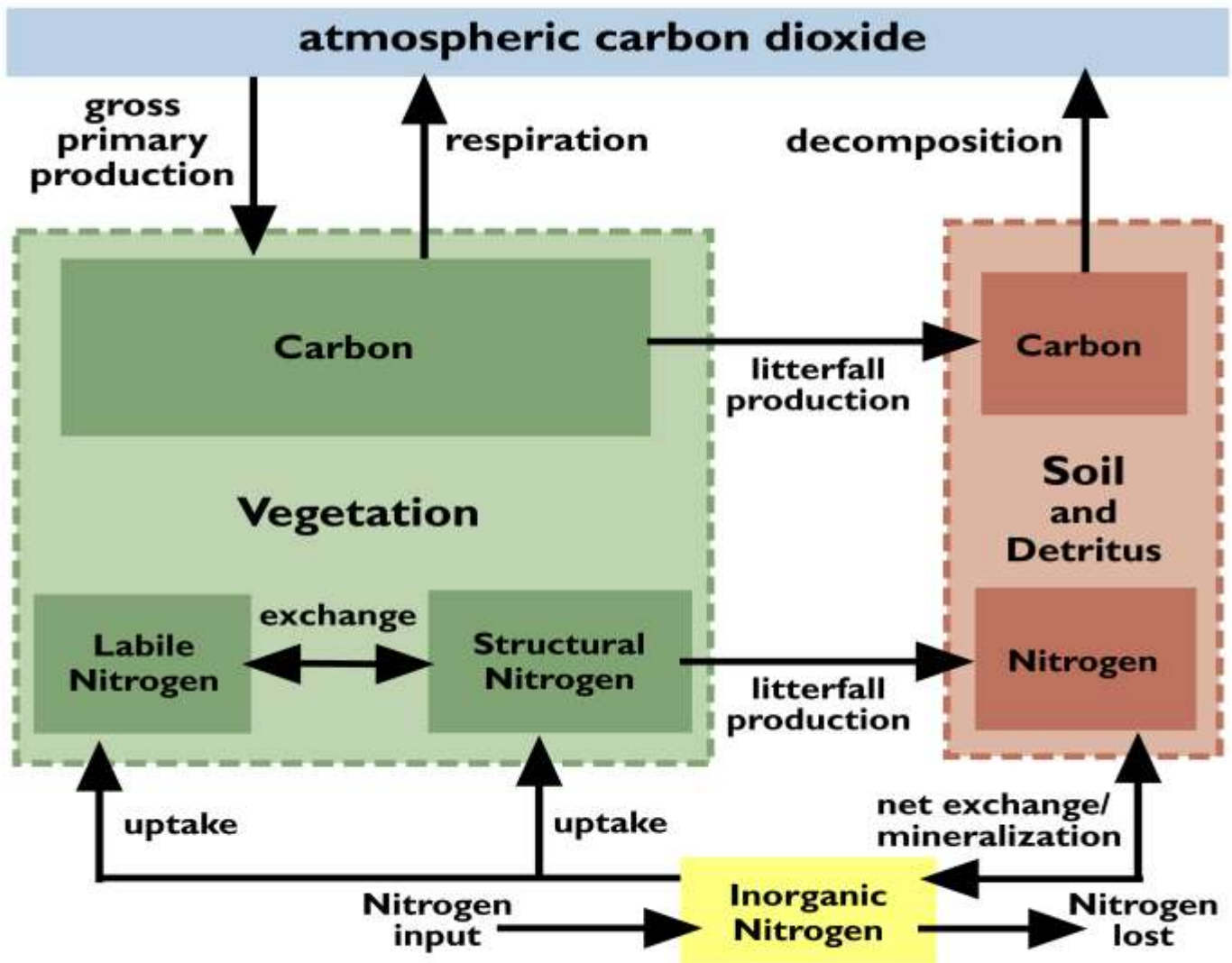


- Fire disturbance
increase ($\sim 1\% \text{ yr}^{-1}$)



Questions

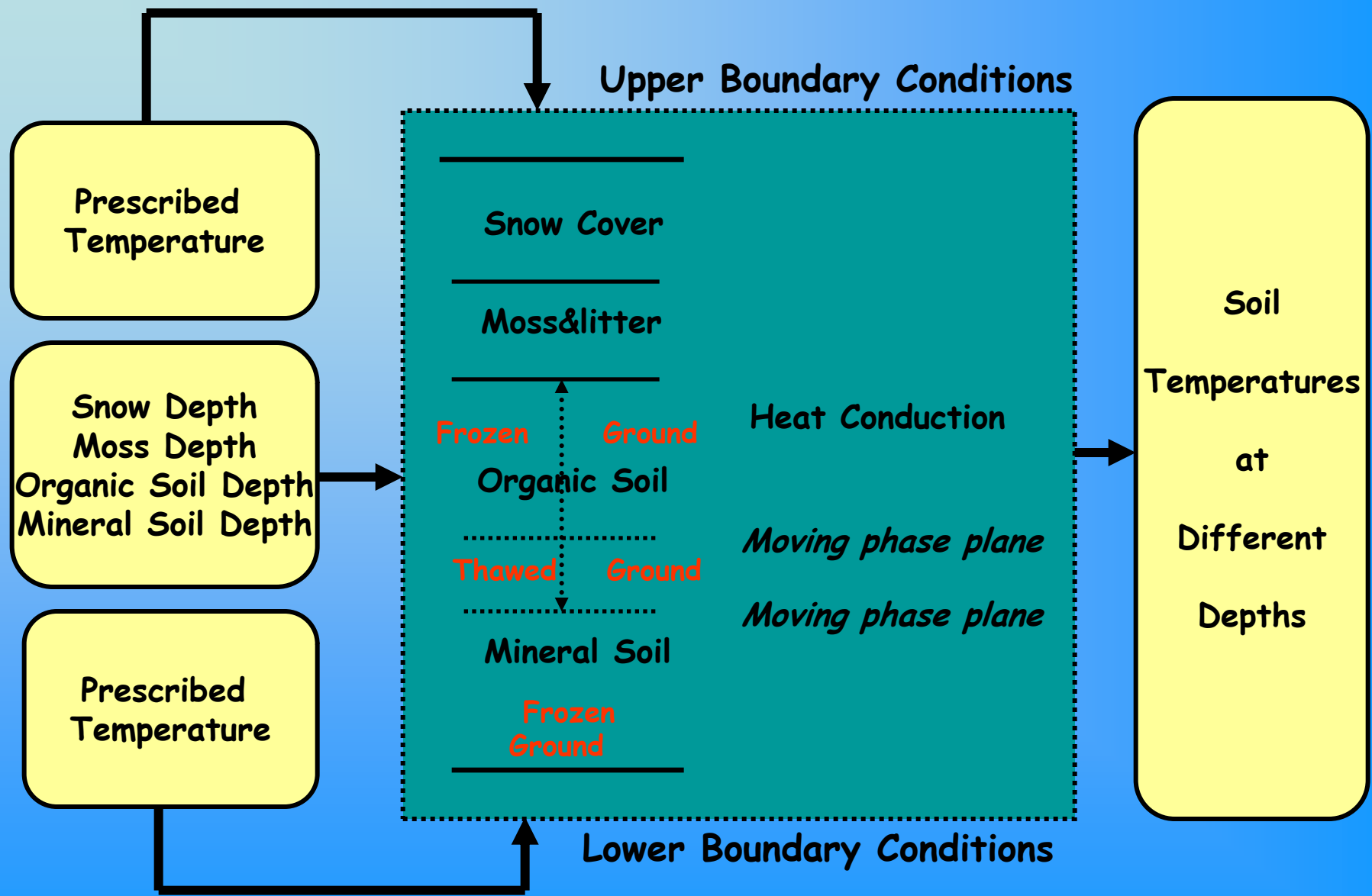
- What is the current budget of CO_2 and CH_4 for the region?
- How will the budget change over the 21st century under different land cover conditions due to changes of human activity and natural environment?



Terrestrial Ecosystem Model (TEM)

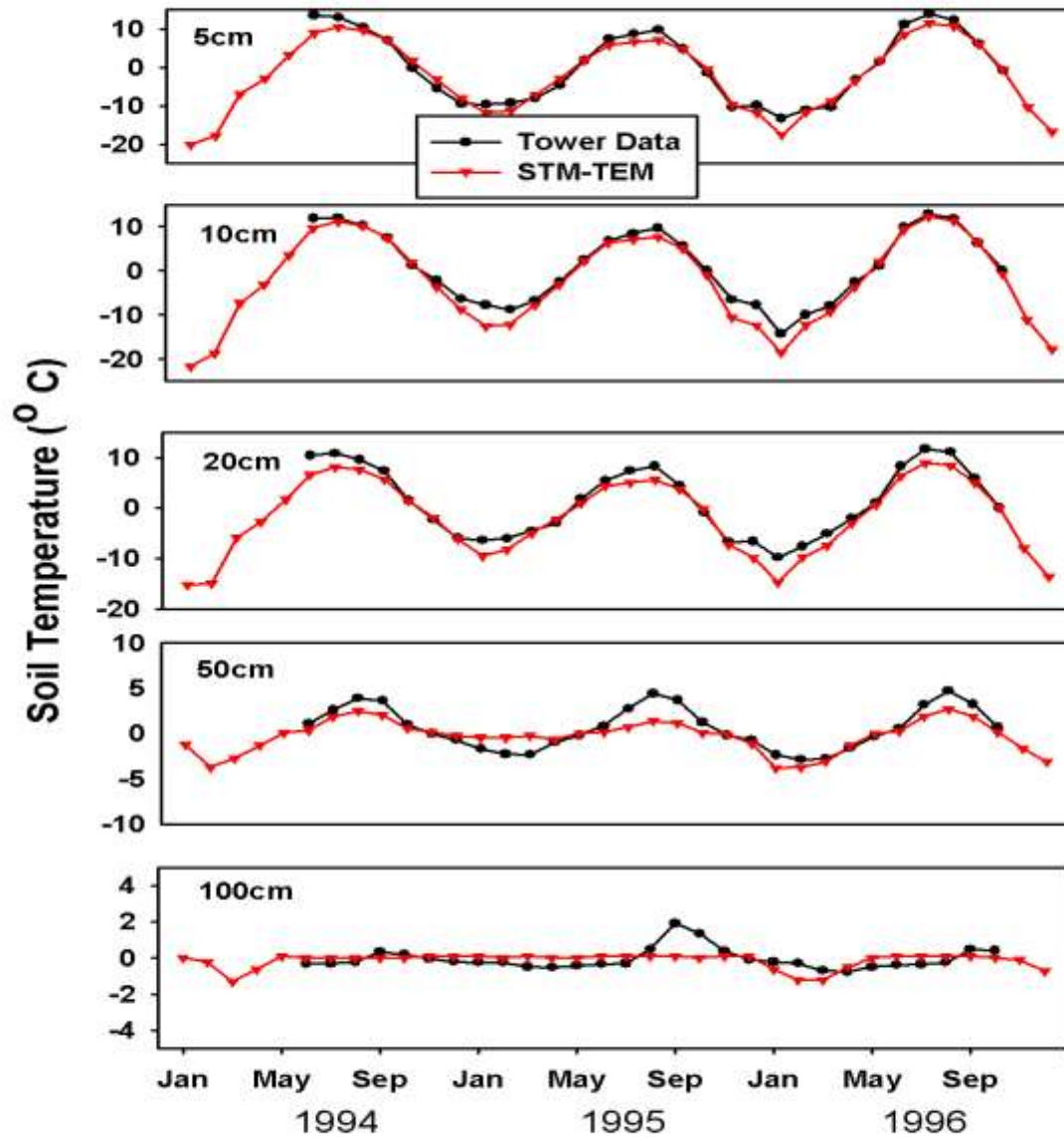
The Ecosystems Center, Marine Biological Laboratory (Woods Hole, Massachusetts)

Soil Thermal Module

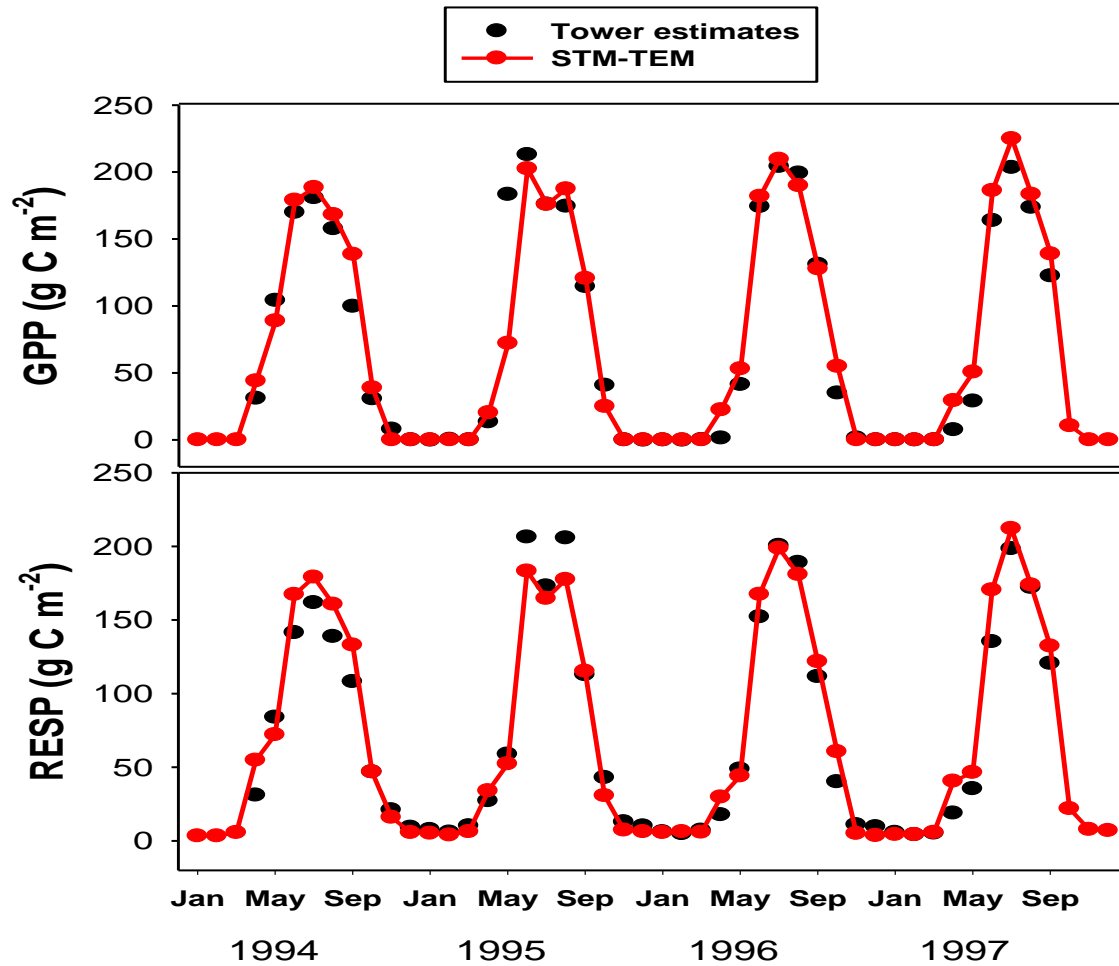


(Zhuang et al., 2001JGR)

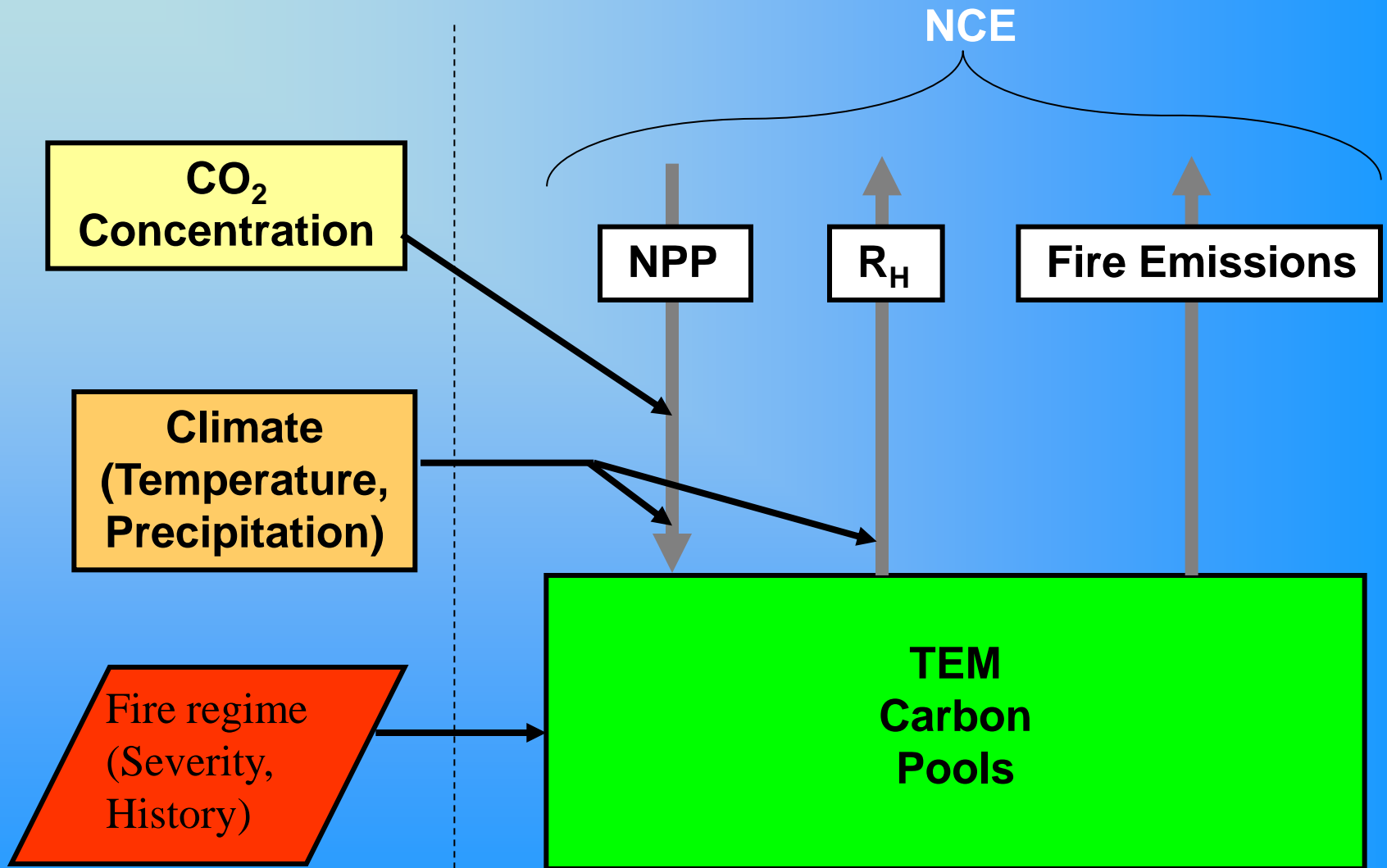
Soil Temperatures of an Old Black Spruce Ecosystem in Canada



Carbon Fluxes of an Old Black Spruce Ecosystem in Canada

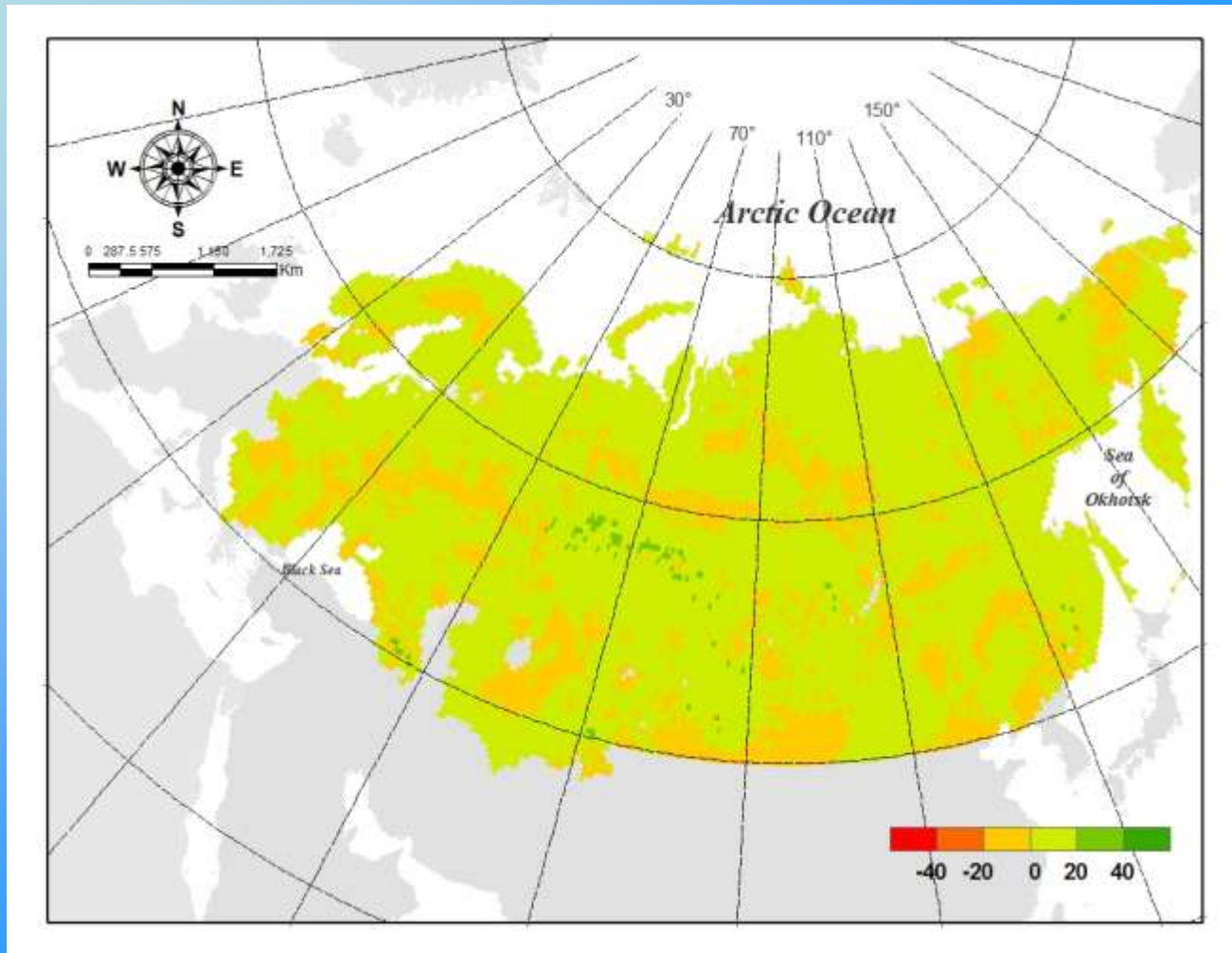


The Modified Terrestrial Ecosystem Model



Current Net Carbon Exchanges in NE

Region as
a sink
at 0.15
Pg C year⁻¹

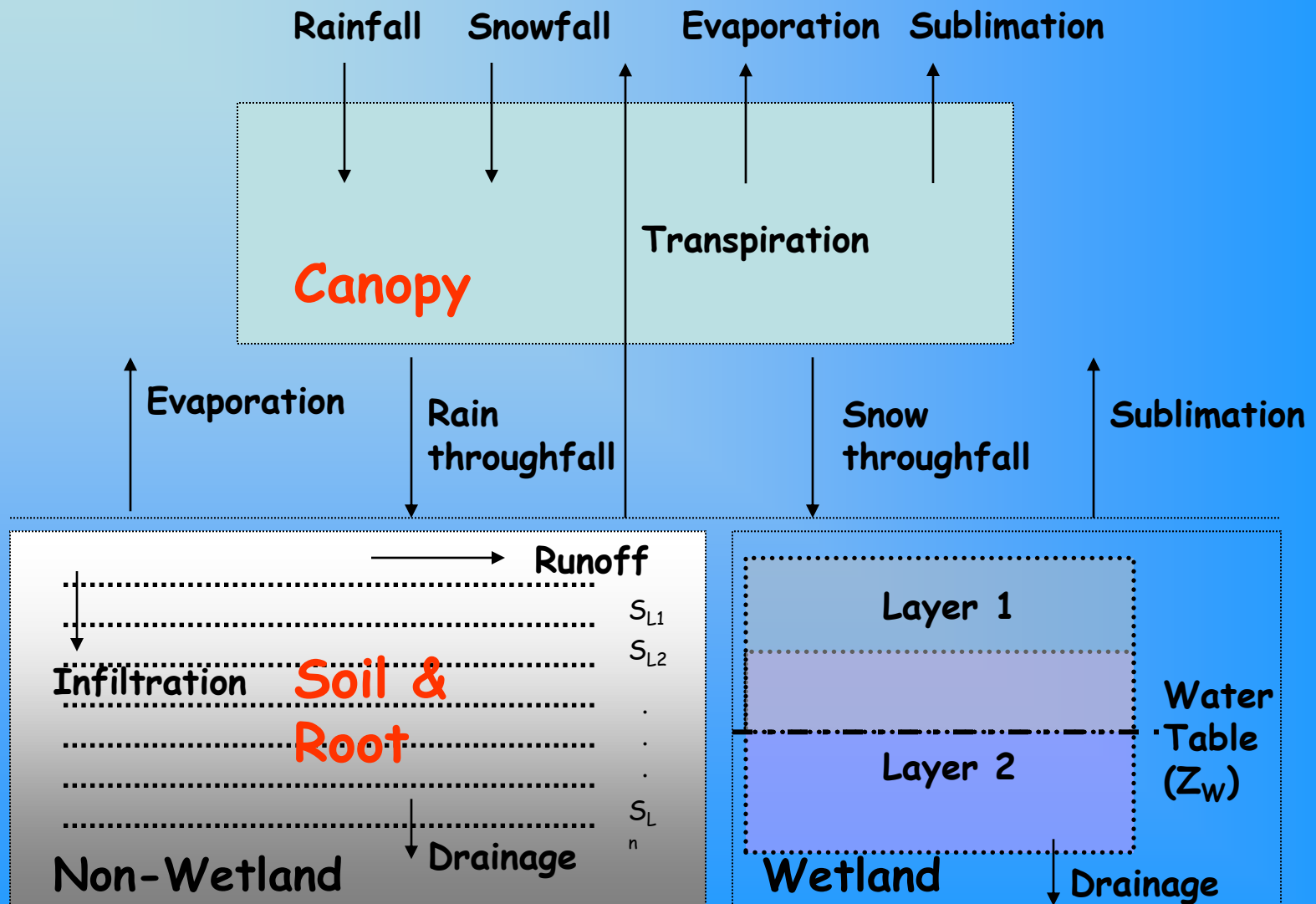


(g C m⁻² year⁻¹)

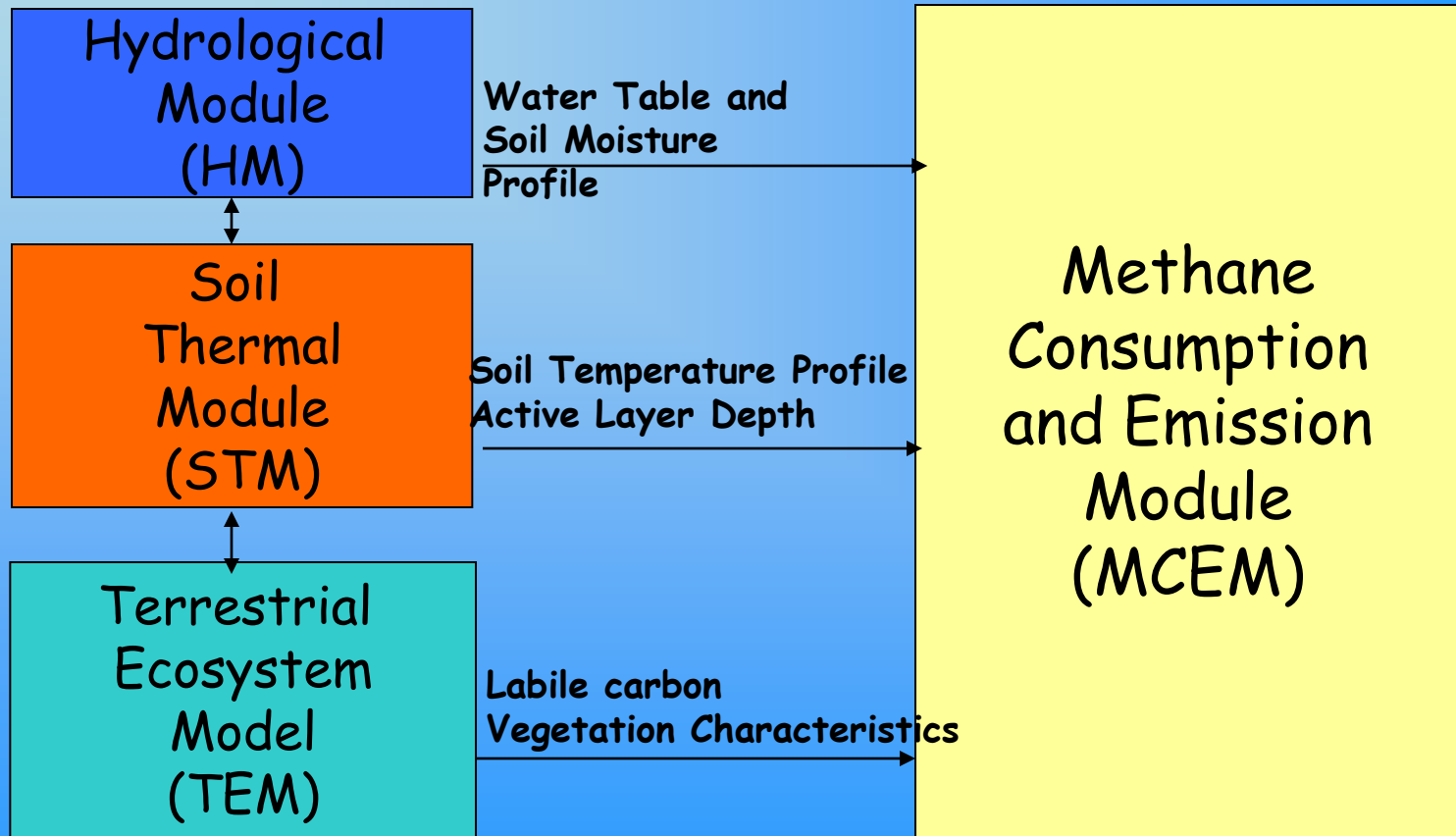
Progress Summary

- The region currently is a sink at about $0.15 \text{ Pg C yr}^{-1}$

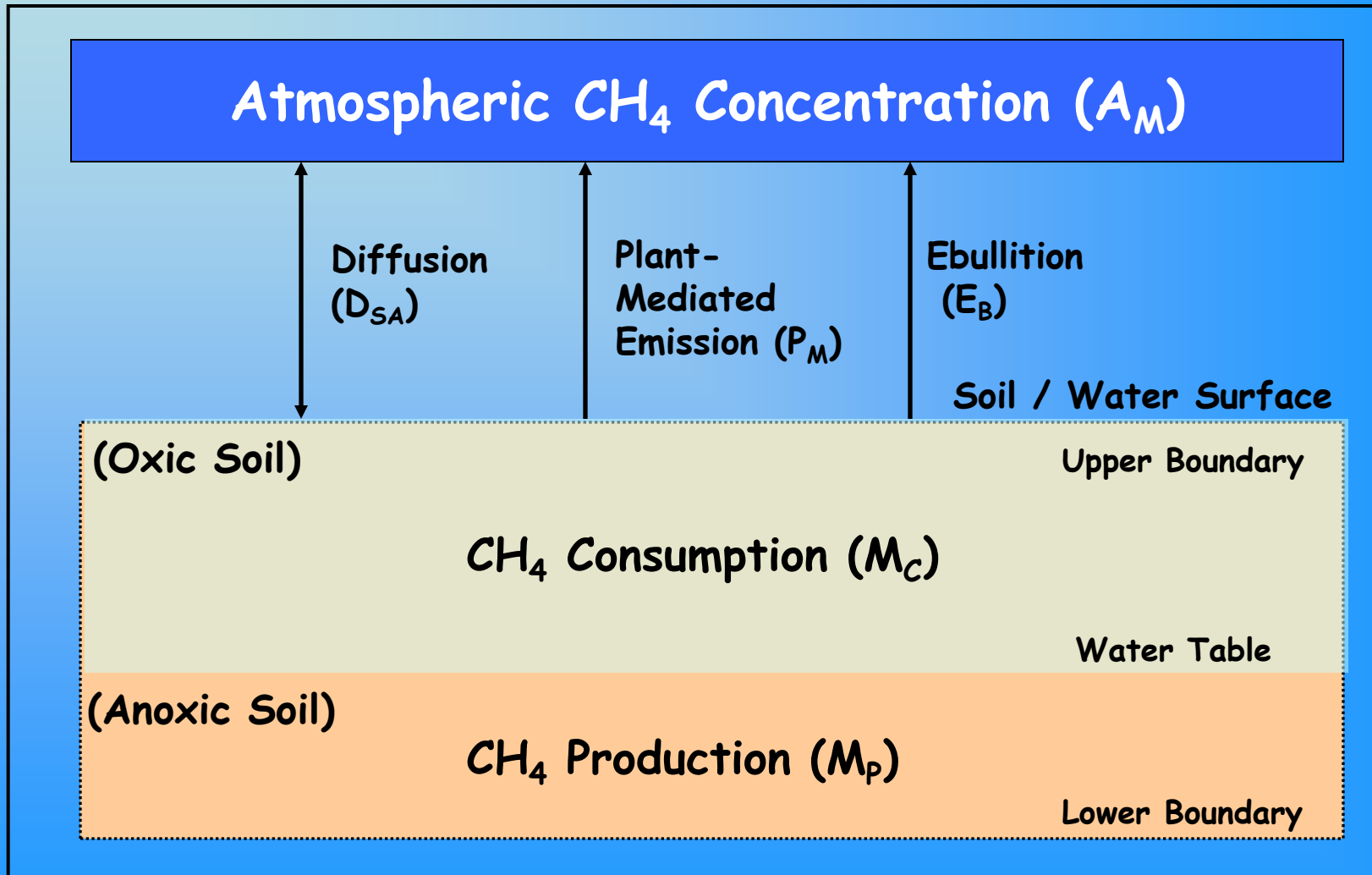
Updated Hydrological Module



Model Framework

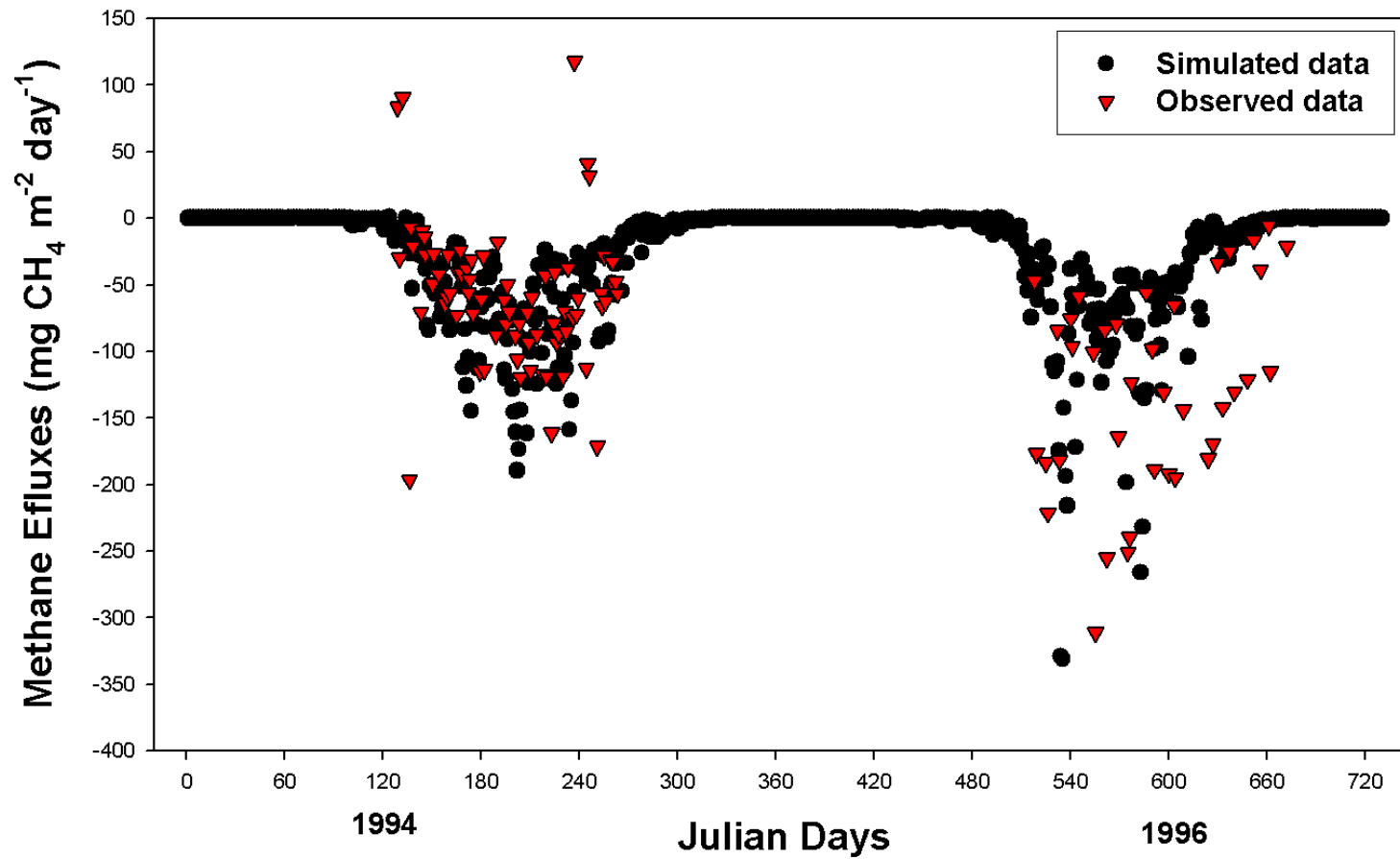


Methane Consumption and Emission Module

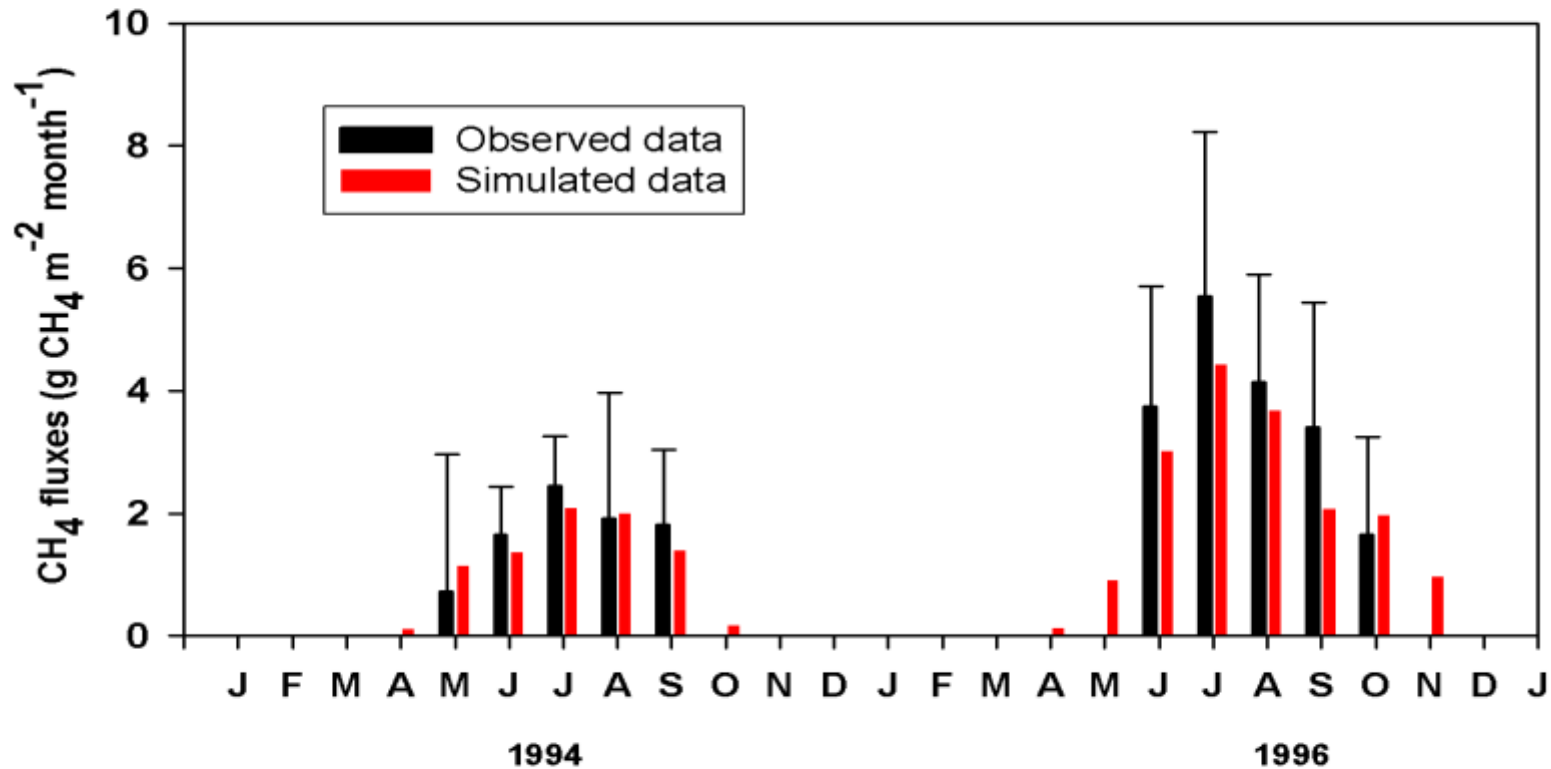


(Zhuang et al., 2004 GBC)

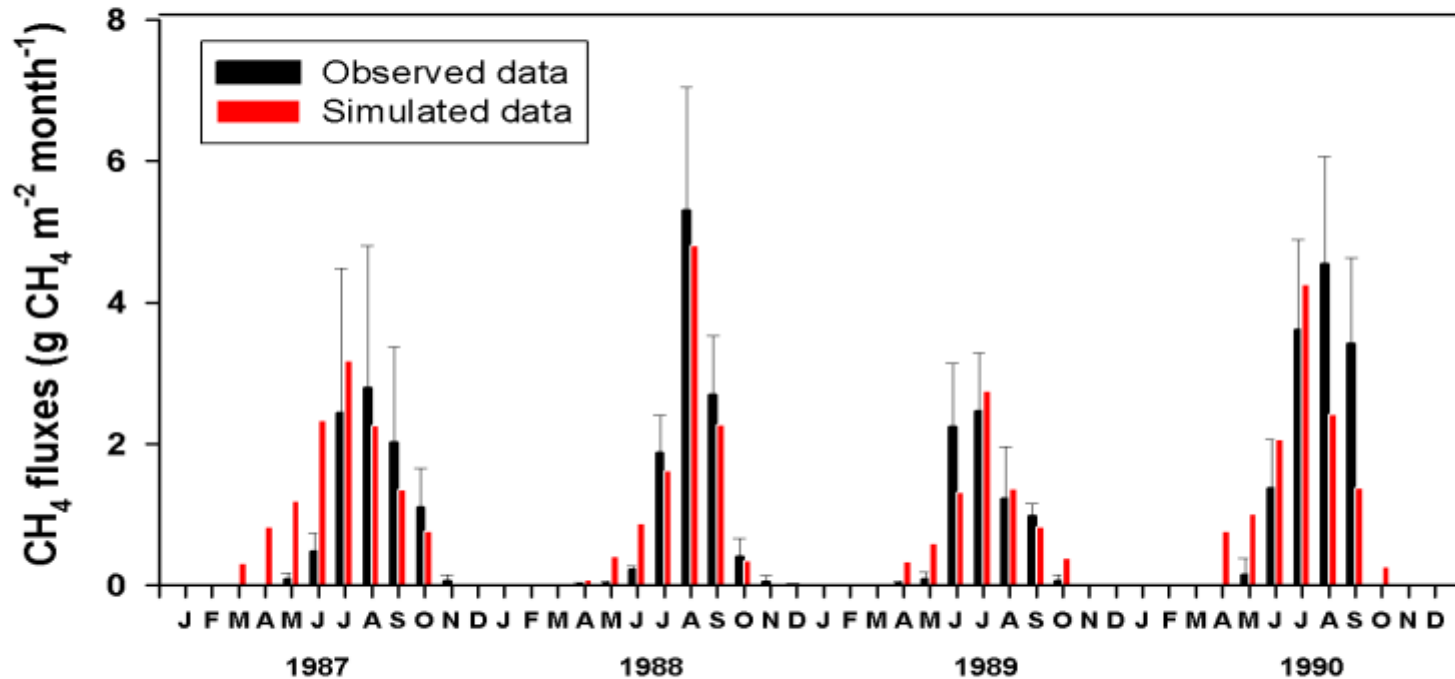
Daily Methane Fluxes for 1994 and 1996 at the Fen Site of Northern Study Area of BOREAS



Methane Fluxes at a Fen Site in Canada



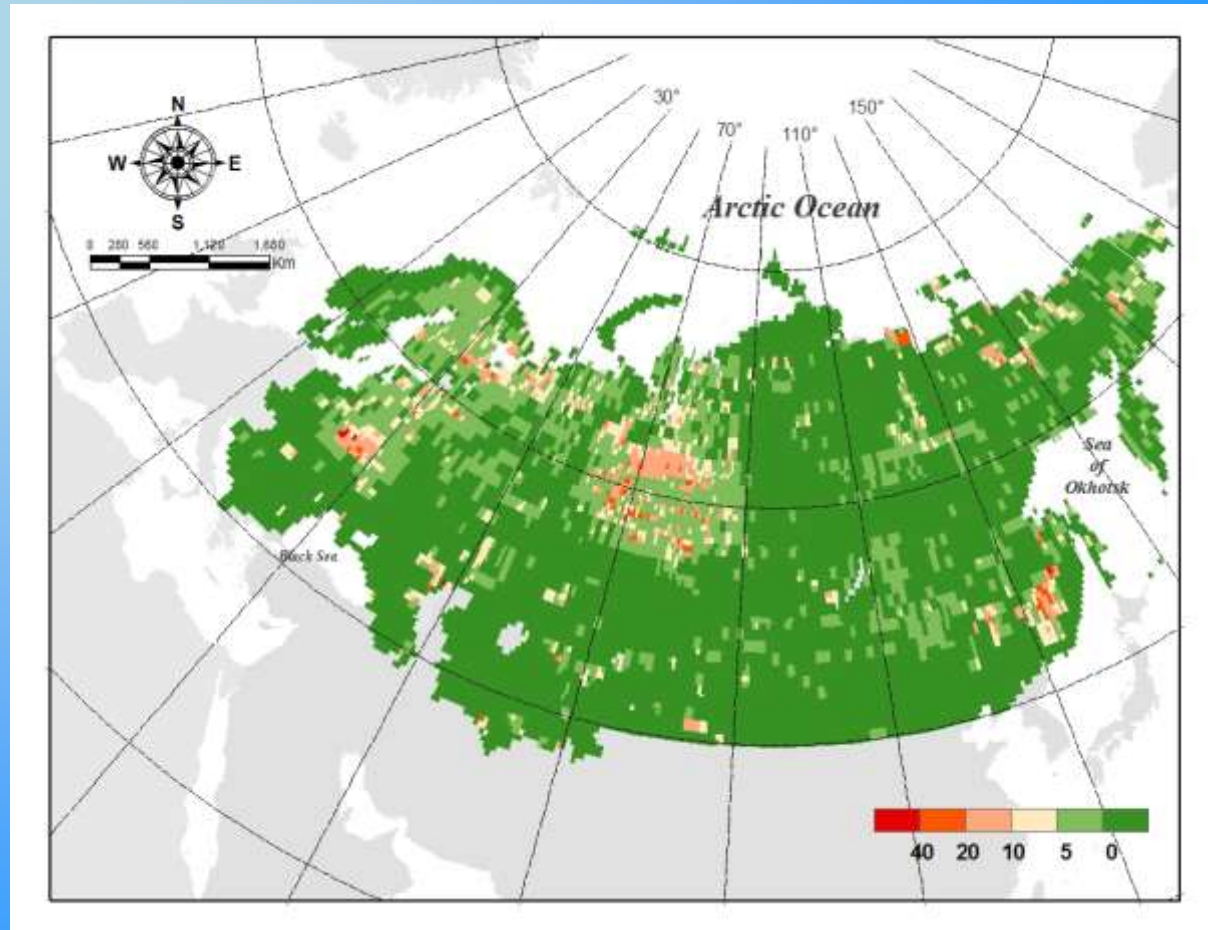
Methane Fluxes of a Wet Tundra Ecosystem in Alaska



(Zhuang et al., 2004GBC)

Net Methane Fluxes in the 1990s

Net Methane
Fluxes
= 22 Tg CH₄ yr⁻¹



(g CH₄ m⁻² year⁻¹)

Progress Summary

- Wetlands represent “hotspots” of CH_4 emissions
- Large areas of upland ecosystems in the region consume CH_4
- The region currently acts as a source of 22 $\text{Tg CH}_4 \text{ yr}^{-1}$

Current GHG Budget of CO₂ and CH₄

Calculation of GHG Budget

1. Convert net methane fluxes (NMF) into global warming potentials (CO₂-equivalent) on 100-year time horizon:

$$GWP_{CH_4} = NMF \cdot 25$$

2. Convert net carbon dioxide fluxes (NCE) from C into CO₂ units:

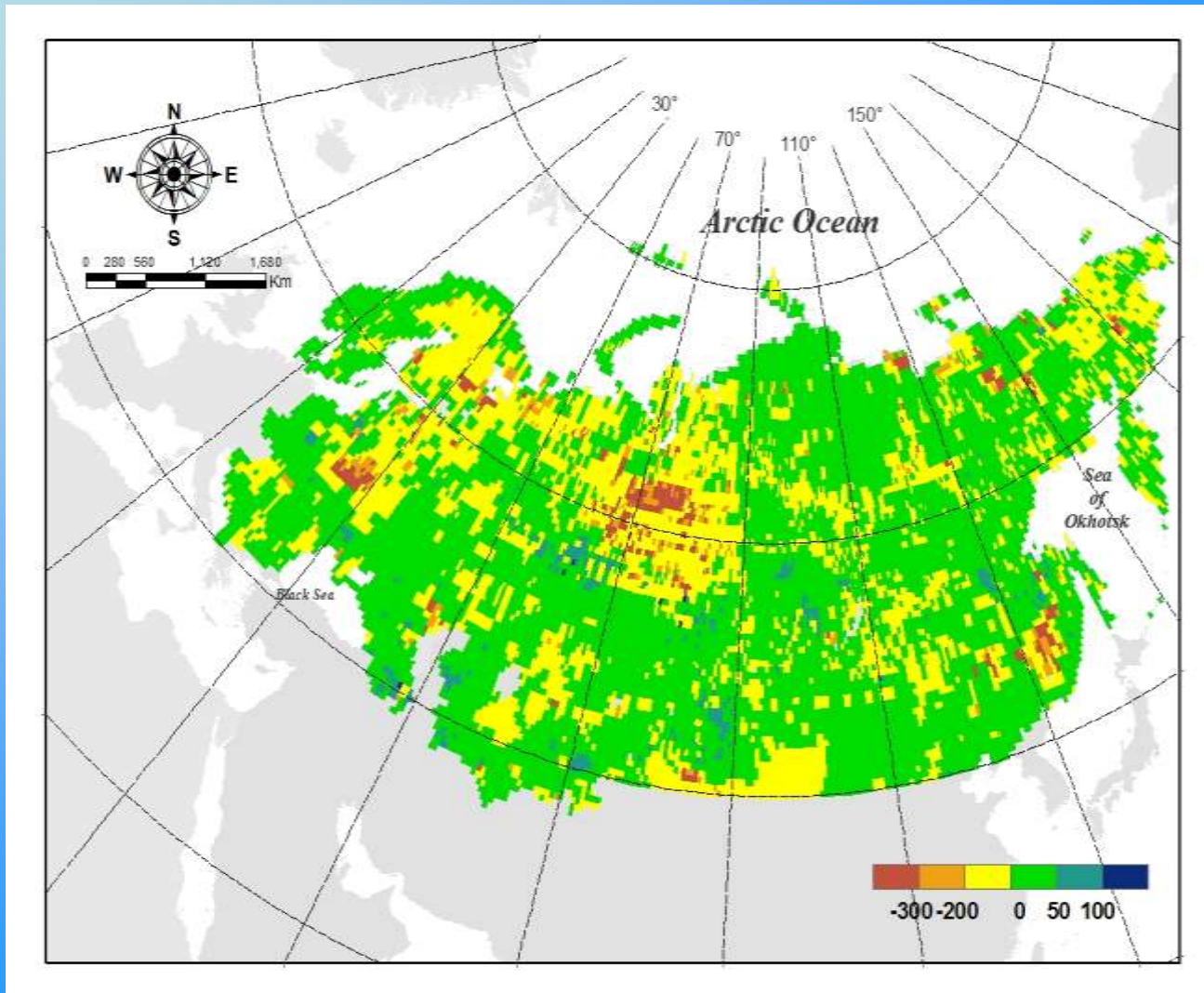
$$NCE' = NCE \cdot 44/12$$

3. Obtain greenhouse gas budget:

$$\text{Greenhouse gas budget} = GWP_{CH_4} + NCE'$$

Greenhouse Gas Budget in the 1990s

GHG source
= 0.02
Pg CO₂-eq. yr⁻¹



(g CO₂-eq. m⁻² yr⁻¹)

Progress Summary

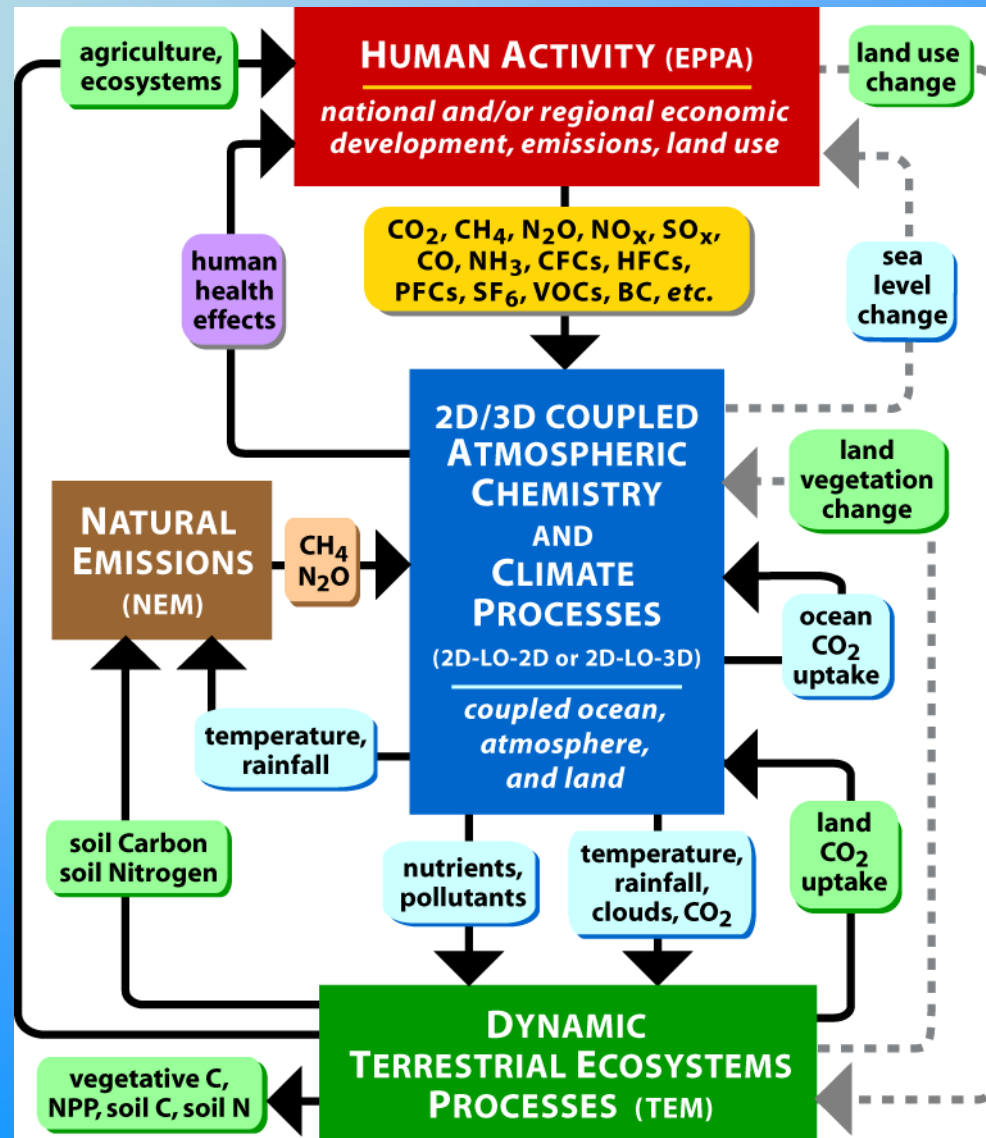
- GHG budget is source of 20 Tg CO₂-eq.yr⁻¹

Future GHG Budget of CO_2 and CH_4

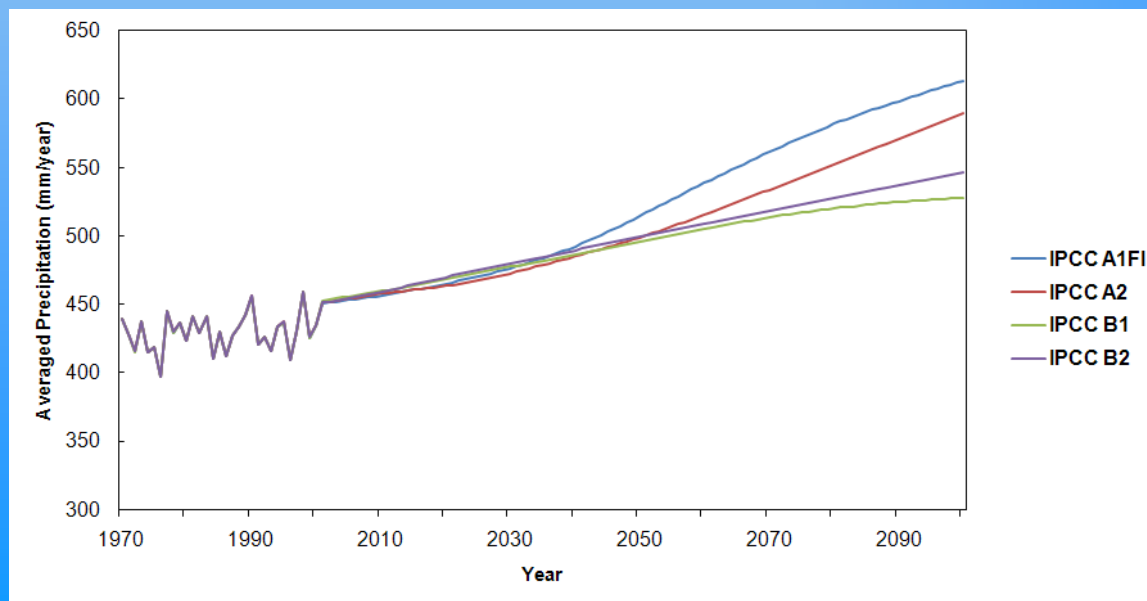
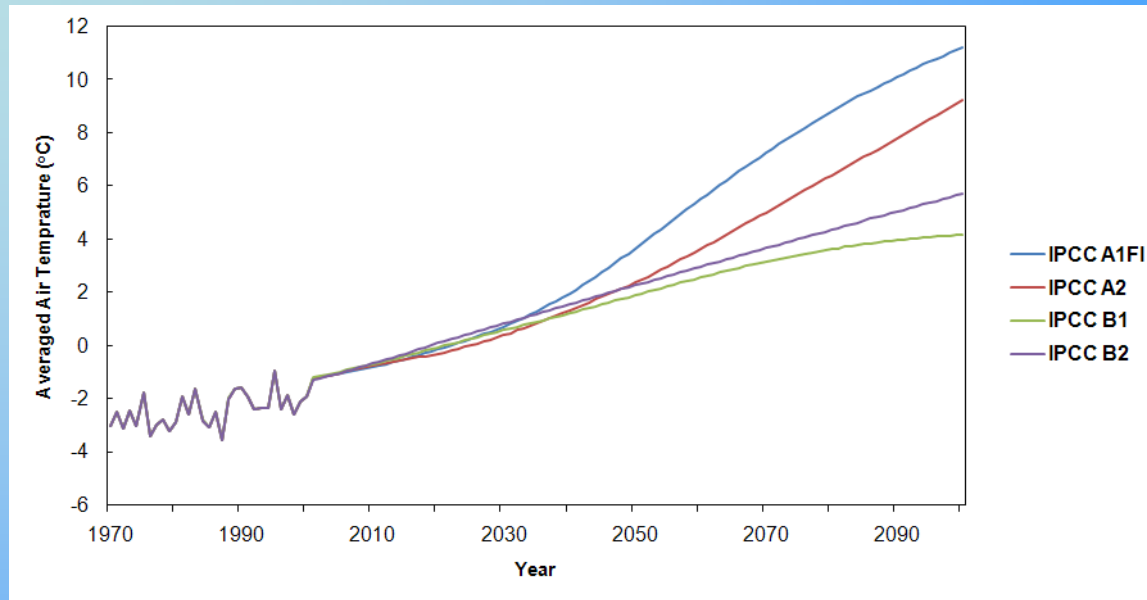
Project Future GHG Budget with Various Climate Scenarios

- Four plausible IPCC climate and atmospheric CO₂ concentration scenarios
- Seven MIT climate scenarios

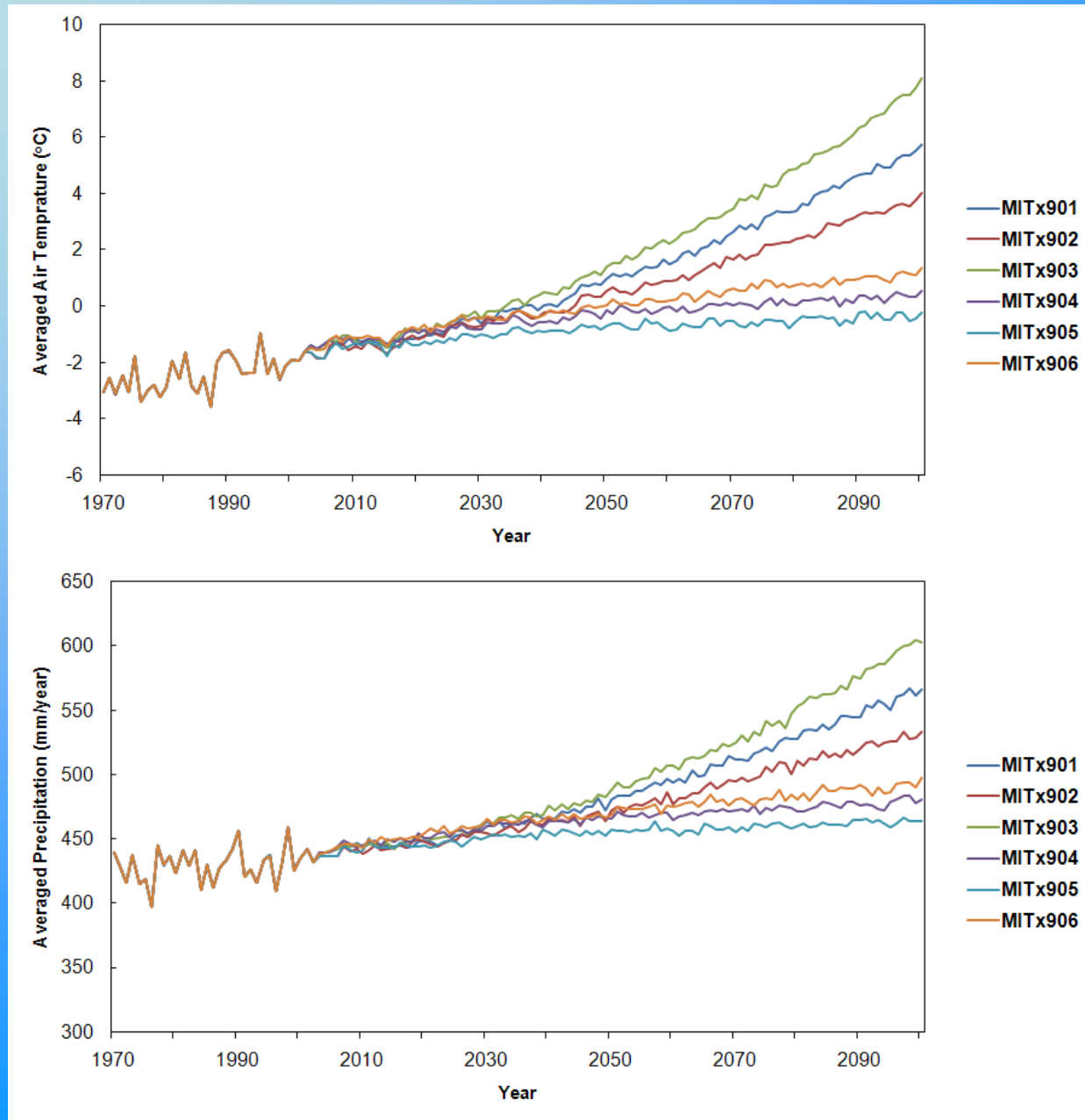
MIT Integrated Global System Model (IGSM)



Four IPCC Climate and Atmospheric CO₂ Concentration Scenarios In the NE

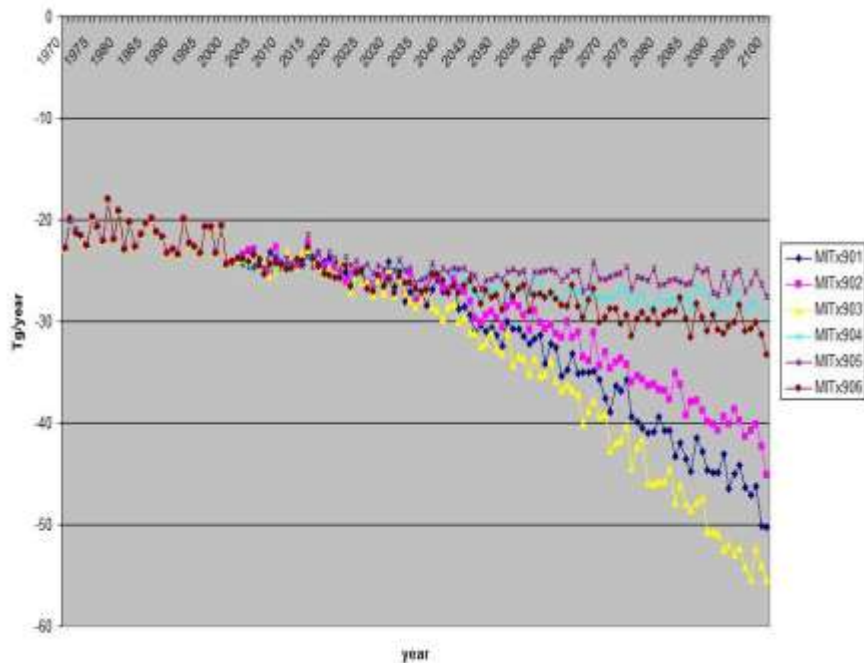


Six MIT IGSM Climate Scenarios in the NE

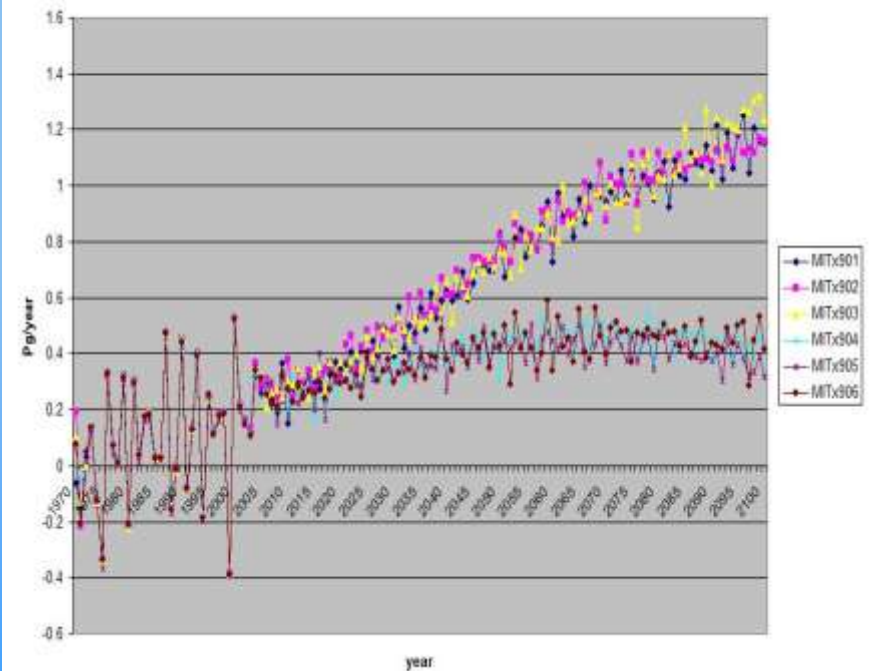


Exchanges of CO_2 and CH_4 under Climate Scenarios in NE

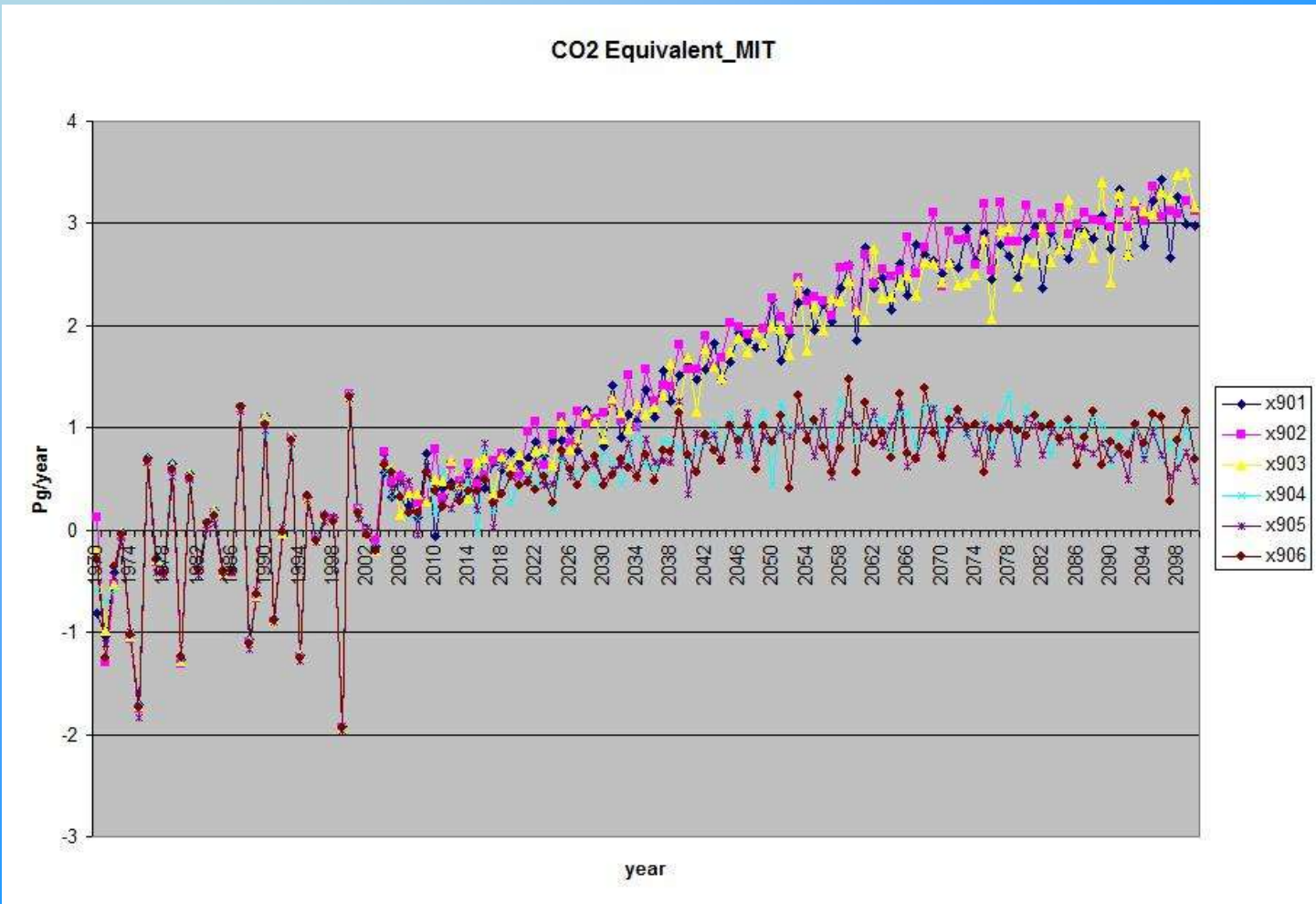
CH₄ Total_MIT



NEP_MIT



Net Radiative Forcing (CO₂-Eq.) under Climate Scenarios in NE



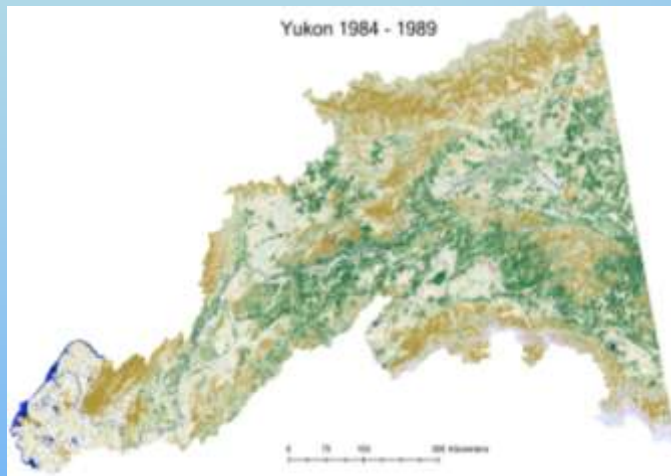
Scenario Simulations of CO₂ and CH₄ and their Radiative Budget in NE

Simulations	Current(2000)			Future (2100)		
	NEP (Pg/year)	CH ₄ (Tg/year)	CO ₂ -eq (Pg/year)	NEP (Pg/year)	CH ₄ (Tg/year)	CO ₂ -eq (Pg/year)
IPCCa1	0.15	-22.21	-0.02	-0.34	-58.23	-2.69
IPCCa2				0.29	-56.45	-0.33
IPCCb1				0.59	-46.52	0.98
IPCCb2				0.64	-51.16	1.06
MITx901				1.14	-46.22	3.02
MITx902				1.13	-40.77	3.11
MITx903				1.22	-52.96	3.14
MITx904				0.43	-28.43	0.85
MITx905				0.37	-26.31	0.71
MITx906				0.45	-30.63	0.87

Progress Summary

- Regional NEP ranges from a source 0.34 to a sink 1.2 Pg C per year in the end of the 21st century
- Regional CH₄ emissions range from 26 to 58 Tg CH₄ per year
- Regional radiative forcing ranges from a source 2.7 to a sink 3.1 Pg CO₂-eq. per year

Developing Land Cover Data for the Last 30 Years for the Region - in Progress

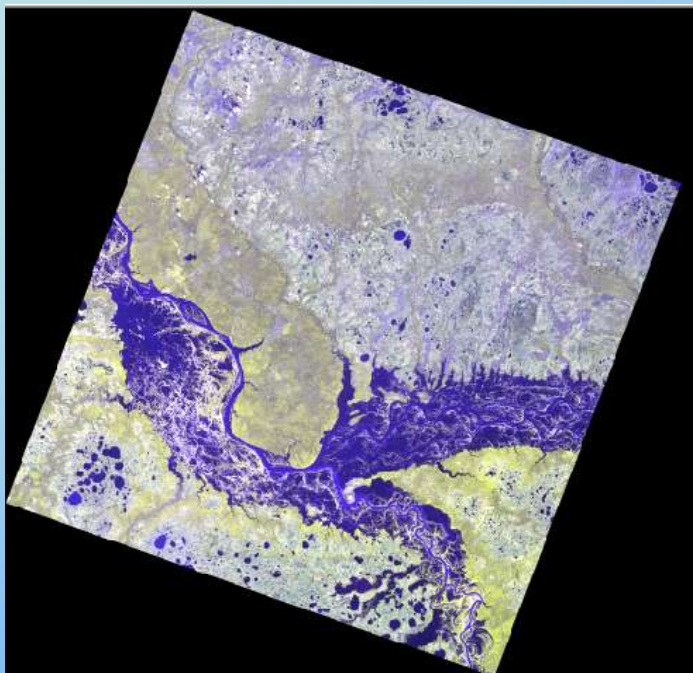


NLCD 2001 Land Cover Classification Legend

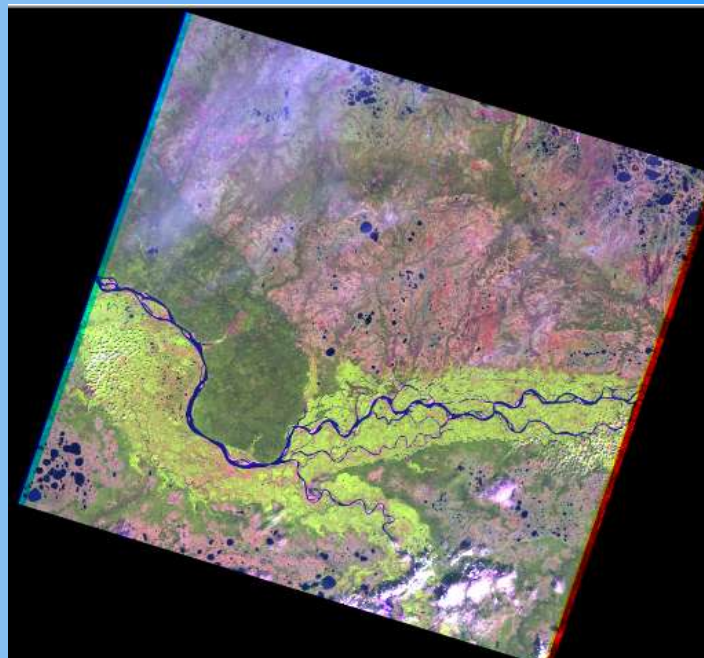
- 11 Open Water
- 12 Perennial Ice/Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/ Scrub
- 71 Grassland/ Herbaceous
- 72 Sedge/ Herbaceous *
- 74 Moss *
- 81 Pasture Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska Only

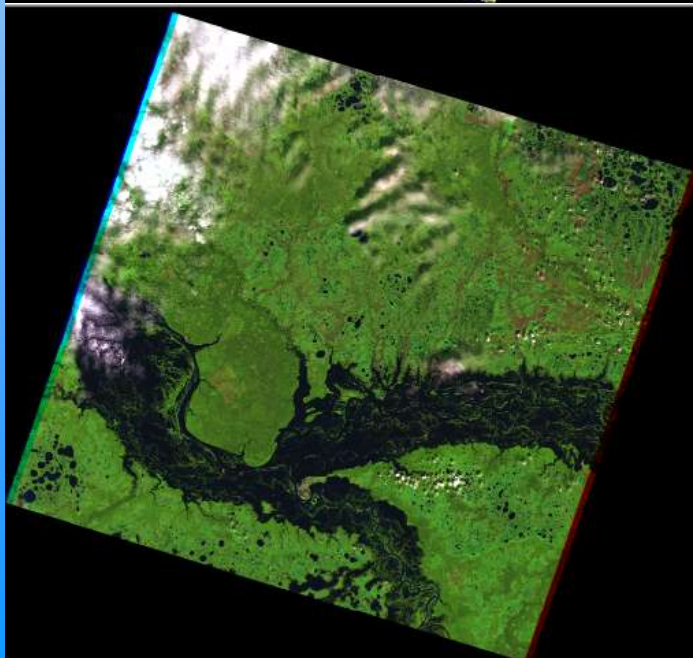
The land-use and land-cover change in Alaskan Yukon River Basin based on Landsat imageries. Top-left panel shows the land-cover composite during 1984-1989. Bottom-left panel shows the land-cover composite during 2003-2008. The classification was conducted based on 2001 National Land Cover Data (NLCD 2001) land cover classification scheme (www.epa.gov/mrlc/nlcd-2001.html).



6/16/1973



8/22/1988



7/20/1999

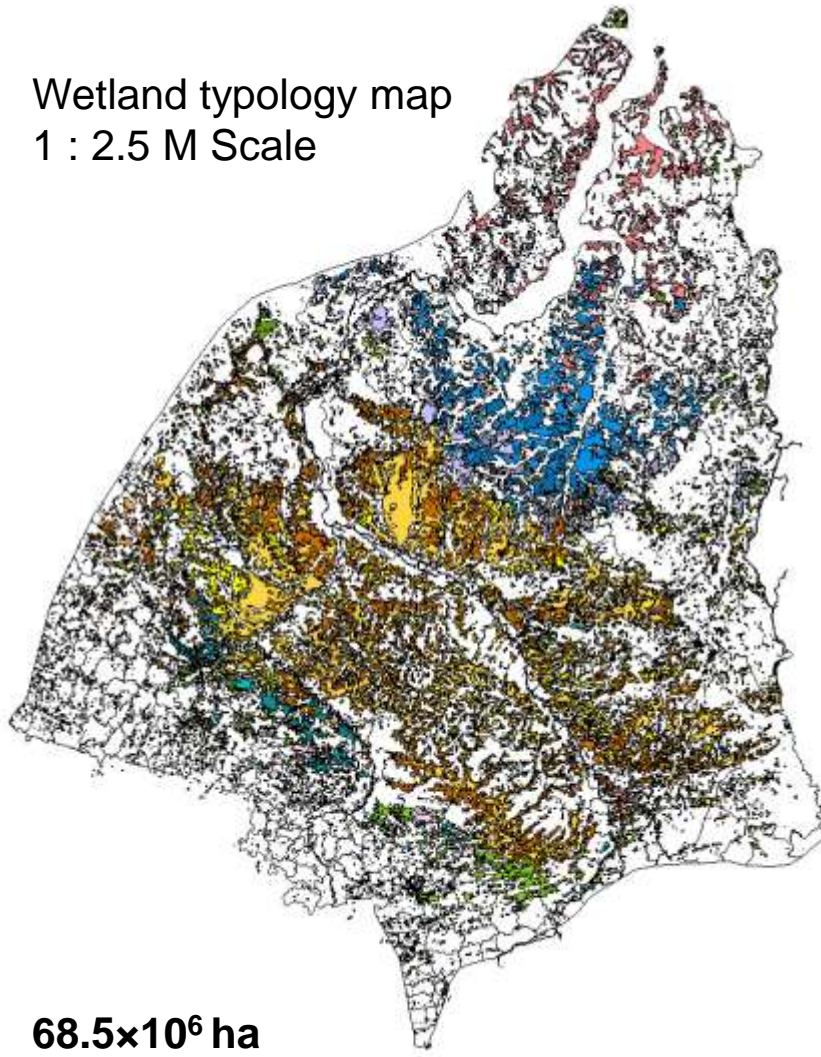


9/4/2007

Wetland area in Western Siberia

West Siberian wetlands are a major source of atmospheric CH₄ and important sink of CO₂ in Northern Eurasia (Smith *et al.*, 2004), but its area remain uncertain.

Wetland typology map
1 : 2.5 M Scale



68.5×10⁶ ha

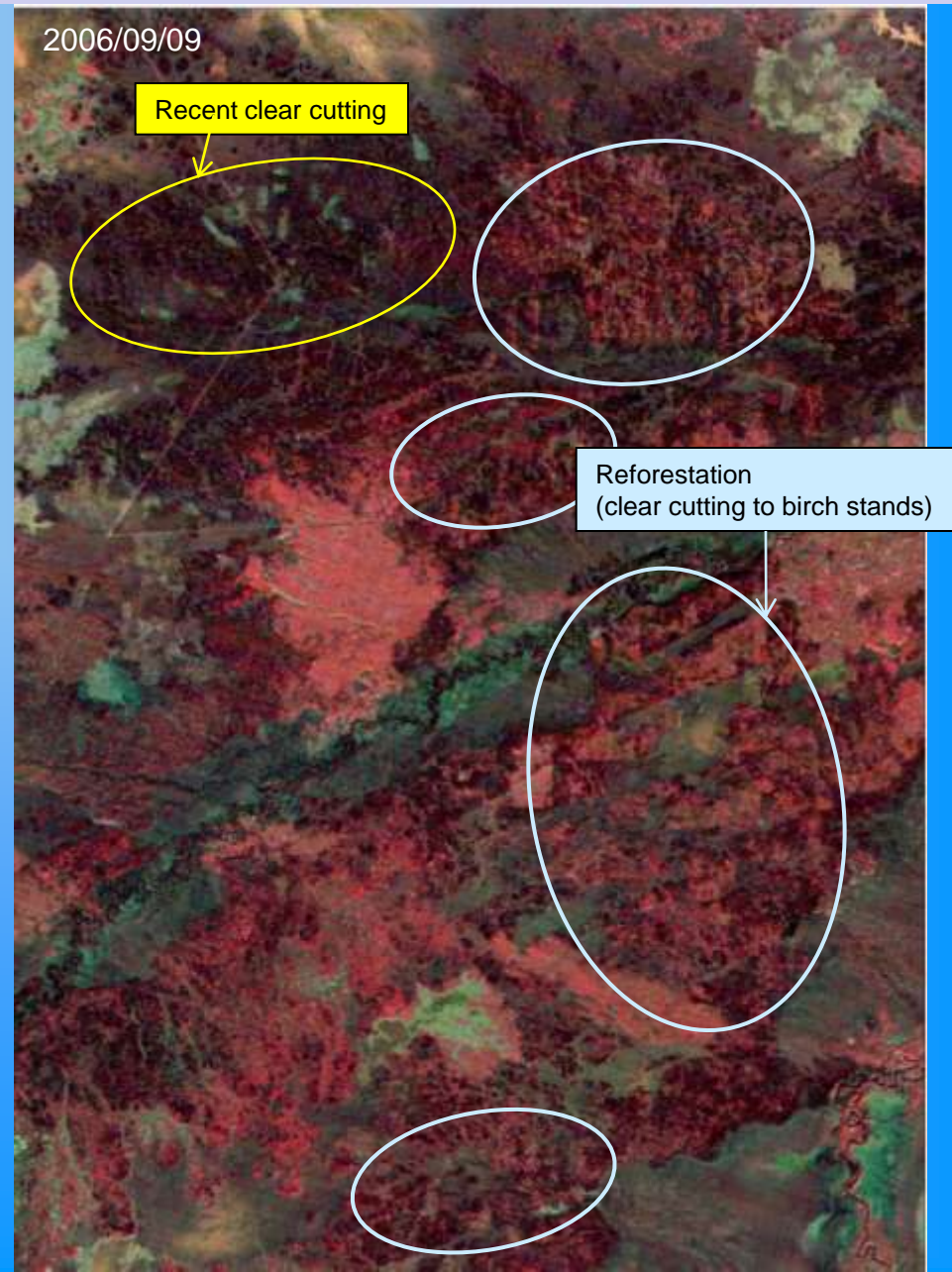
Peregon et al., 2005, 2009)

Earlier estimates of the wetland area:
32.5×10⁶ ha (Neustadt, 1971)
58.3×10⁶ ha (Vompersky et al., 1999)
59.2×10⁶ ha (Sheng et al., 2004)

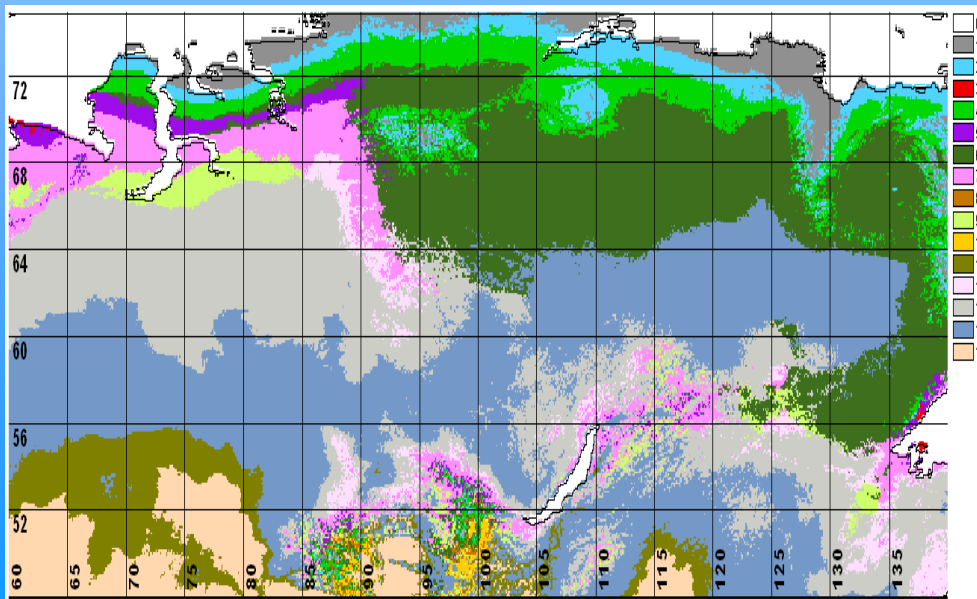
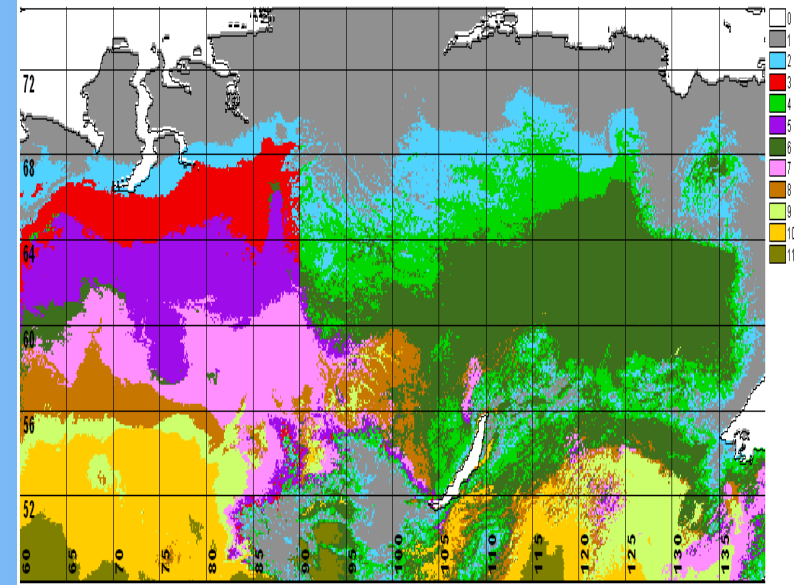
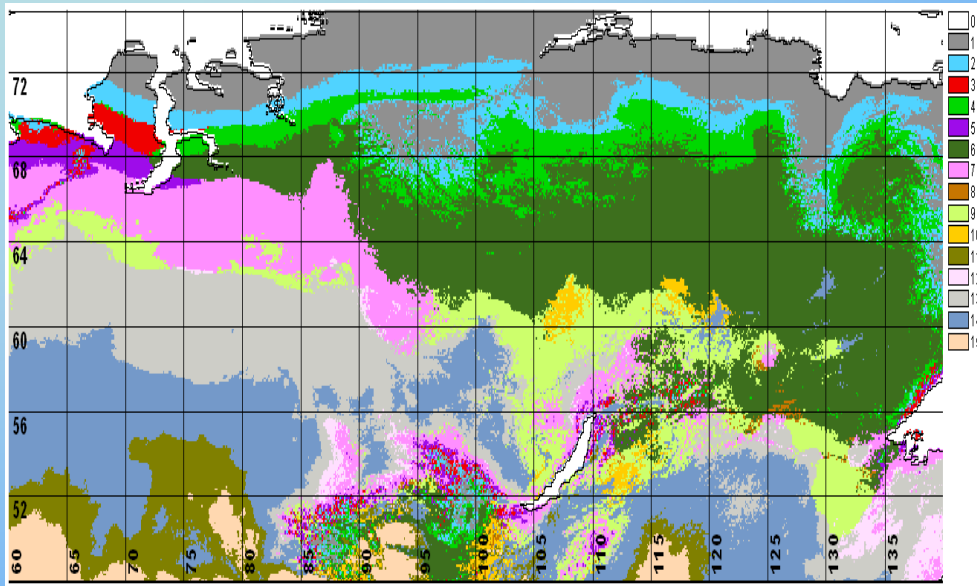
Area, 10⁶ ha

4.0		Polygonal-roller and polygonal-fissure (grass-sedge-mosses and shrub-Sphagnum-lichen) mires
2.0		Polygonal mires in combination with grass and grass-mosses mires
6.2		Flat palsa-hollow and flat-palsa-hollow-lake complexes (shrub-brown moss-lichen vegetation on the palsa; sedge-mosses and Eriophorum-mosses vegetation in hollows)
1.5		Flat palsa in combination with High palsa complexes
1.9		Shrubby small-palsa complexes
2.2		High palsa-hollow and High palsa-pool-hollow complexes (shrub-Sphagnum-lichen vegetation on the palsa; sedge-brown mosses and sedge-Eriophorum-Sphagnum vegetation in hollows)
0.7		High palsa in combination with Flat palsa complexes
10.8		Mire-pools (Sphagnum-shrubs and lichen-shrubs, rarely with Pine and Cedar micro-landscapes with big pools and lakes) complexes
10.8		Ridge-hollow and ridge-hollow-pool (with Pine-Sphagnum-shrubs vegetation on the ridges; Sphagnum-Scheuchzeria and Sphagnum-sedge vegetation in hollows) complexes
18.5		Forested and moss-forested (Pine-shrubs and Pine-Sphagnum-shrubs) mires
2.2		Mosses (dwarf shrub-Sphagnum and Eriophorum-dwarf shrub-Sphagnum) mires
0.8		Ridge-hollow (with sedge-brown moss-shrubs vegetation on the ridges and sedge-brown-mosses vegetation in hollows) complexes
0.1		Herbaceous-mosses (sedge-brown mosses) mires in combination with ombrotrophic raised bogs (dwarf shrubs sphagnum bog - ryam)
1.4		Herbaceous and herbaceous-mosses (sedge-brown mosses; sedge-Sphagnum and sedge) mires
1.0		Birch-Calamagrostis-sedges, birch-Sphagnum-sedges and Pine-birch-Sphagnum-sedges forested swamps
0.3		Reed and herbaceous tussock sedge-reed mires in combination with ombrotrophic raised bogs (dwarf shrubs sphagnum bog - ryam)
2.1		Reed, reed-sedges and herbaceous mires
0.1		Herbaceous mires on the soils with the considerable salty rate

Human-induced land cover change at Icha-Tara test site (LANDSAT scenes in 17-yrs time interval)



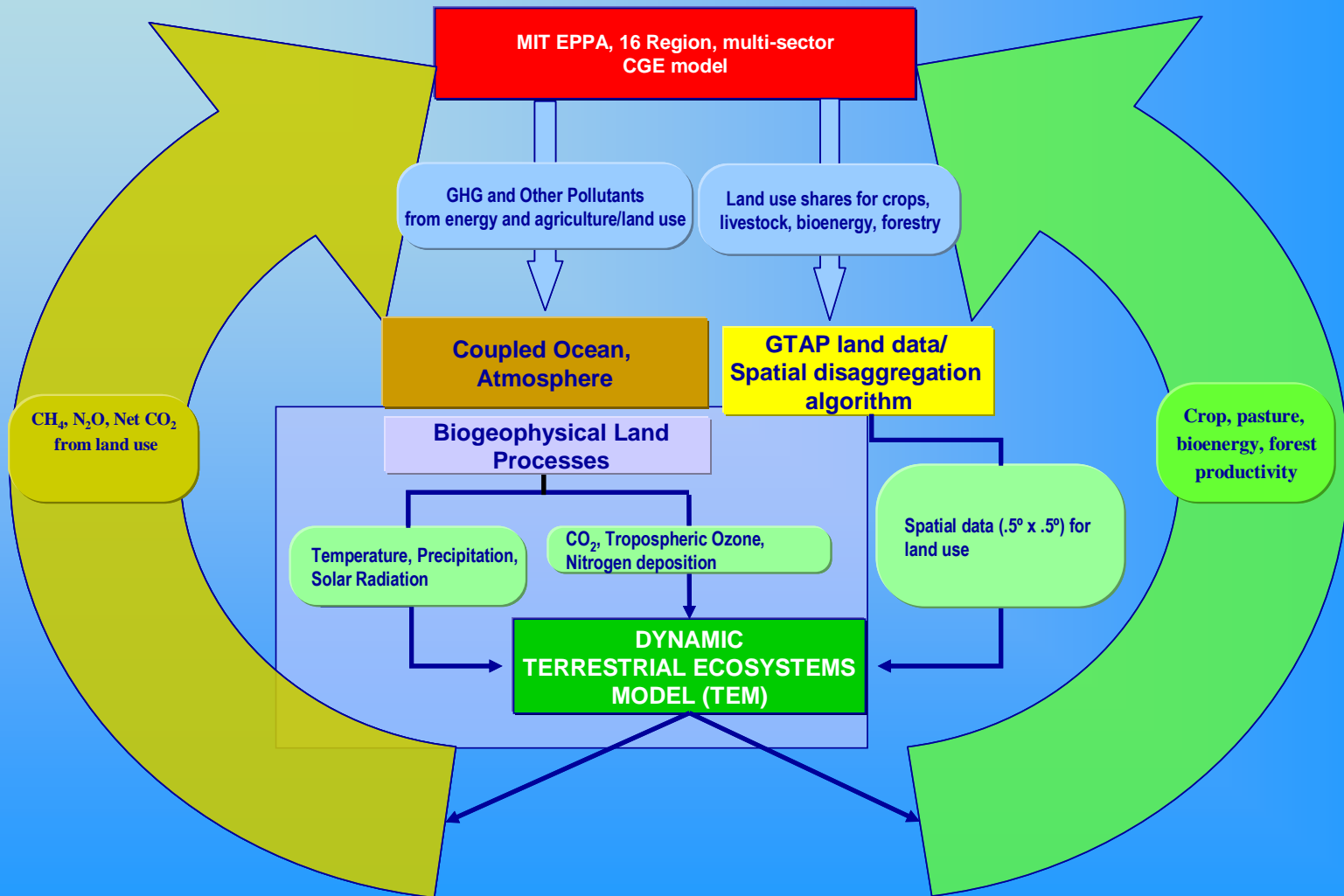
Vegetation Distribution in NE Simulated with SiBCliM Considering Effects of Permafrost and Fire



Vegetation distribution in Siberia for the current (top right) and in 2080 mapped by coupling our SiBCliM with bioclimatic indices and the permafrost for HadCM3 B1 (top left) and HadCM3 A2 (bottom) with no albedo feedbacks

Vegetation class key: 0- Water; Boreal: 1 - Tundra; 2 - Forest-Tundra; Northern Taiga: 3 - dark, 4 - light; Middle taiga: 5 - dark, 6 - light; Southern Taiga: 7 - dark, 8 - light; 9 - Subtaiga, Forest-Steppe; 10- Steppe; 11 - Semidesert

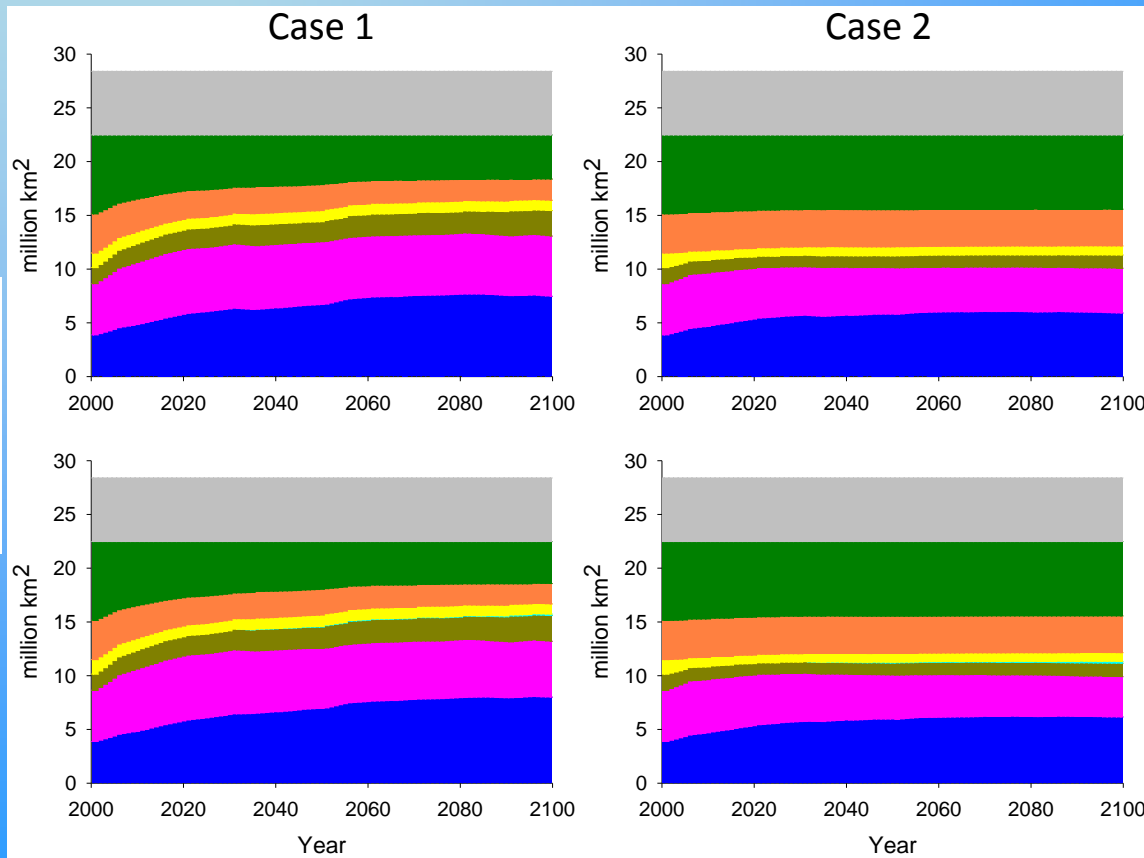
Modeling Land Cover Change in the Future



Projected Land Use Change in Northern Eurasia - in progress

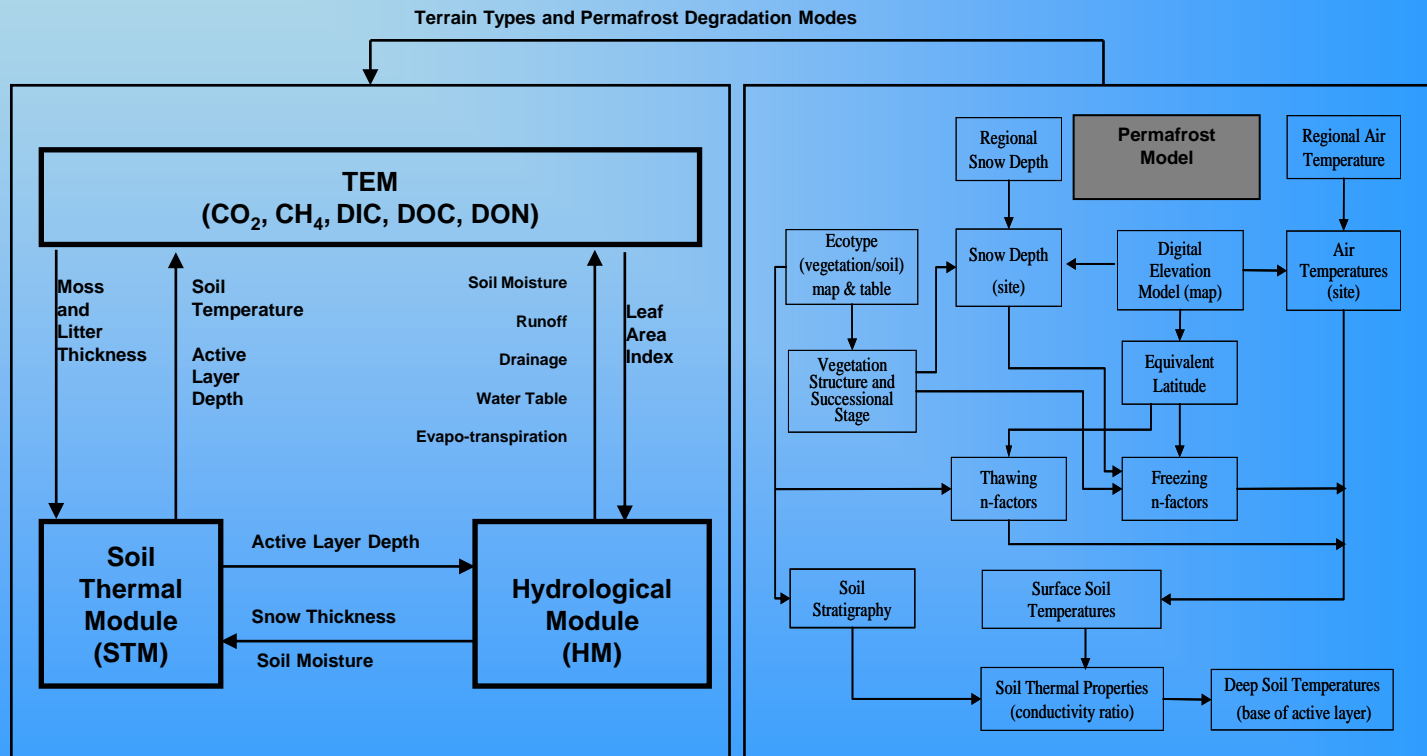
Without Biofuels

With Biofuels



There are four scenarios created by two alternative characterizations of land use response and cases with and without a large second generation biofuels industry. All cases assume a greenhouse gas policy that is eventually operating globally and succeeds in keeping CO₂ concentrations to no more than about 550 ppm. The case 1 scenario land use allows unrestricted conversion of natural lands as dictated by economics. Case 2 creates a land supply elasticity based on land conversion response to rising land prices over the last decade.

Coupled modeling systems of TEM and a spatially-explicit permafrost model



Acknowledgement

- NASA LCLUC Program
- NSF Biocomplexity Program - carbon and water
- DOE Abrupt Climate Change Program