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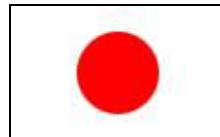
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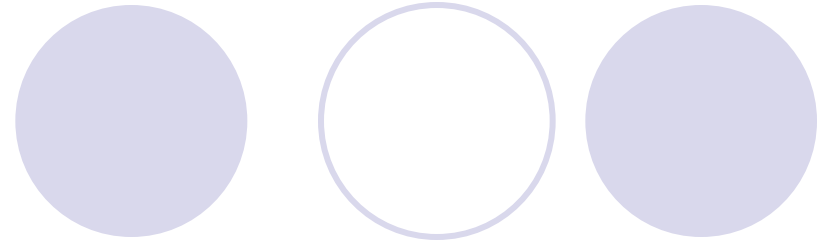
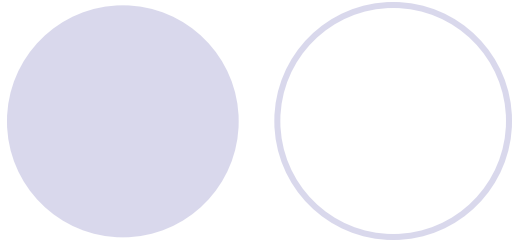




Permafrost-dominated Ecosystems in a Changing Climate

Trofim MAXIMOV
IBPC SD RAS, Yakutsk. Russia

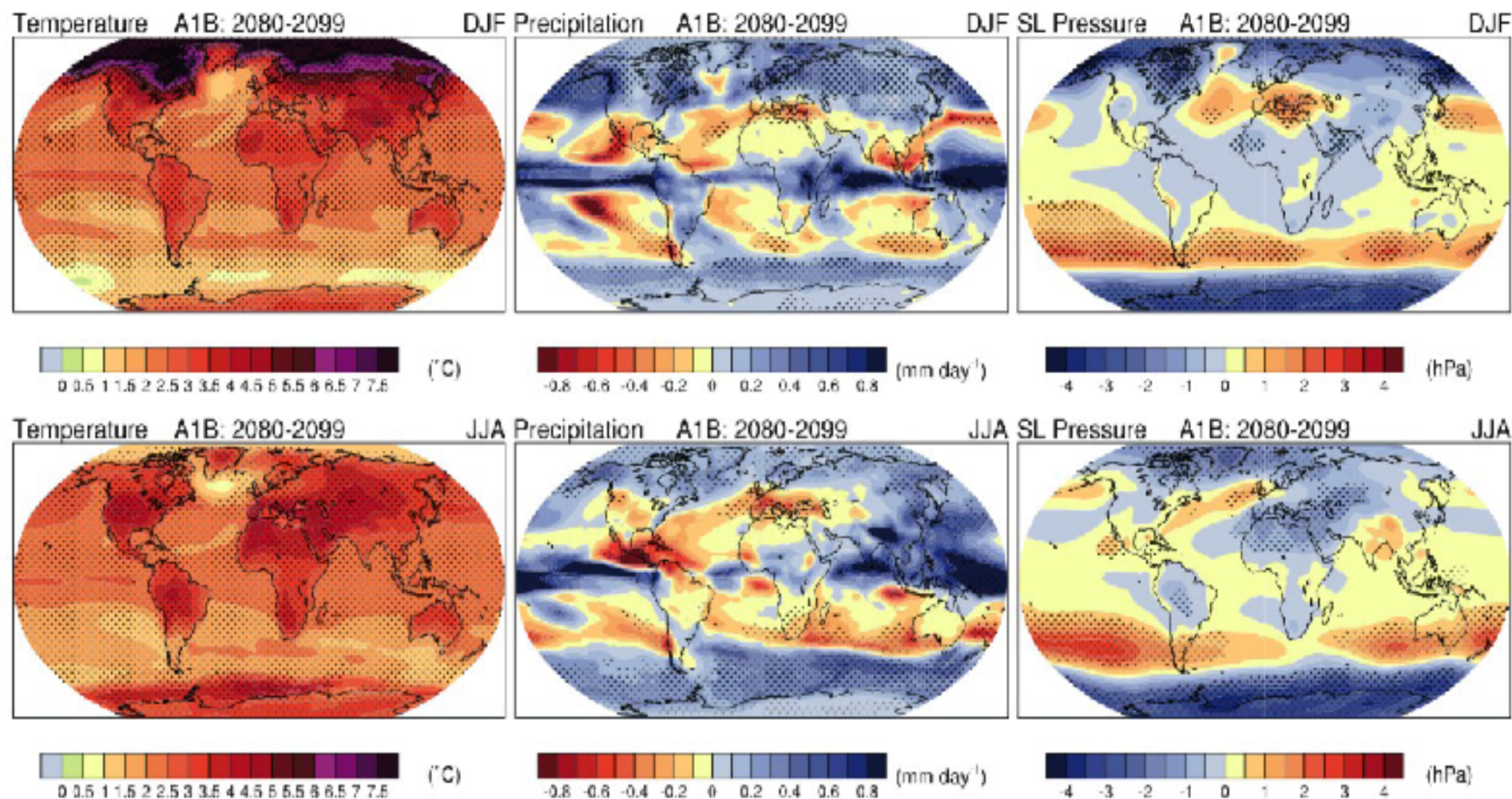




Outline

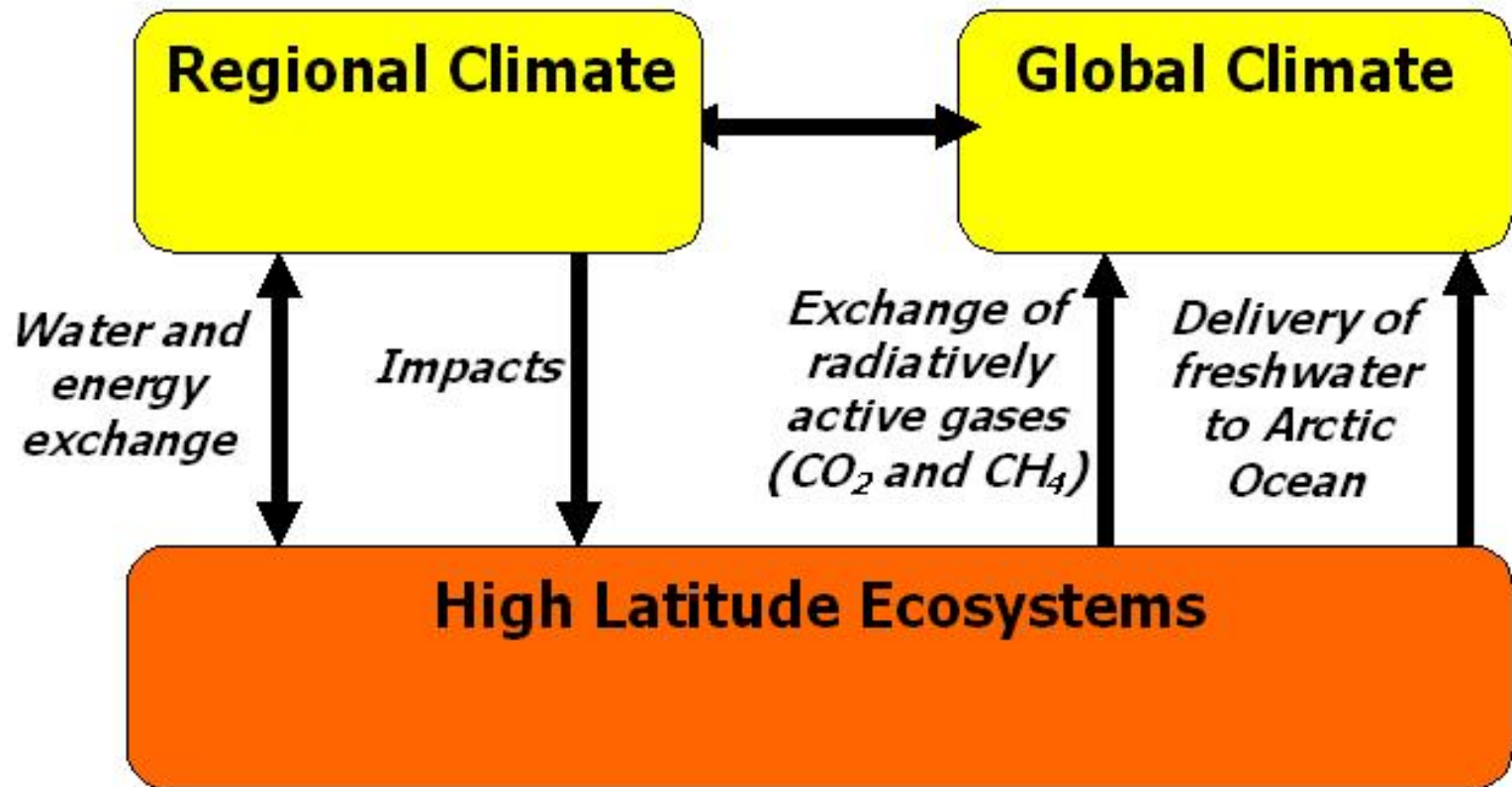
1. Overview of changing of climate
2. On infrastructure of experimental sites
3. Long-term obtained results (past, current, future)

Global warming strongest in the arctic

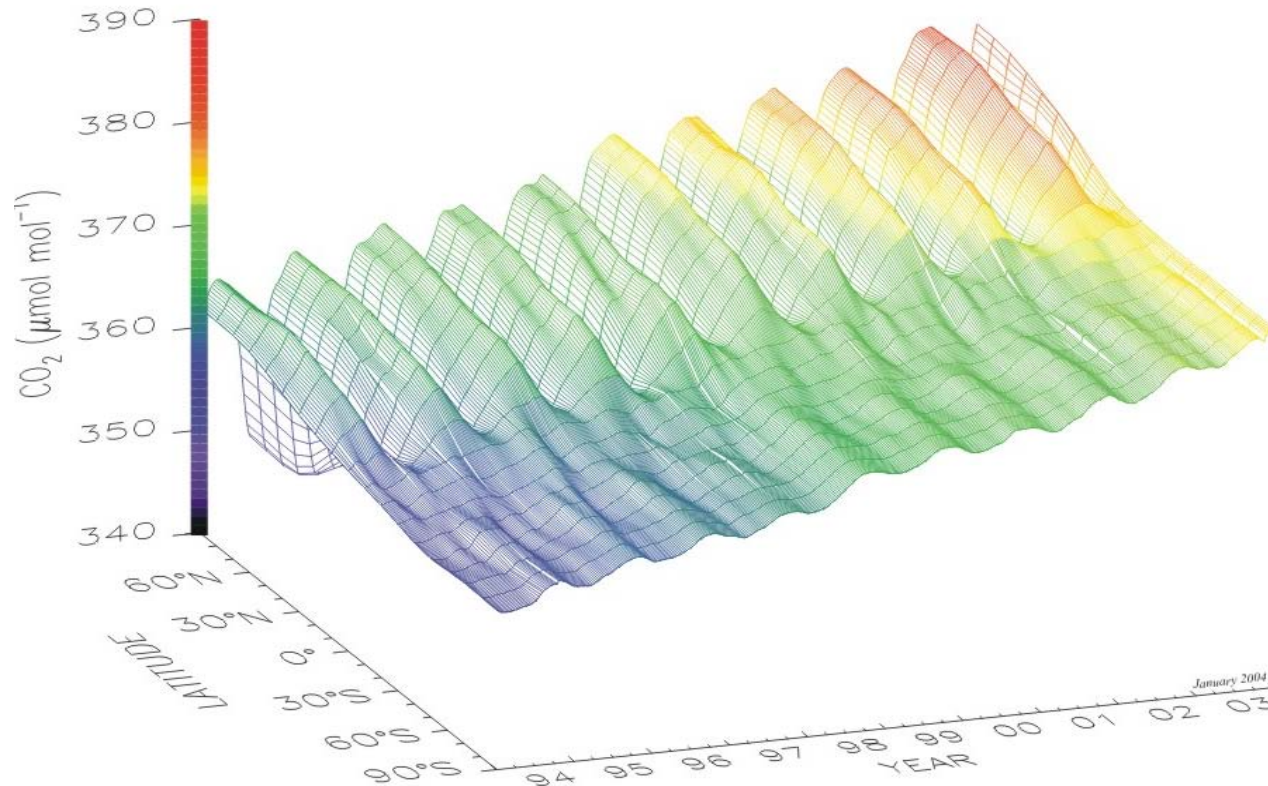


Strongly increased temperatures and precipitation
In particular in winter

The major pathways through which high latitude ecosystems may influence the climate system

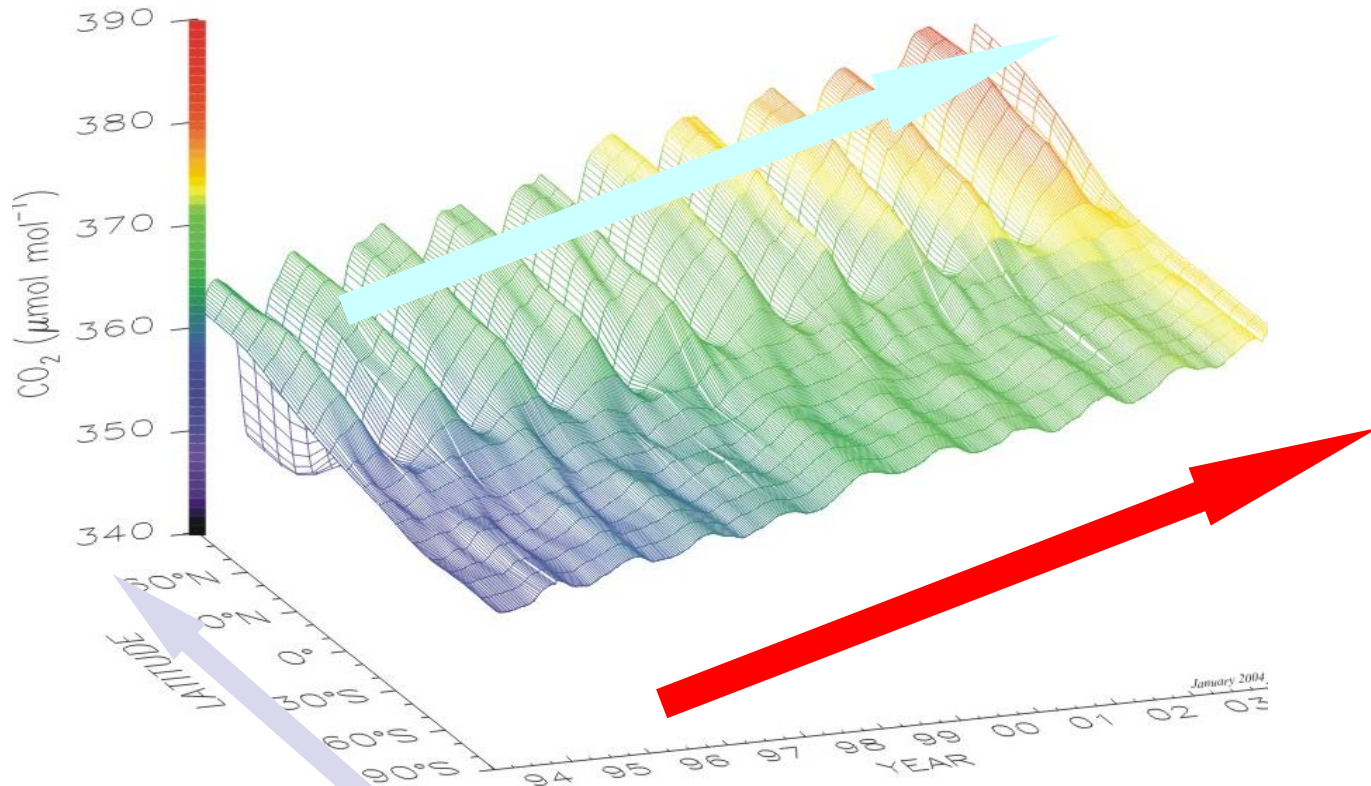


Global distribution of atmospheric CO_2



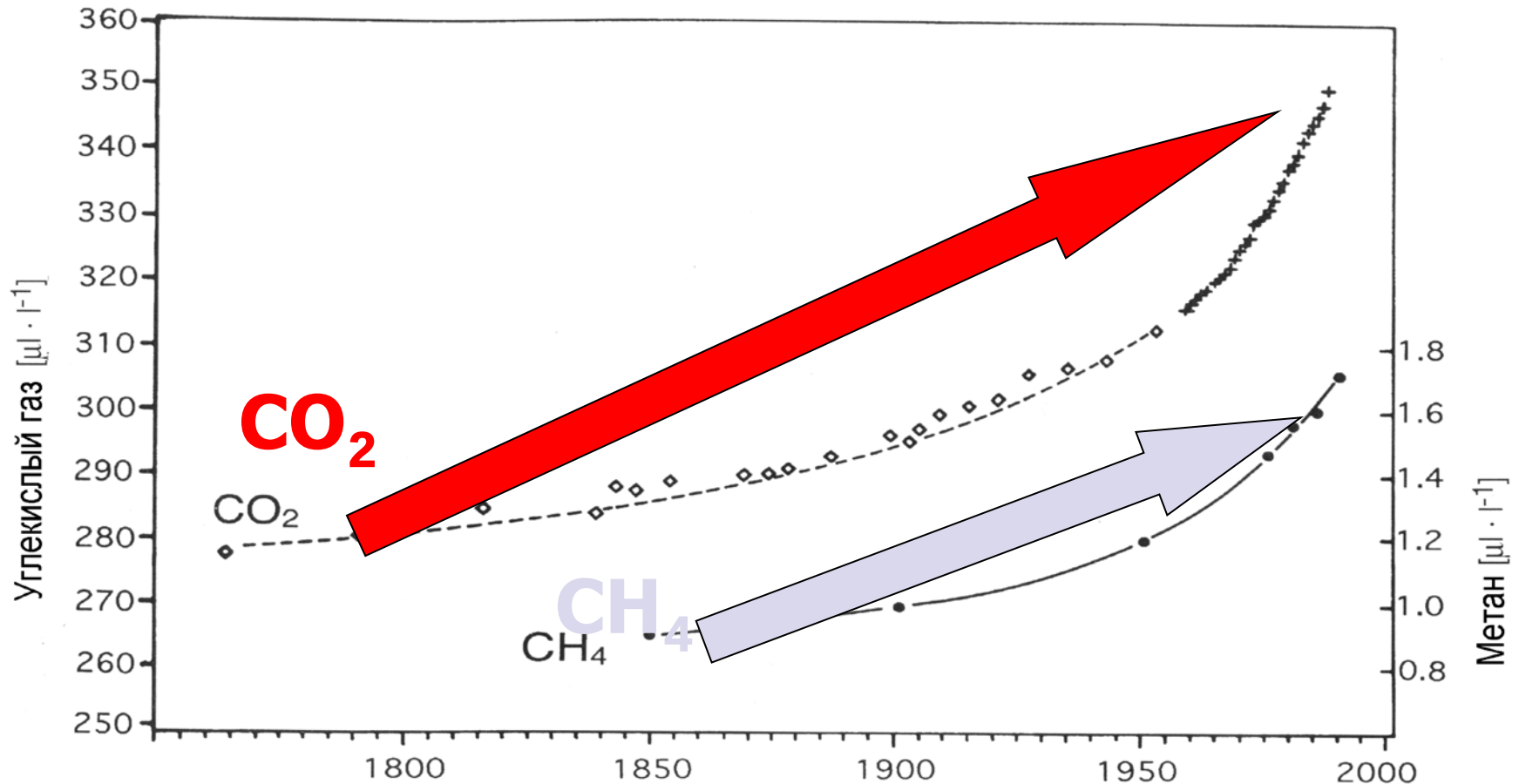
Three dimensional representation of the latitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the NOAA CMDL cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Principal investigators: Pieter Tans and Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678 (pieter.tans@noaa.gov, <http://www.cmdl.noaa.gov/ccgg>).

Global distribution of atmospheric CO_2



Three dimensional representation of the longitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the NOAA CMDL cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Principal investigators: Pieter Tans and Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678 (pieter.tans@noaa.gov, <http://www.cmdl.noaa.gov/ccgg>).

Increasing $[\text{CO}_2]$ and $[\text{CH}_4]$ in atmosphere from XVIII century

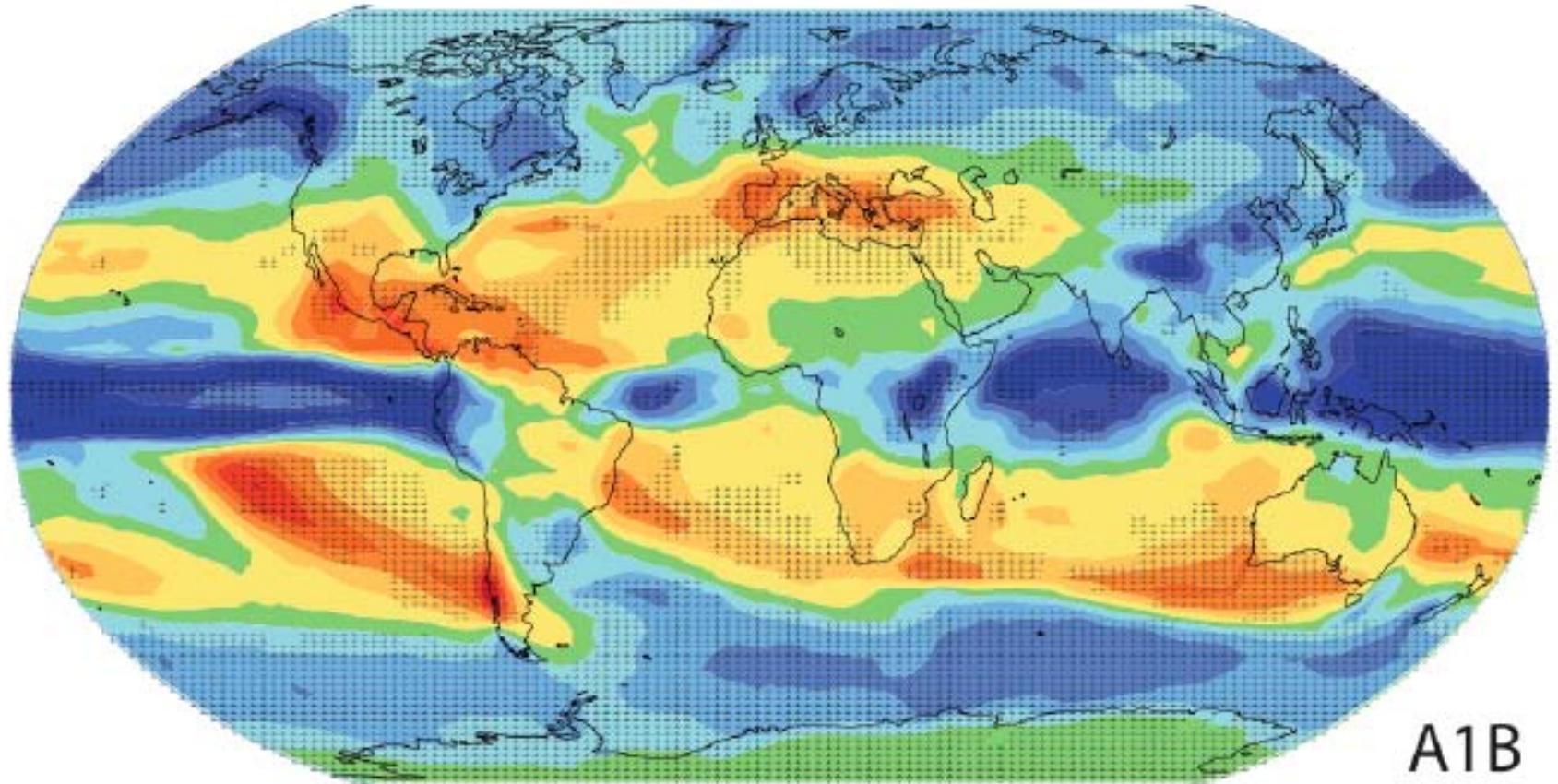


Увеличение концентрации CO_2 и метана в атмосфере с 18-го века.

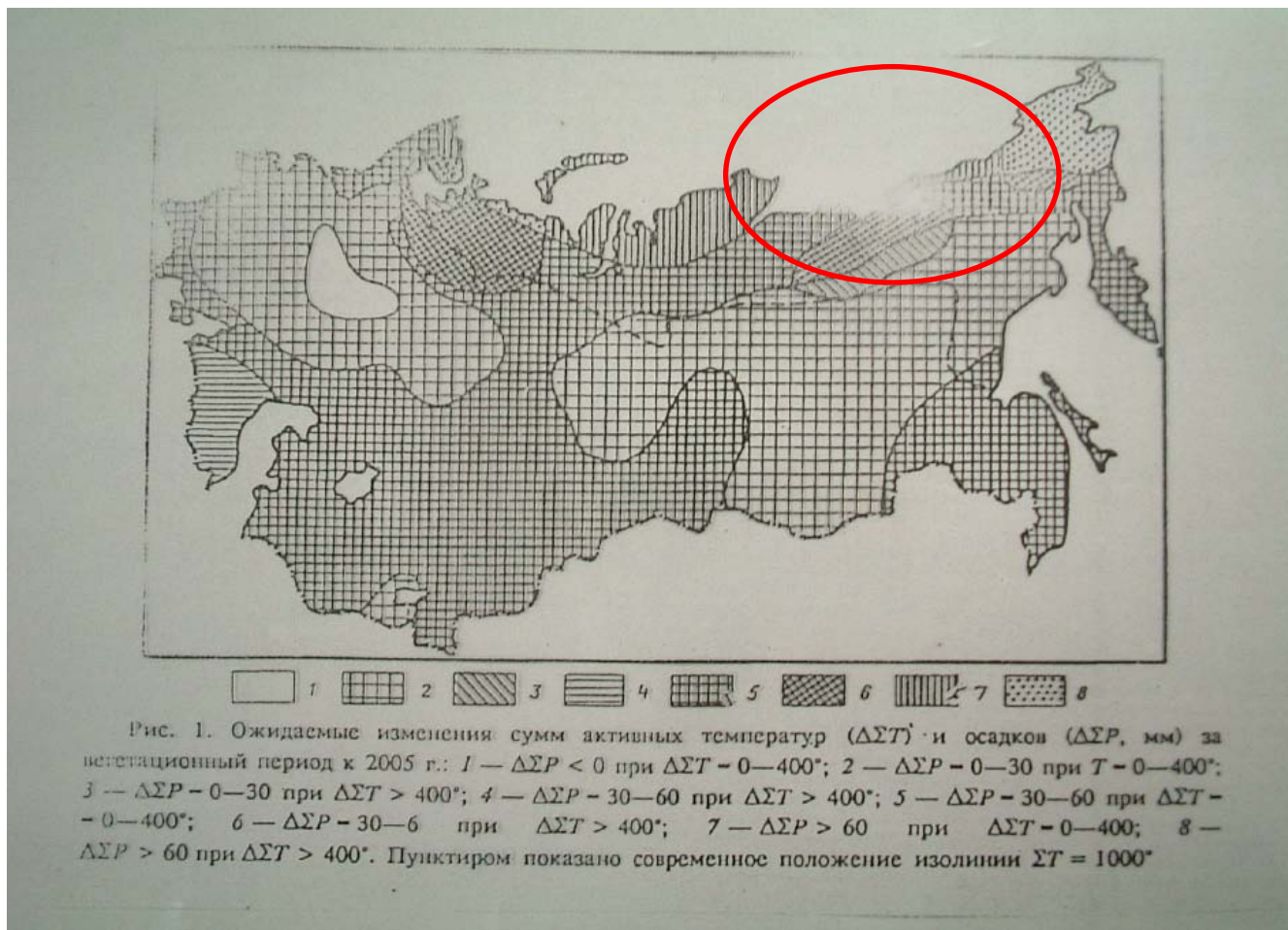
(По Keeling et al., from IGBP 1990 and WMO 1990)

More rain or less rain? (IPCC Report)

2080-2099

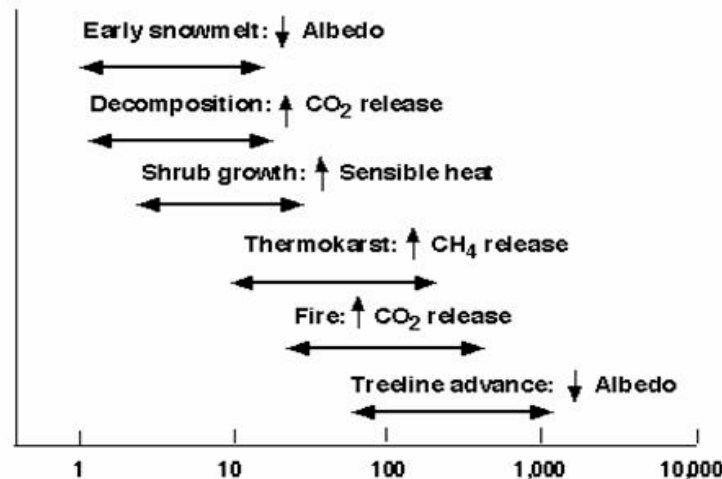


Expected changes in the sum of active temperatures ($\Delta\Sigma T$) and precipitation ($\Delta\Sigma P$, mm) over growing season by 2005

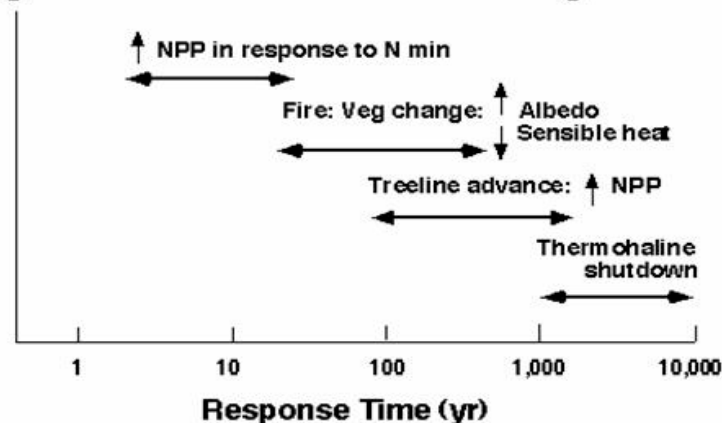


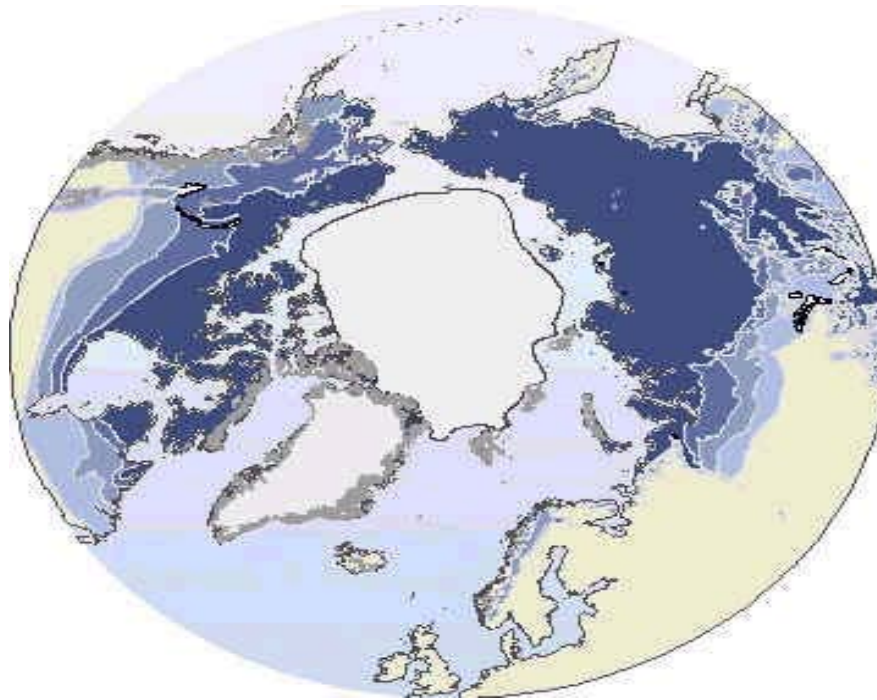
The response times over which different positive and negative feedbacks to climate are most pronounced

Positive Feedbacks to Warming



Negative Feedbacks to Warming



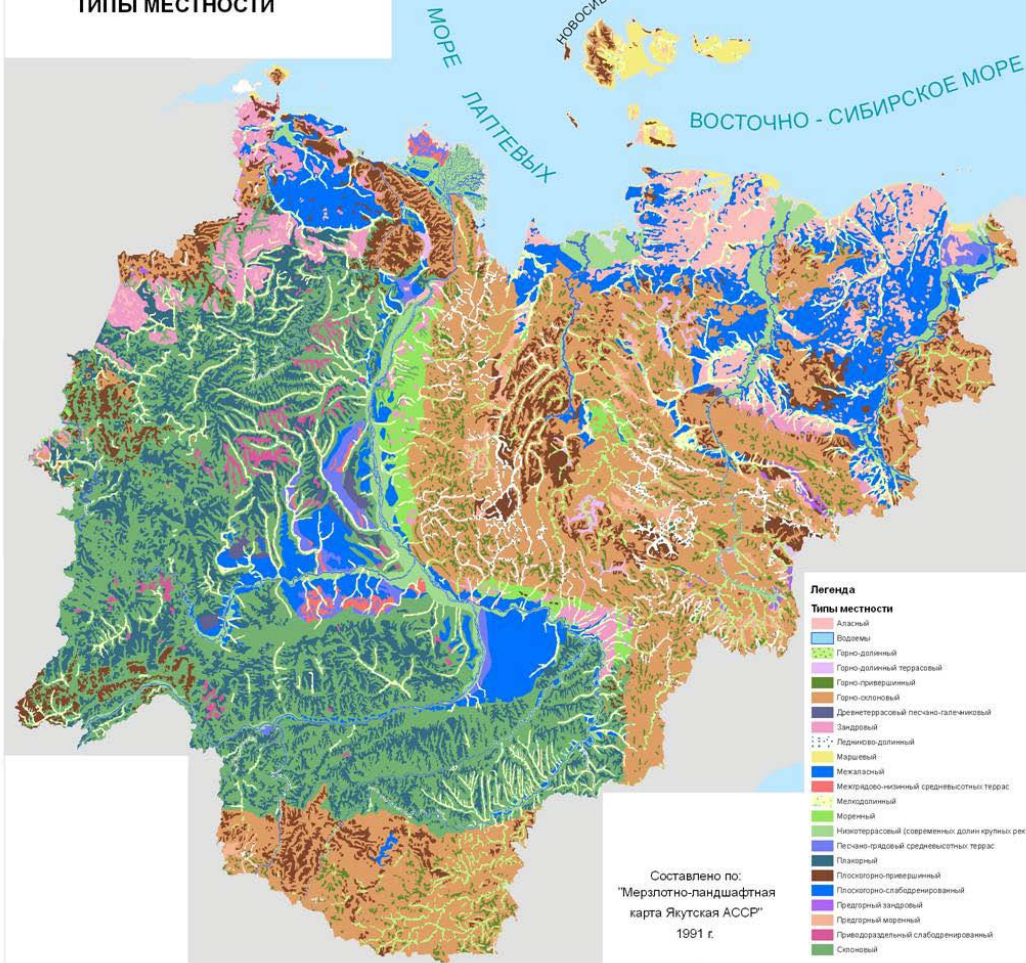


Whole Permafrost Zone	35 mln sq.km
Northern Hemisphere	22
Russia	11
Yakutia	3
Canada	5.7
Alaska	1.5
Greenland	1.6
China, Mongolia	1.2
Antarctica	13.5

Important role of Yakutia (3.1 mln. sq.km) in the Earth's climate ecosystem

- i) As an integral Arctic part within the boundaries of the Indivisible Circumpolar ecology space, differs by a number of specific natural climatic conditions that influence the directions, scales and forms of economy, use of nature and keeping environment safe
- ii) There are all the environmental-forming components of the North that can be transformed with the climate change: The Arctic Ocean, permafrost, northern forest frontier, northern species of flora and fauna.
- iii) Accumulation of CO₂ via flexible system of 1997 UN Kyoto Protocol on Reduction of Greenhouse Gases Emission into the Atmosphere

Институт мерзлотоведения СО РАН
МЕРЗЛОТНО-ЛАНДШАФТНАЯ КАРТА ЯКУТИИ
ТИПЫ МЕСТНОСТИ



Thermokarst – Alas formations

10%

Inter-Alas with big Ice-Wedges (Ia II-III)

2,5%

Moraine with big Ice-Wedges (g,fg II-III)

Thermokarst with Surface Subsidence

1,2%

Marsh with small Ice-Wedges (b III-IV)

4,1%

Alas with small Ice-Wedges (t III-IV)

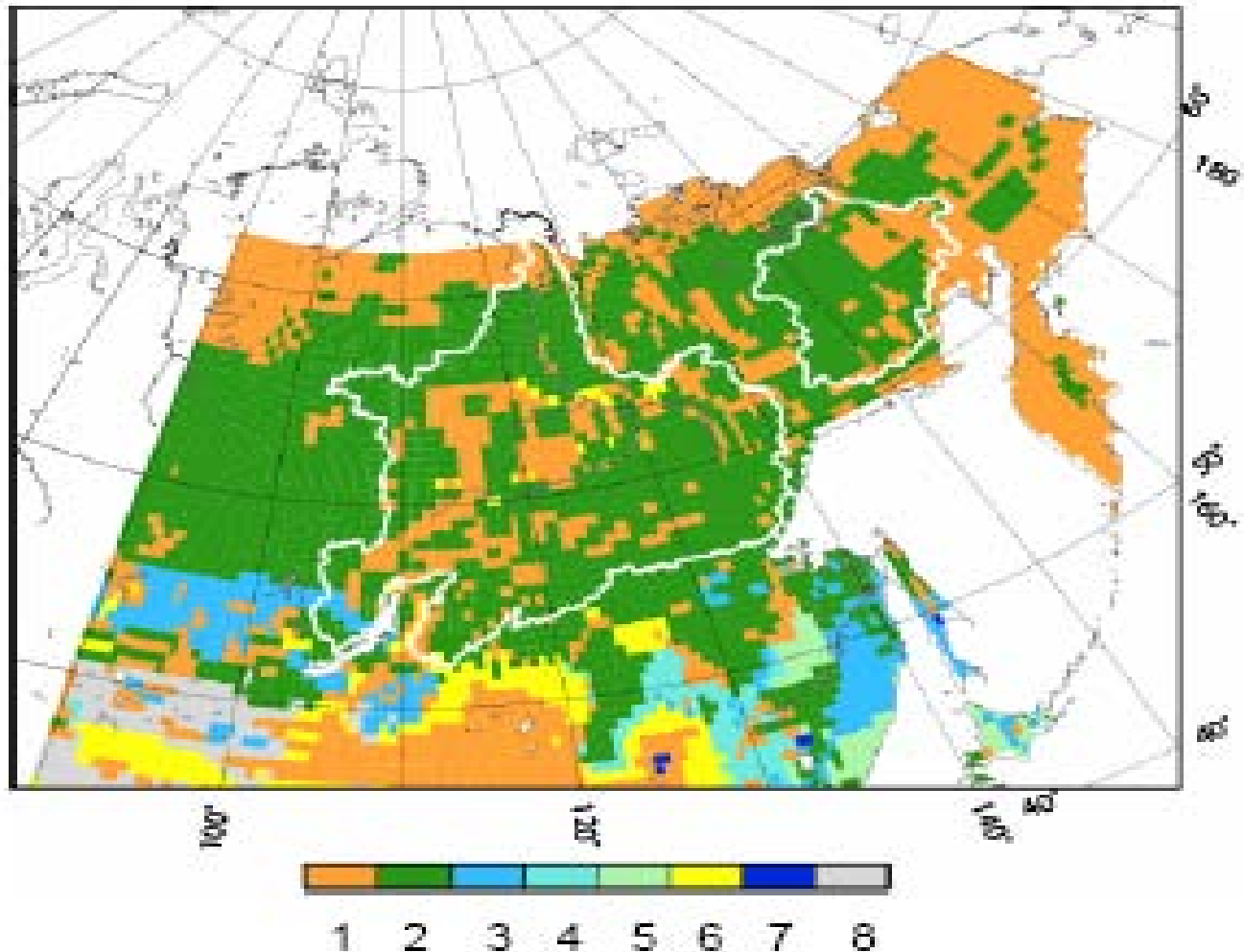
6%

Valley with small Ice-Wedges (a III-IV)

**Potential of thermokarst distribution
in Yakutia (Permafrost Landscape map
of Yakutia, 1991)**

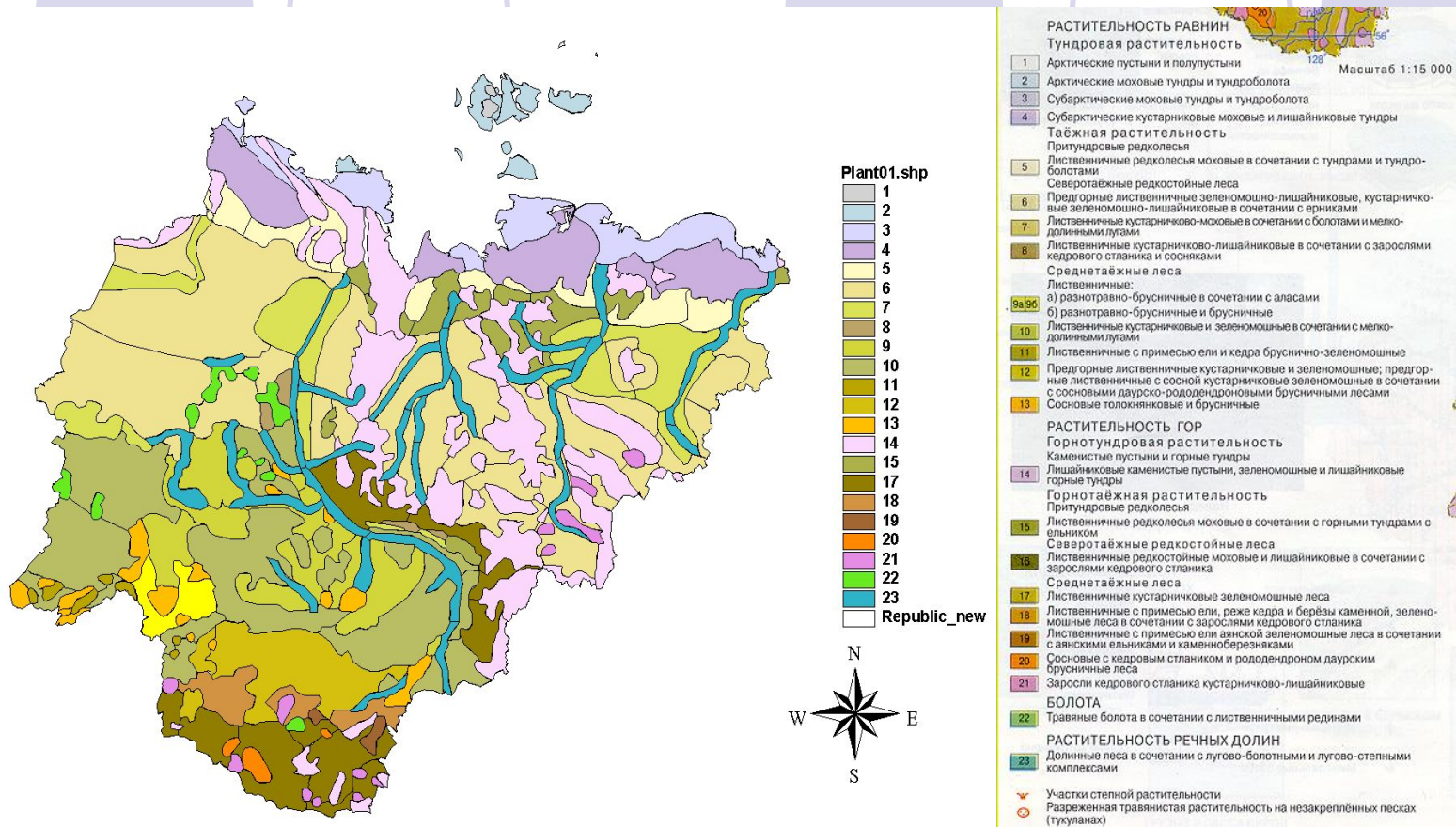
Fedorov, 2007

Distribution of the re-categorized land-cover types



The category is defined as follows; 1: tundra, 2: taiga/boreal forest, 3: cool deciduous conifer forest, 4: cool deciduous broad-leaved forest, 5: cool mixed forest, 6: grassland, 7: permanent wetland, 8: permanent snow and ice

Vegetation map of Yakutia



The territory of Yakutia is weakly populated (980 ths people over 3,1 mln km²), 90% of the area is free from large industrial and agrarian units.

Vast areas of virgin lands allow us to recommend this region as a model one to arrange a network for the complex monitoring of the environment including making a prognosis of possible trends and consequences of the global environmental change as well as finding the ways to mitigate them.

Sliding 10-year average temperatures, °C, Arctic, Northeastern and Central Yakutia

ВЕРХОЯНСК -- VERKHOJANSK

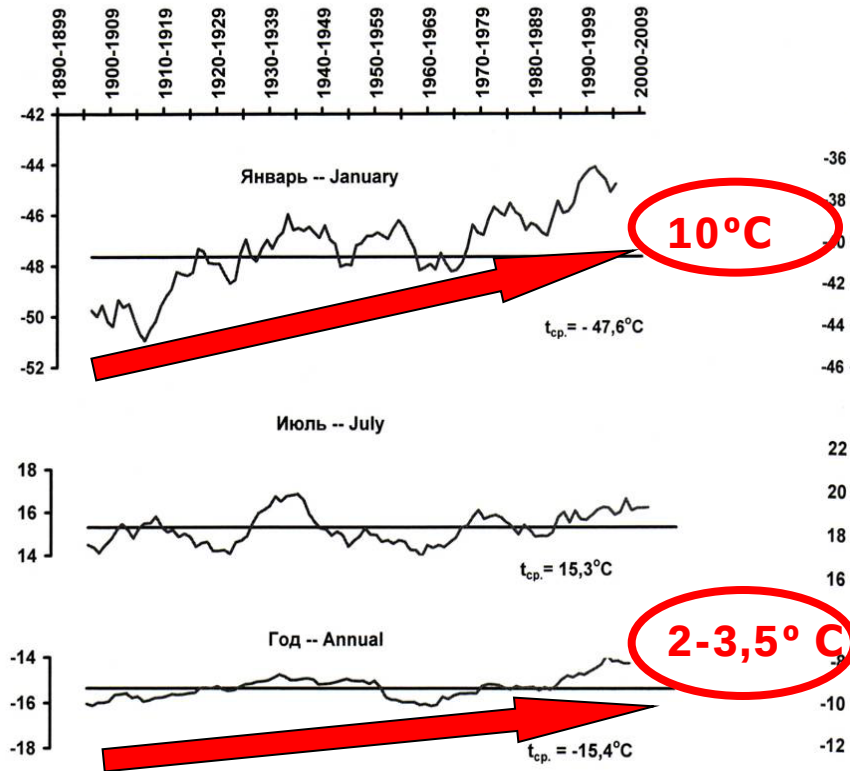


Рис. Скользящие 10 - летние средние температуры воздуха, °C. Северо - Восточная Якутия

Fig. Sliding 10 - year average temperatures, °C. The North - Eastern Yakutia.

ЯКУТСК -- YAKUTSK

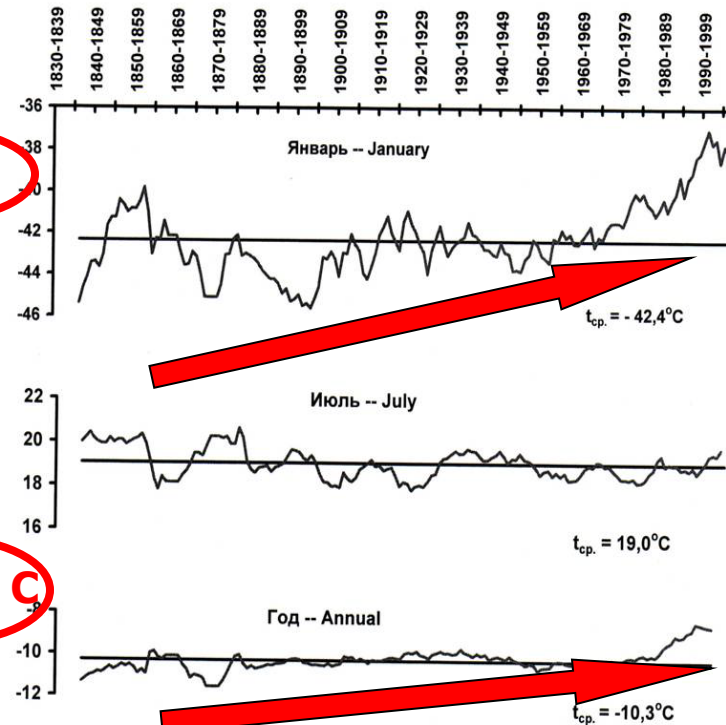
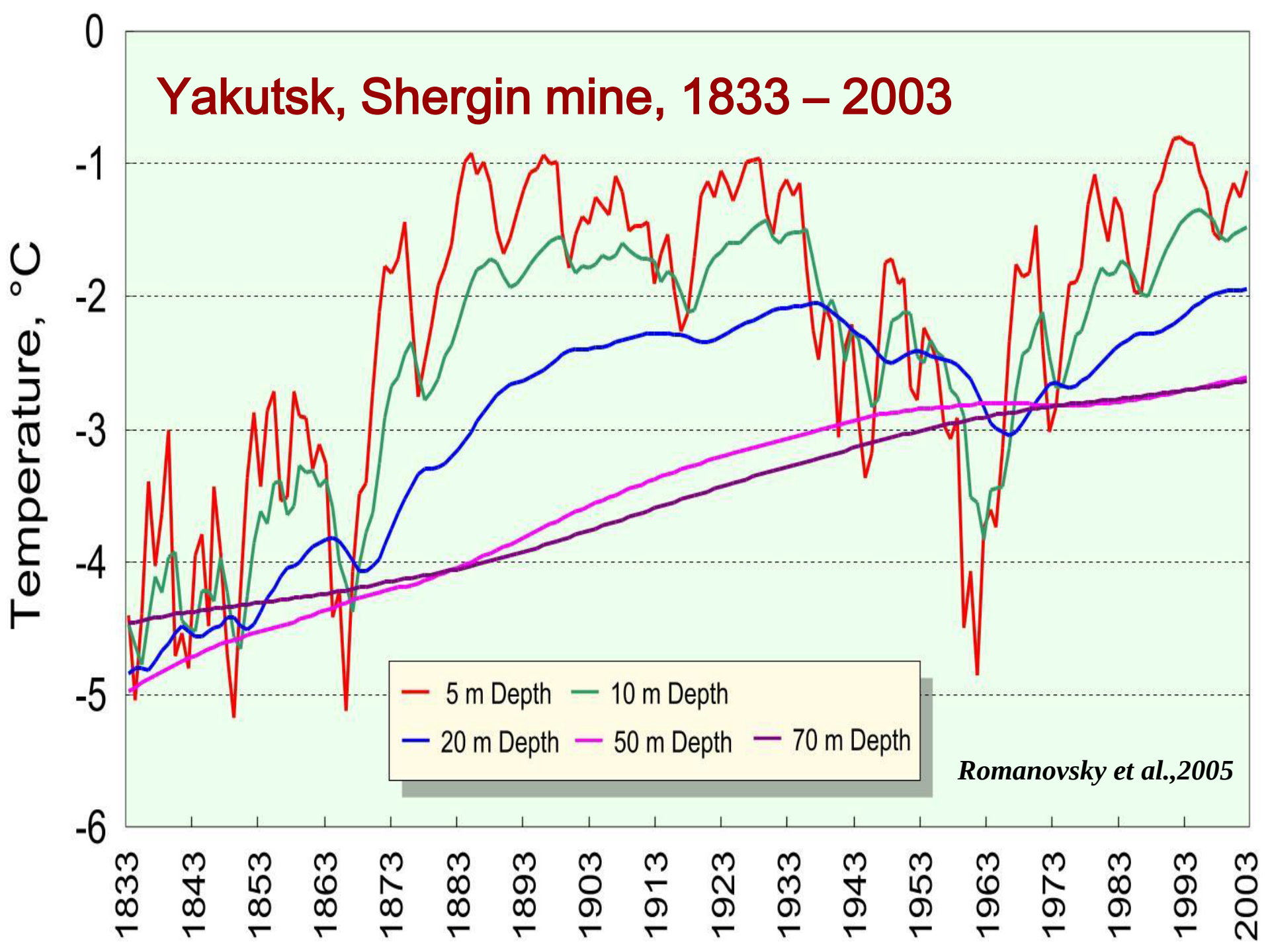


Рис. Скользящие 10 - летние средние температуры воздуха, °C. Центральная Якутия.

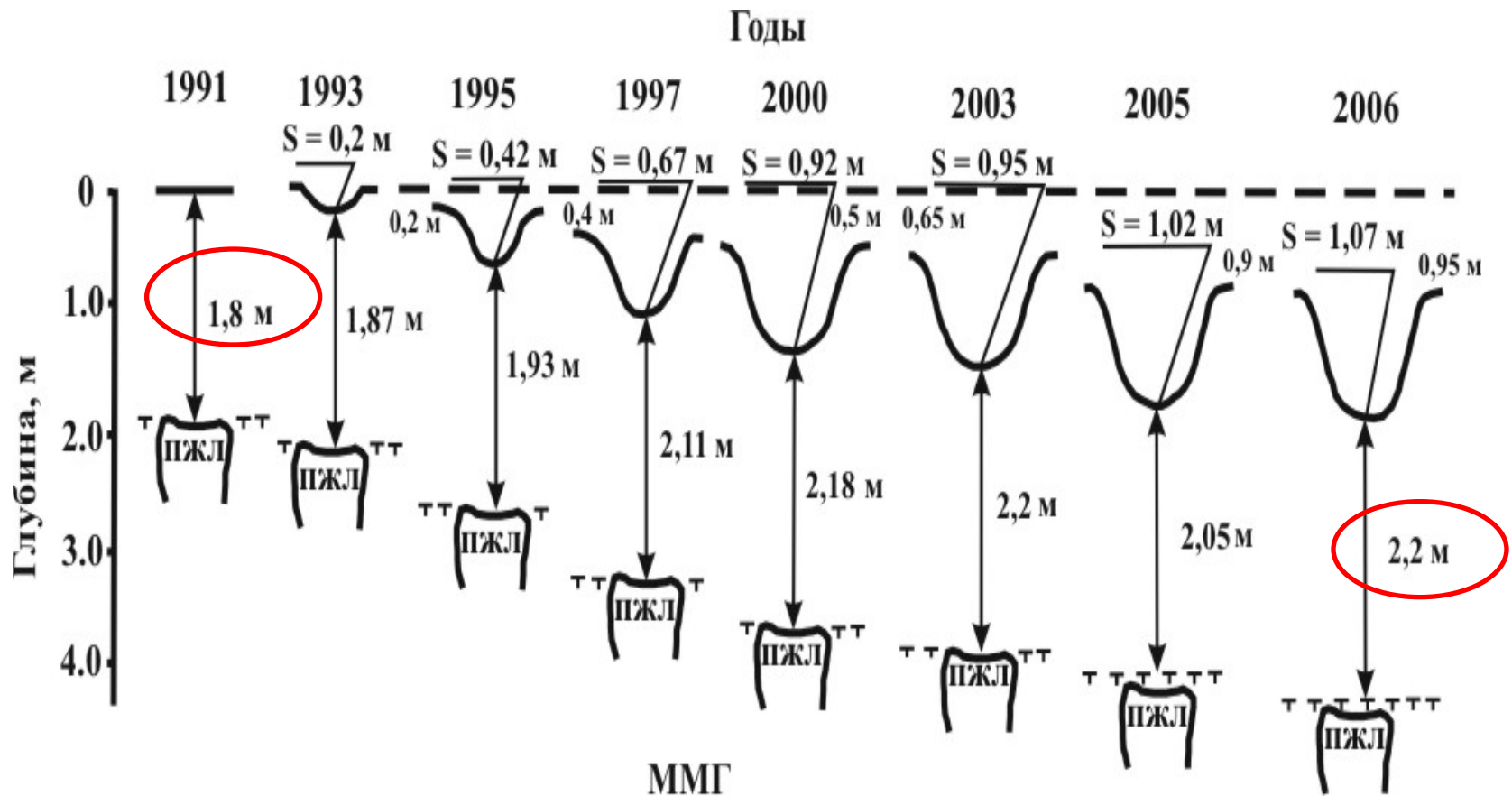
Fig. Sliding 10 - year average temperatures, °C. Central Yakutia.

Meteorological observations for the last 100-150 years in «ever frost» region of Siberian and Central Asia

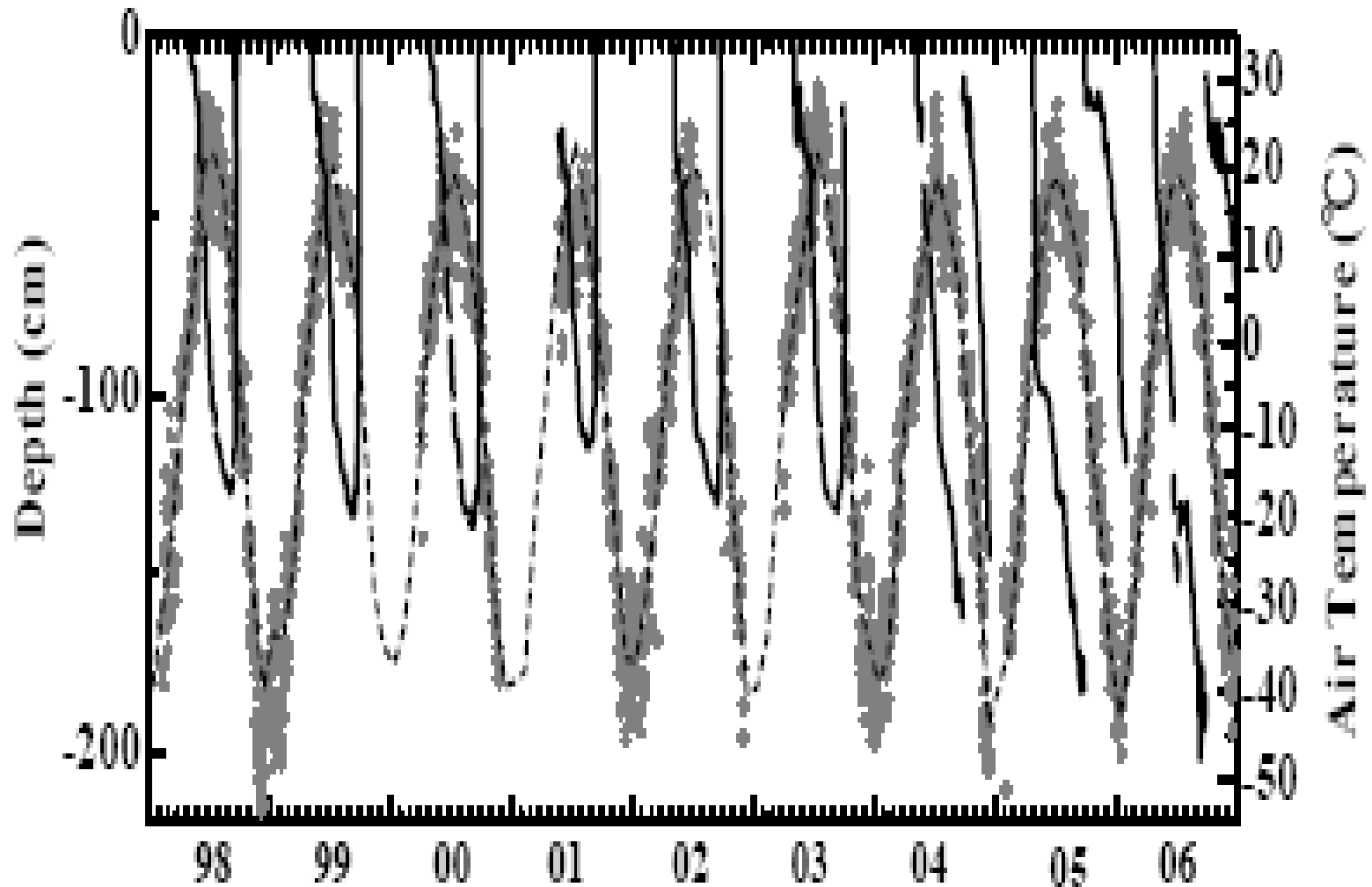
- XX century was warmer than XIX, over all the northern half of Asia. So, for 100 years since the end of before last century, winter temperatures in Eastern Siberia (Yakutia) have arisen by 10 °C. Annual temperatures for the last century increased by 2-3.5 °C everywhere.
- Steady warming appeared at the second half of XX century, especially since 70-80s. For the last 50 years the temperature in Yakutia increased by 7 °C for January, i.e. 1.5-2 times as intensive as at the first half of the century. Annual temperatures rose by 1-2 °C.
- The trend of warming at high latitudes (Central and Eastern Yakutia) is 1.5 times as much as in Southern Siberia and 3 times of that in Mongolia.



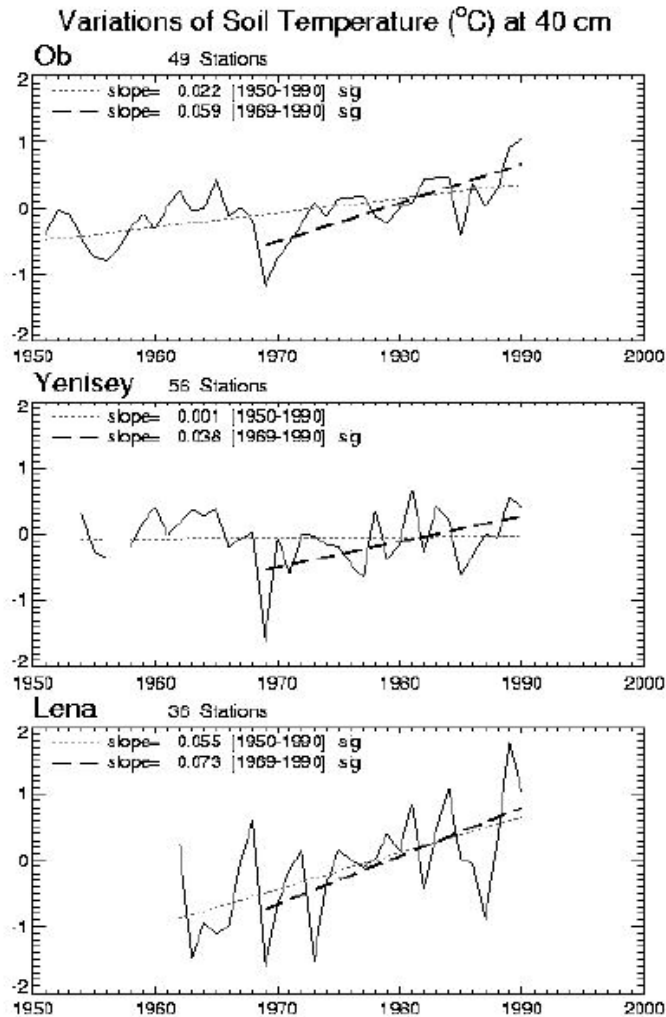
Dynamic of thawing of ice wedge and development of thermo depression, Dyrgyabai Ataga polygon within 1993-2006



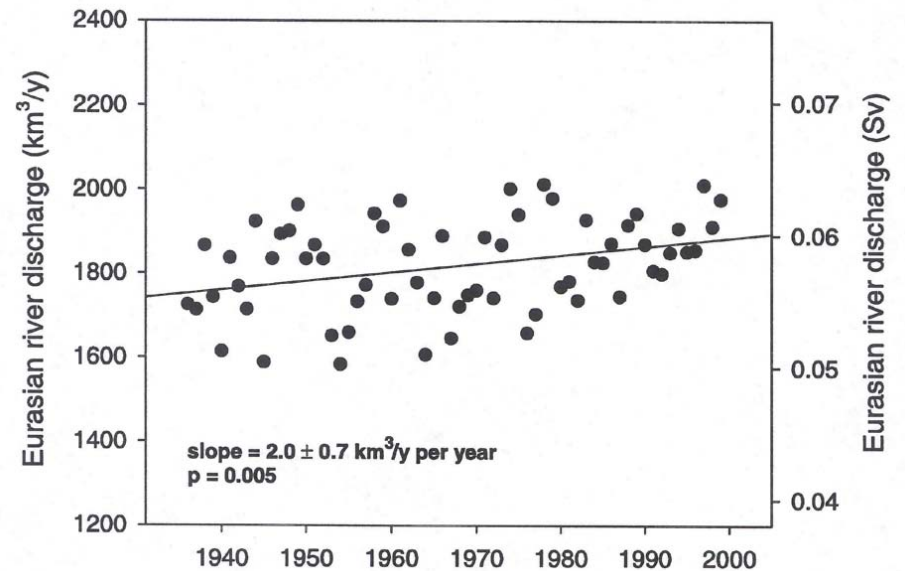
Time series of the depth of soil temperature of 0°C (solid line), daily mean air temperature at Spasskaya Pad (gray dots) and monthly mean air temperature in Yakutsk (dotted line)



Soil temperature



Run-off increase

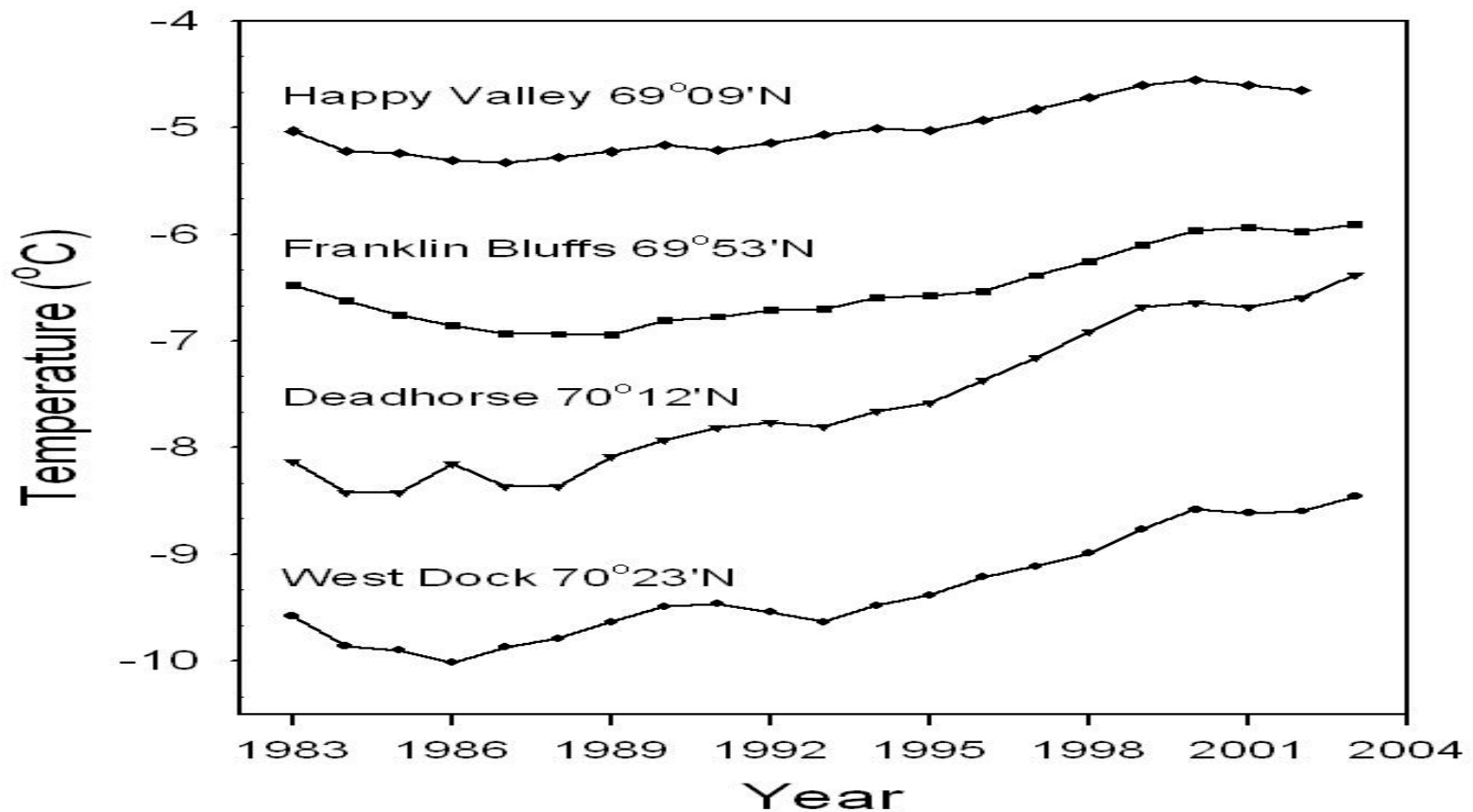


Peterson et al. (2002)

Temperature rise

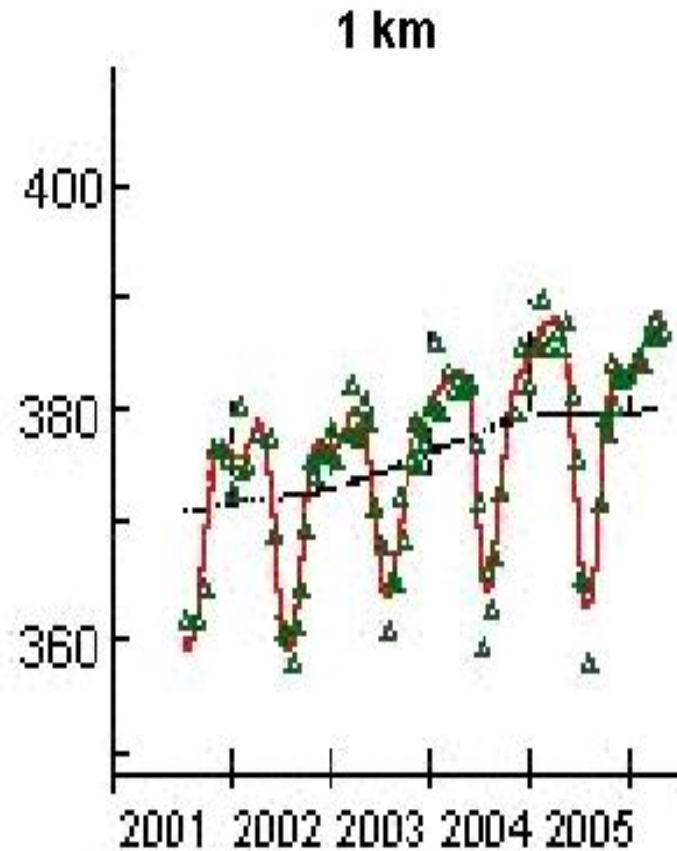
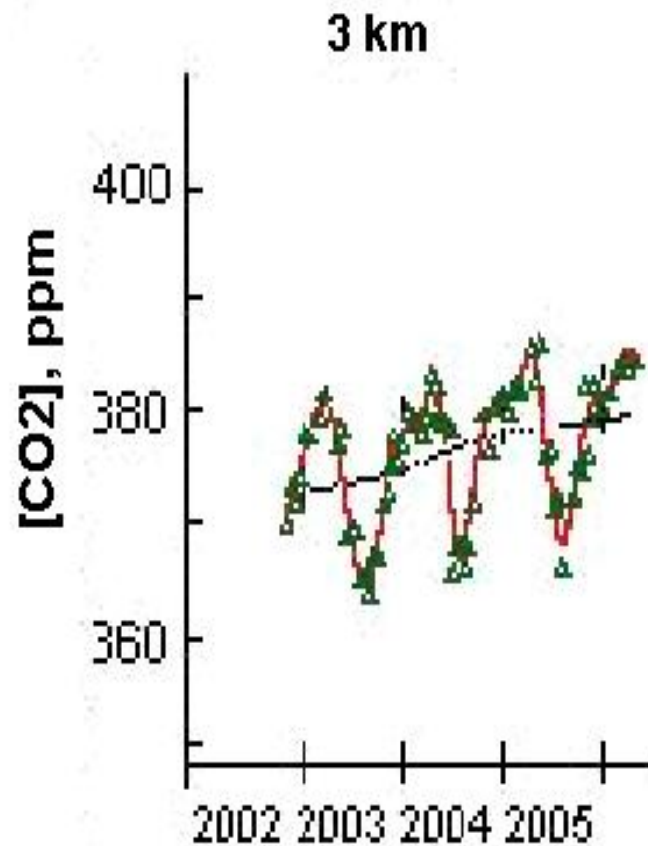
- Ob' - 1.2°C
- Yenisei - 0.8°C
- Lena - 1.5°C
- Forecast: 3-5°C for 50 years

Changes in soil temperature at 20-m depth for several northern sites of the Alaska transect



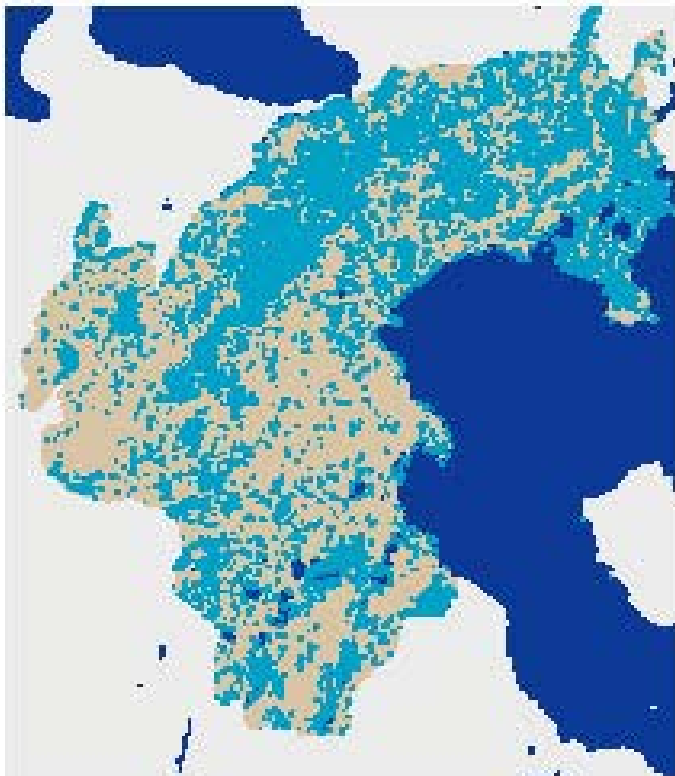
Romanovsky and Osterkamp 1997

Atmospheric [CO₂] over Yakutsk area

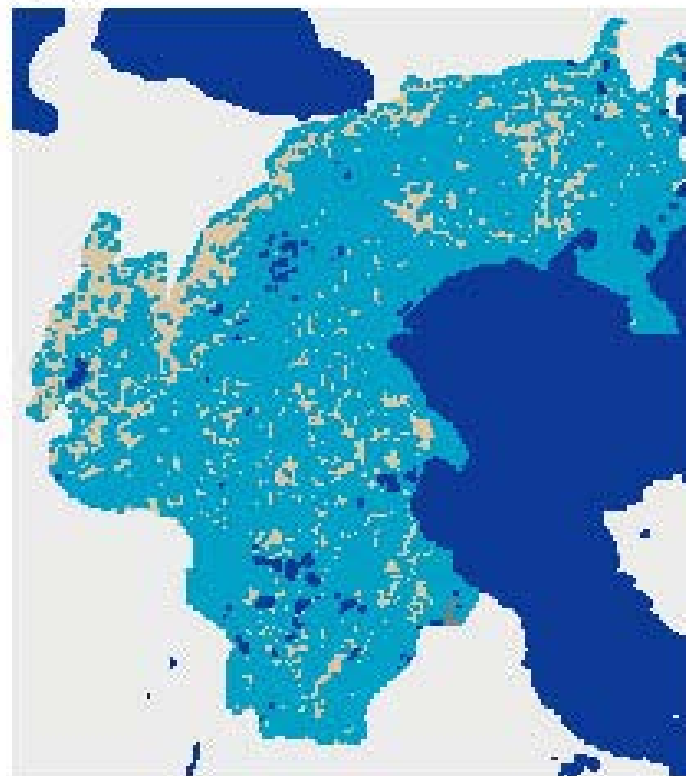


Change in vegetation for 1970-2000

1970

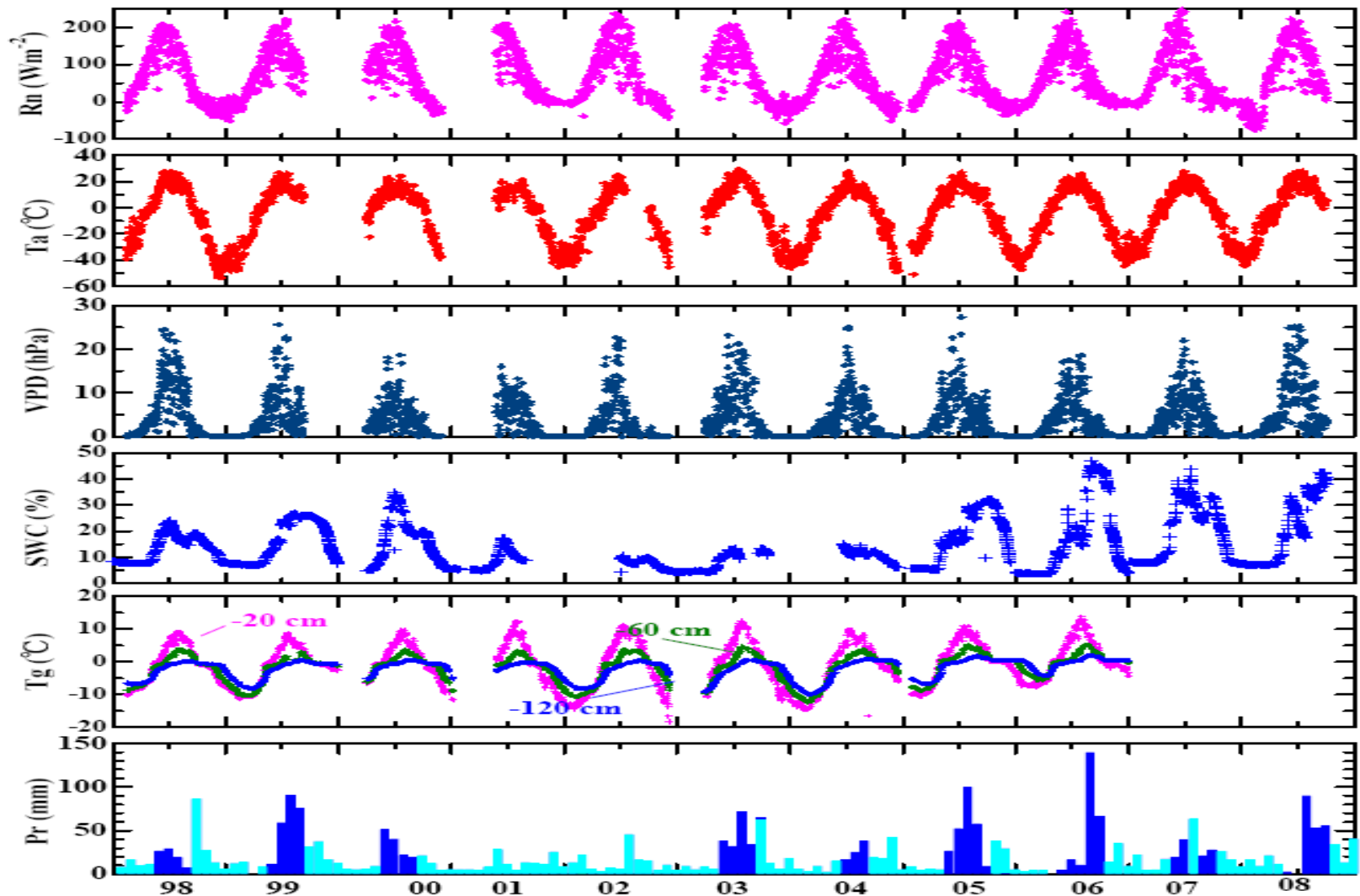


2000

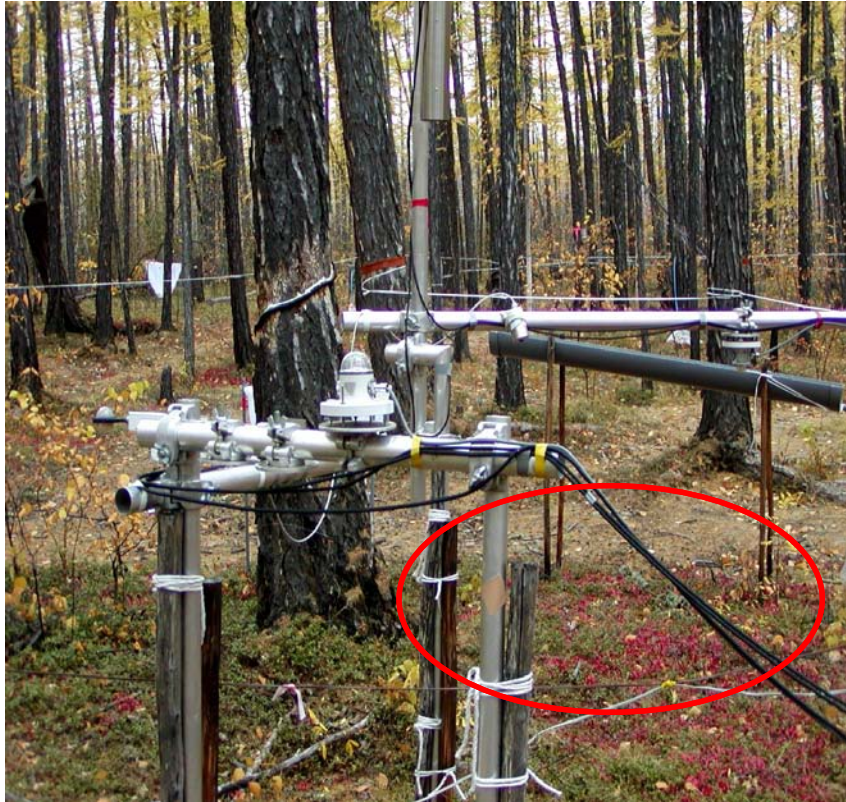


Christensen et al., submitted

Climatic condition variables from 1998 to 2008 at the Spasskaya Pad



Changing of Plant successions during 2001-2009



2001 (subshrubs)

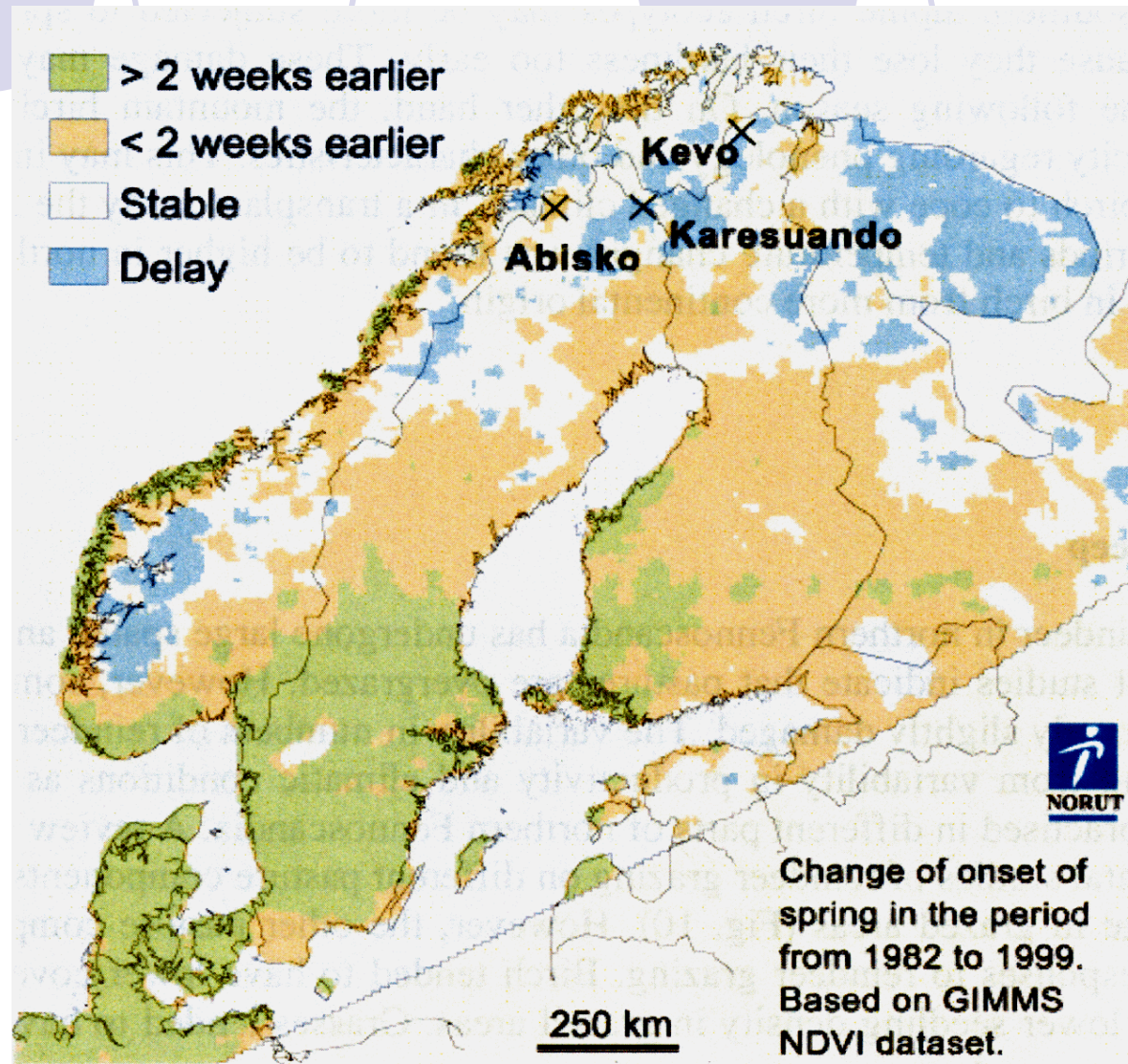
Vaccinium vitis-idaea,
Actae erythrocarpa



2009 (grasses)

Calamagrostis epigeios, *Arctagrostis latifolia*,
Equisetum pretense and *Poa angustifolia* have

Change in spring time coming, 1982-1999



T. Callaghan

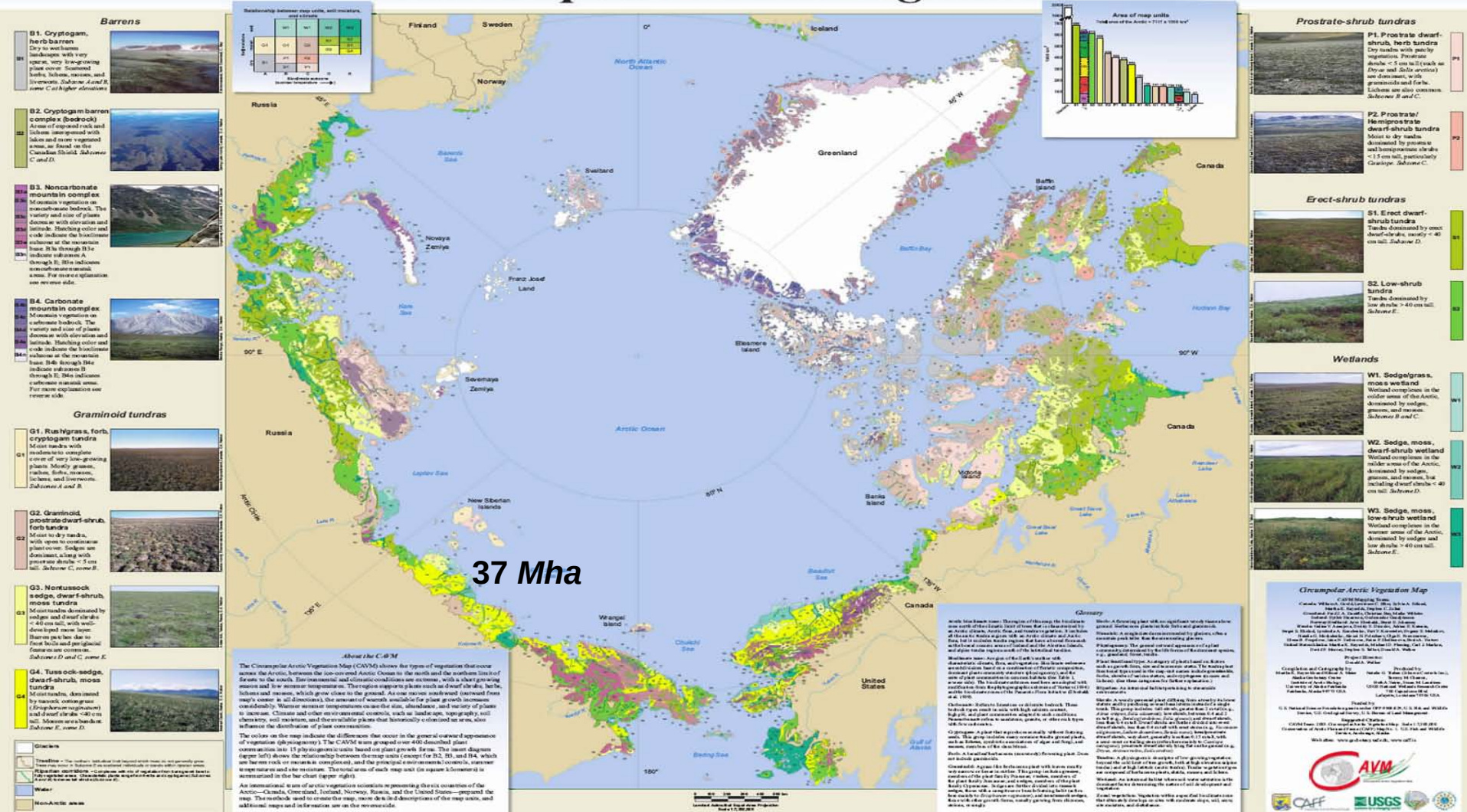
Number of described plant and animal species in Yakutia

Group of organisms	Year			
	1935	1965	1995	2000
Fungi			241	>500
Plants:				
- vascular	1190	1560	1839	1916 (76%*)
- cryptogams	577	1830	3609	3609 (62%)
including:				
- mosses	181	236	444	517 (55%)
- lichens	42	300	550	705 (67%)
- algae	354	1300	2615	2836 (65%)
Animals:				
- insects	600	1100	4000	4300(40%)
- fishes (species and forms)	36	53	53	53(97%)
- amphibians	2	2	4	5(99%)
- reptiles	2	2	2	2(99%)
- birds	138	250	280	291(92%)
- mammals	37	60	63	75(98%)

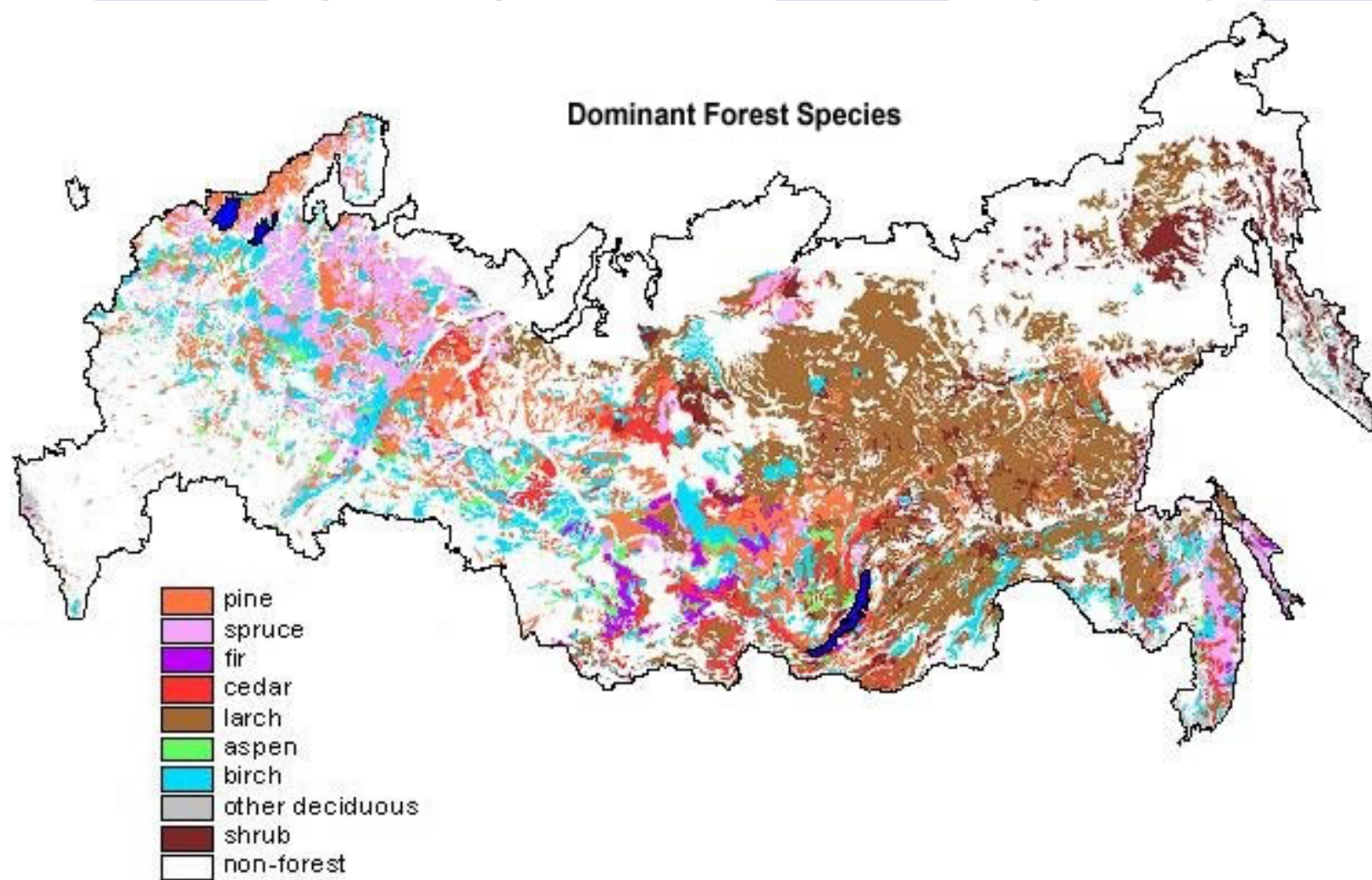
***in parentheses - supposed % of examination**

Solomonov, 2004

Circumpolar Arctic Vegetation



Domination of forest species



Larch area in Siberia and Far East

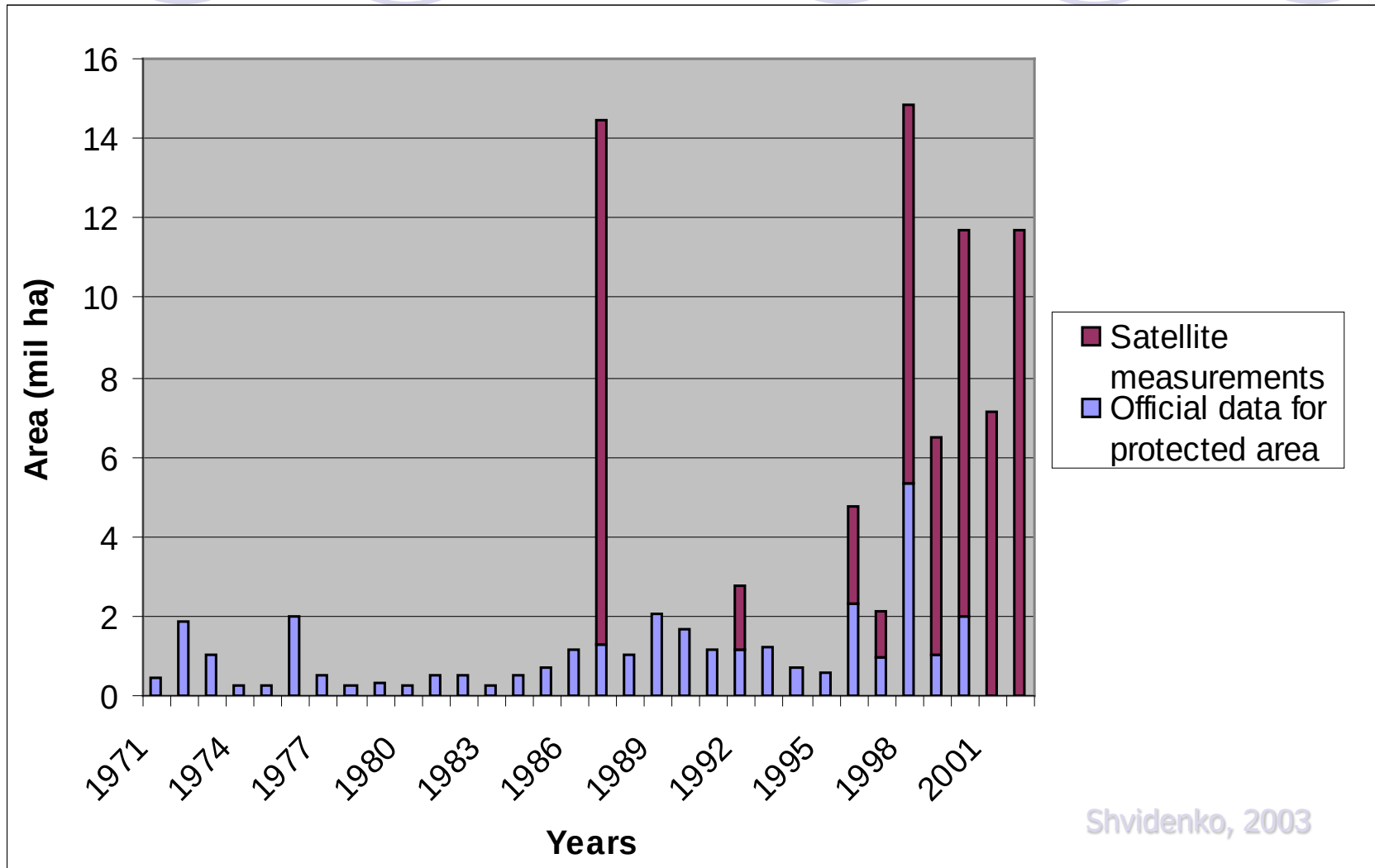
Region

Mha

West Siberia.....	6.0
Krasnoyarsk krai.....	51.6
Tuva.....	3.73
Irkutsk oblast.....	18.23
Buryatia.....	9.57
Chitinskaya oblast.....	16.98
Amurskaya oblast.....	13.9
Khabarovsk krai.....	19.51
Primorskyi krai.....	1.1
Sakhalin oblast.....	1.26
Magadan oblast.....	9.03
Kamchatka oblast.....	0.19
Republic of Sakha (Yakutia).....	106.0 (12.5%)
Total.....	257.1 (30.2%)
Whole Boreal forest.....	850

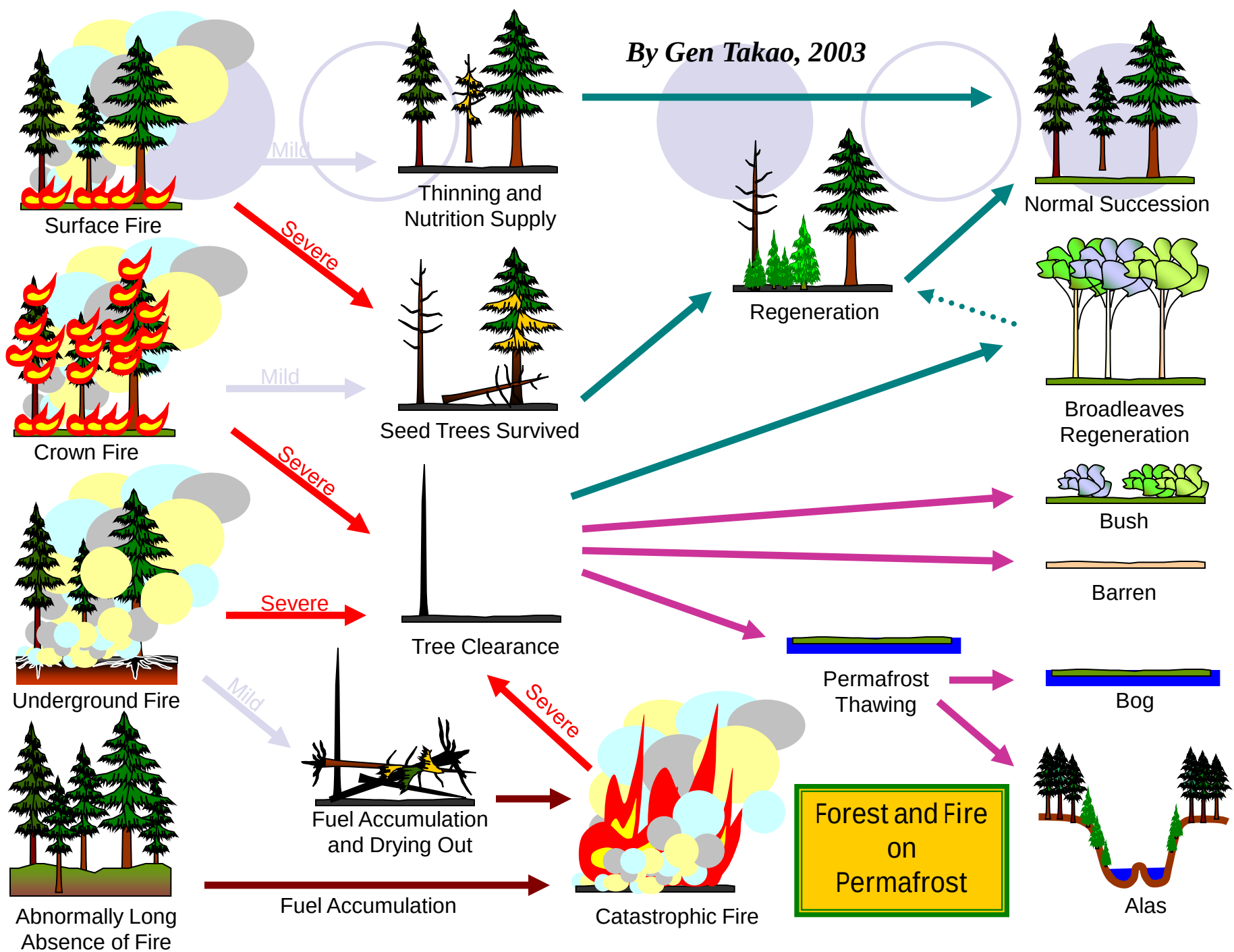
Vegetation fire in Russia in 1971-2002

Forest fires



Shvidenko, 2003

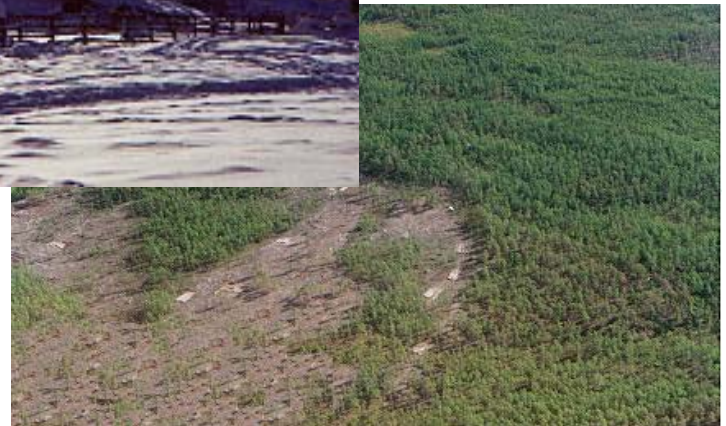
By Gen Takao, 2003



Forest felling

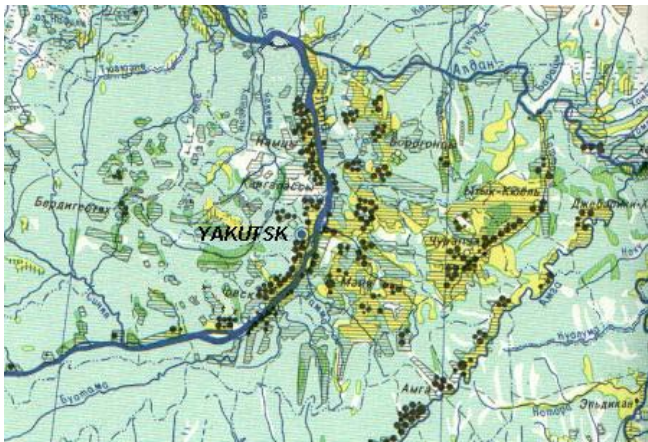
Deforestation

For one steading construction necessary around 100-150 cubic meter of forest, and for one house heating using 25-30 cubic meter firewood annual. Reserves of low productive larch and pine forests amount just 100-110 cubic meter per hectare. It is calculated that all forest users during last thirty year on the territory of Lena-Amga interfluve thinned out dry low productive larch and pine forests on the area to 1.0-1.3 million hectares.

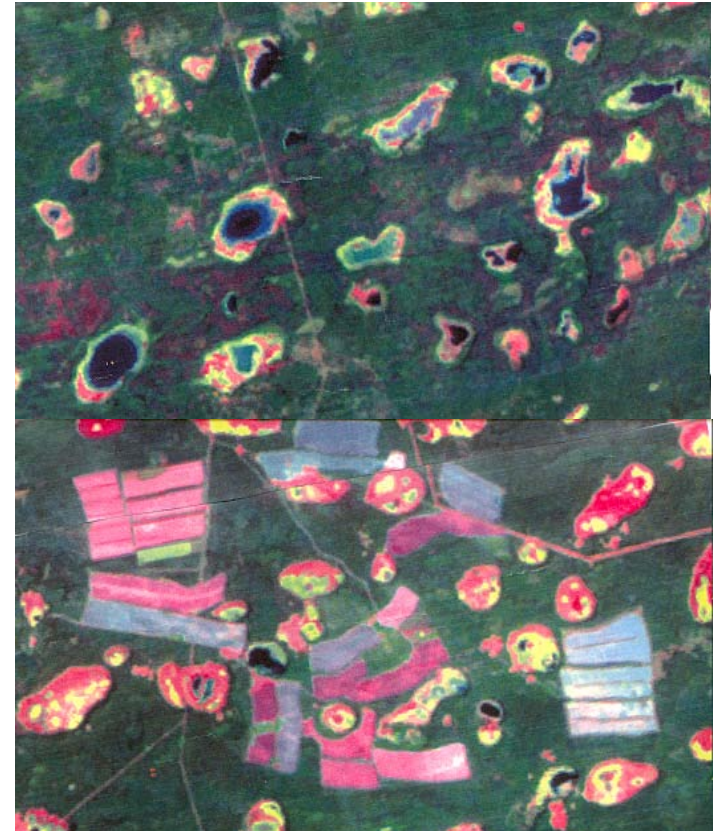


Destruction of forest for the tillage, road, electric line and other line constructions

Total area of arable lands more than 60 000 ha, even greater area of taiga occupied under line constructions



Anthropogenic degradation of forests in Central Yakutia



Insect

Dendrolimus superans sibiricus Tschetv. –
most dangerous pest of the Siberian taiga



♀



♂

Imago



**Caterpillars eat of larch
needles and defoliate trees**



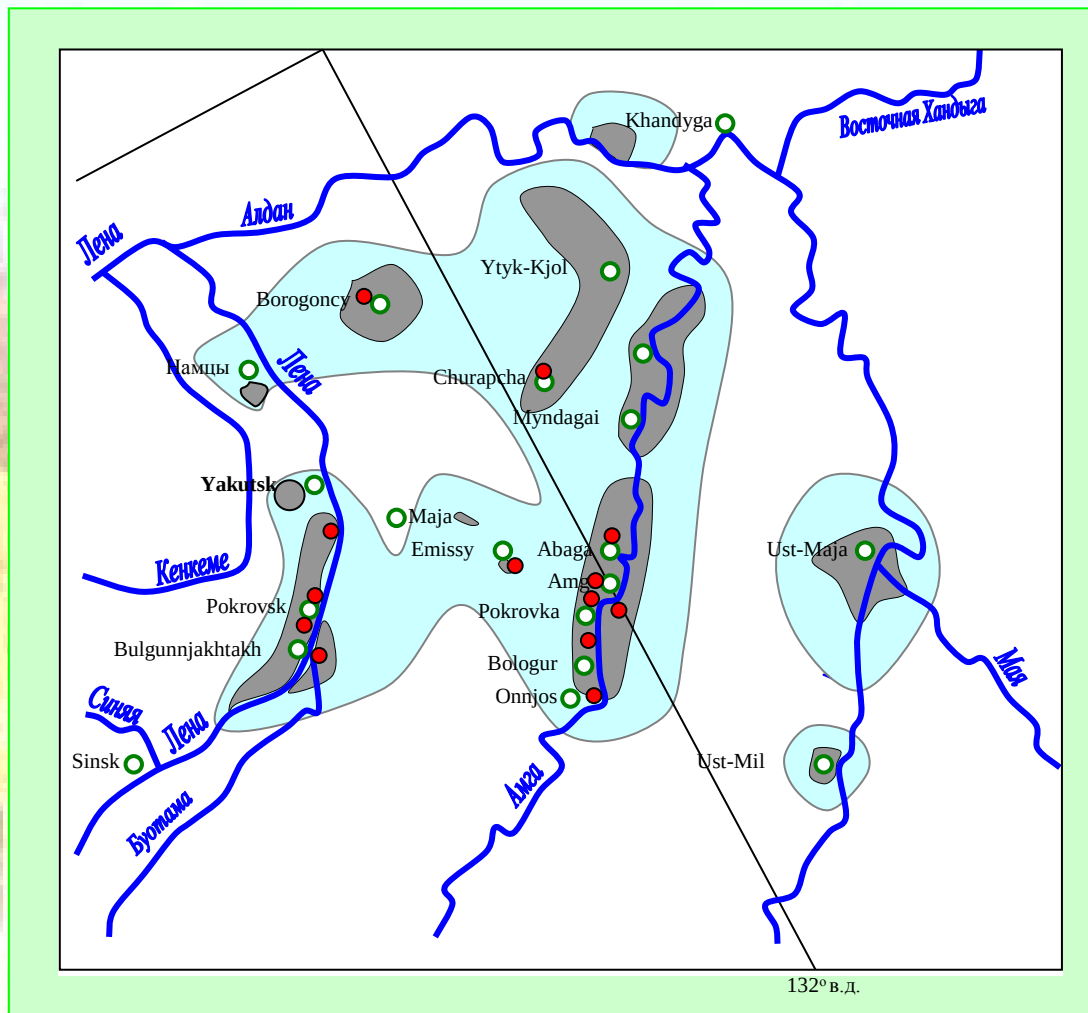


In crown of trees it is possible to find many cocoons, in which develop pupas of butterfly





-  - Area of high quantity
-  - Outbreak localities
-  - Points of field investigation



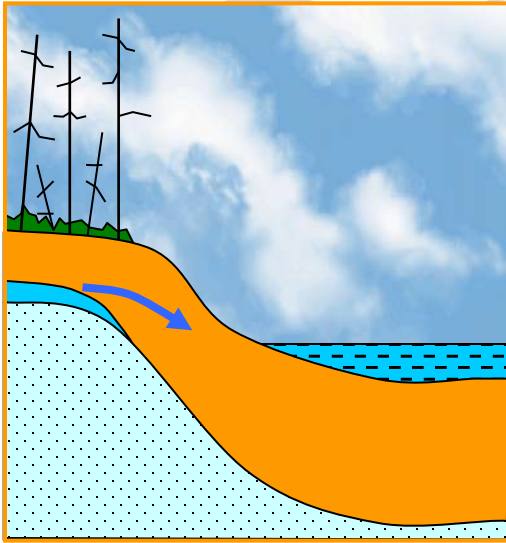
Distribution of *Dendrolimus superans sibiricus* in Central Yakutia. 2000

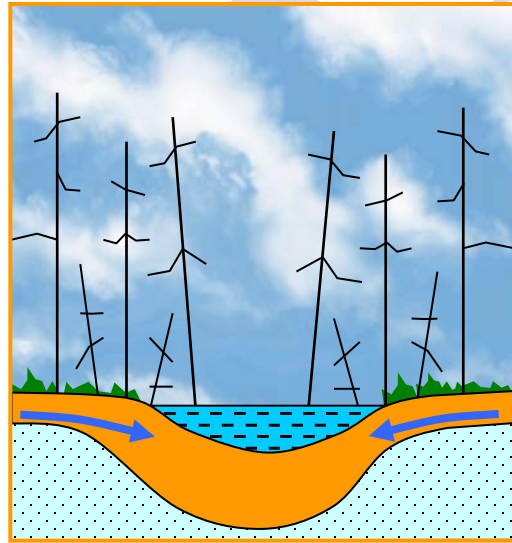
The area of the increased pest density exceeded 5,000 000 ha. The area of complete defoliation amounted 500,000 ha. The inspection of forests showed, that pest is found practically in all larch stands of Central Yakutia

In connection with change of water and temperature regime of soils and plant composition in the some place of dead forest began the thermocarst phenomena, especially on sites with ice complex



Water from thawing of permafrost is accumulated in lowered places near forests

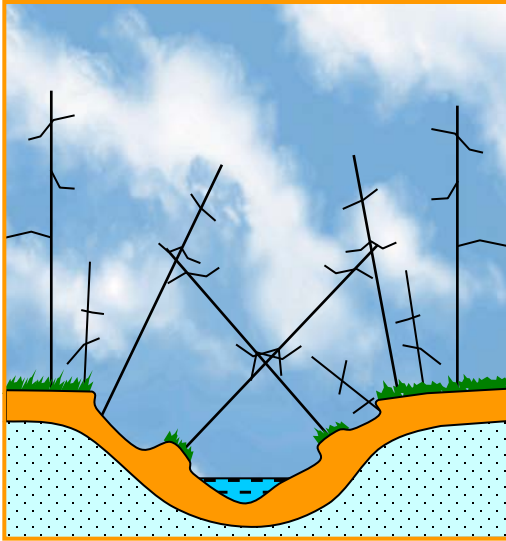




Water is accumulated in lowered places in forest



**In destructed forests on slopes
begin the thermoerosive
process**



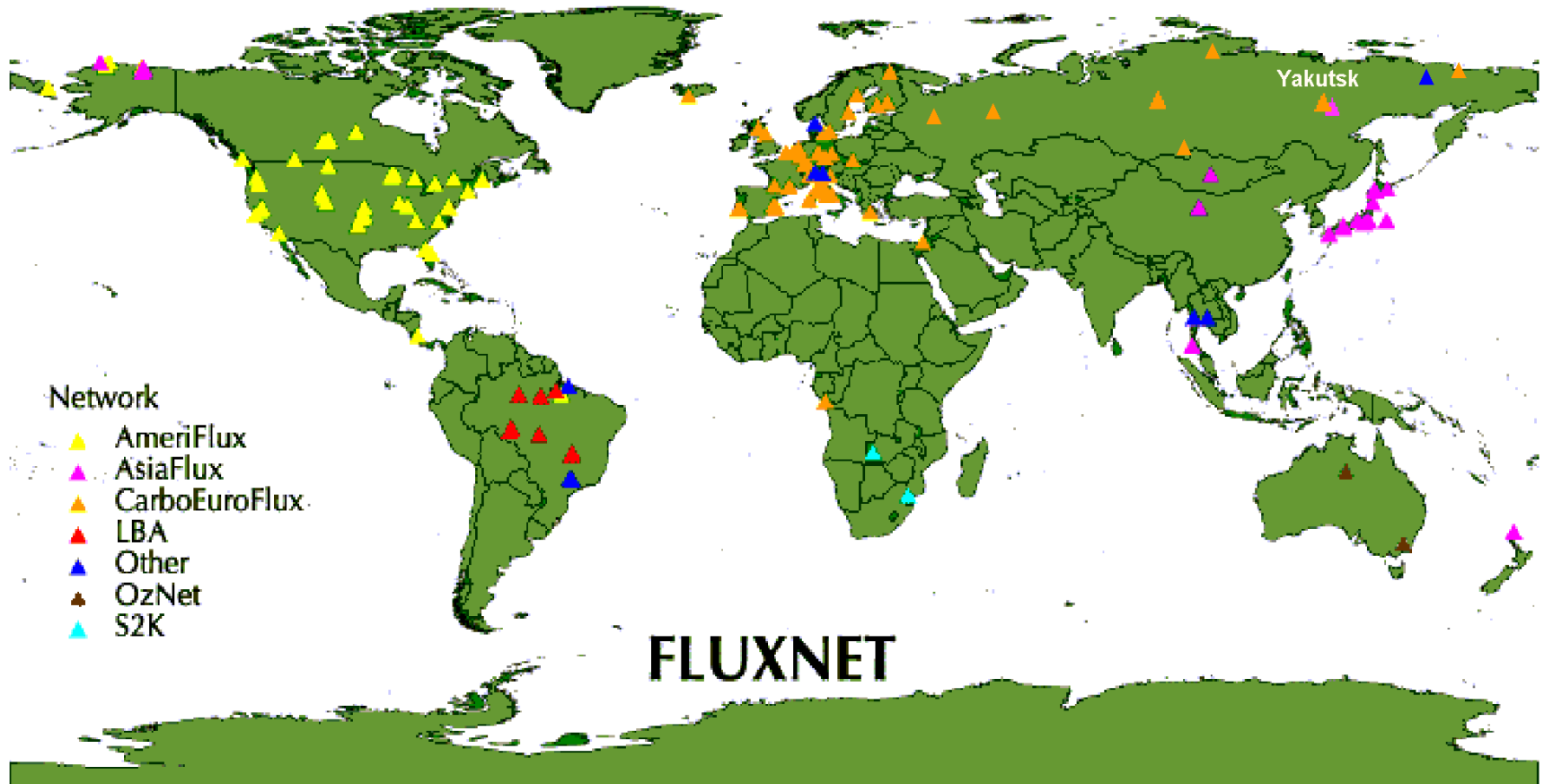
Discoloration of boreal larch forest near Yakutsk in August



Increasing of thermocarst process near town

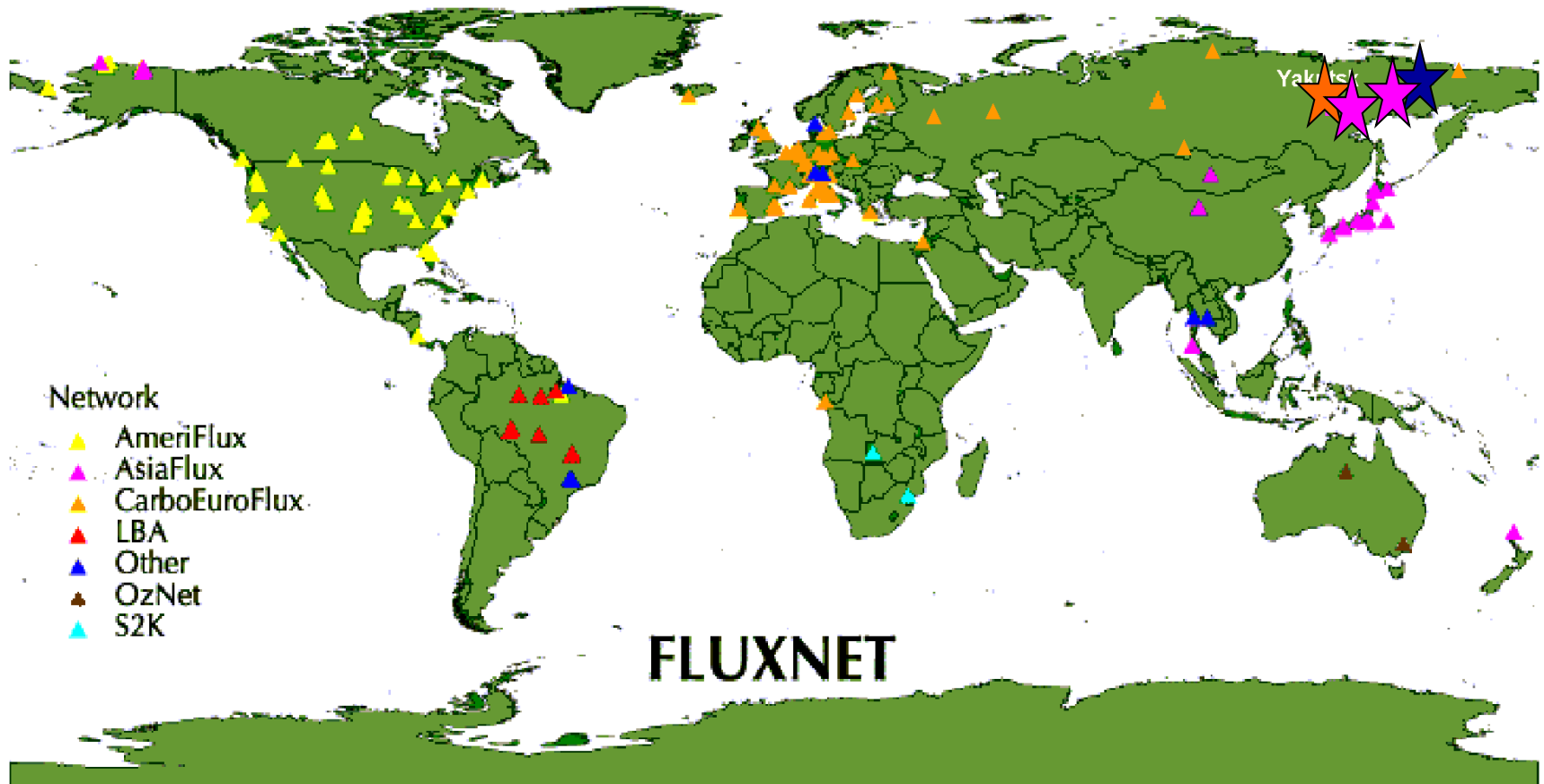


Global, continental and regional observational networks of heat, water and carbon dioxide fluxes



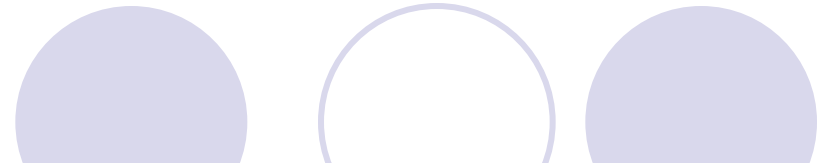
Scientific forest station «Spasskaya Pad» of IBPC SD RAS is the only station in the world that assesses methodologies of scientists of Asia and Europe (*CarboEurope* and *AsiaFlux* projects)

Global, continental and regional observational networks of heat, water and carbon dioxide fluxes



Scientific forest station «Spasskaya Pad» of IBPC SD RAS is the only station in the world that assesses methodologies of scientists of Asia and Europe (*CarboEurope* and *AsiaFlux* projects)

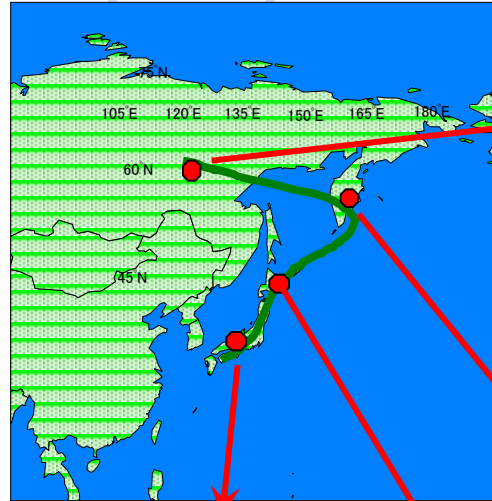
SCANNET (6 countries)



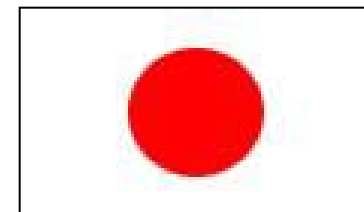
SCANNET (6 countries)



Our experimental stations on BGC in Asia

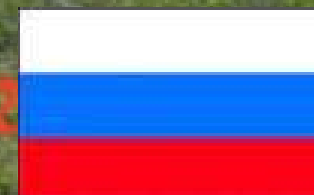


Spasskaya Pad experimental forest station, Central Yakutia

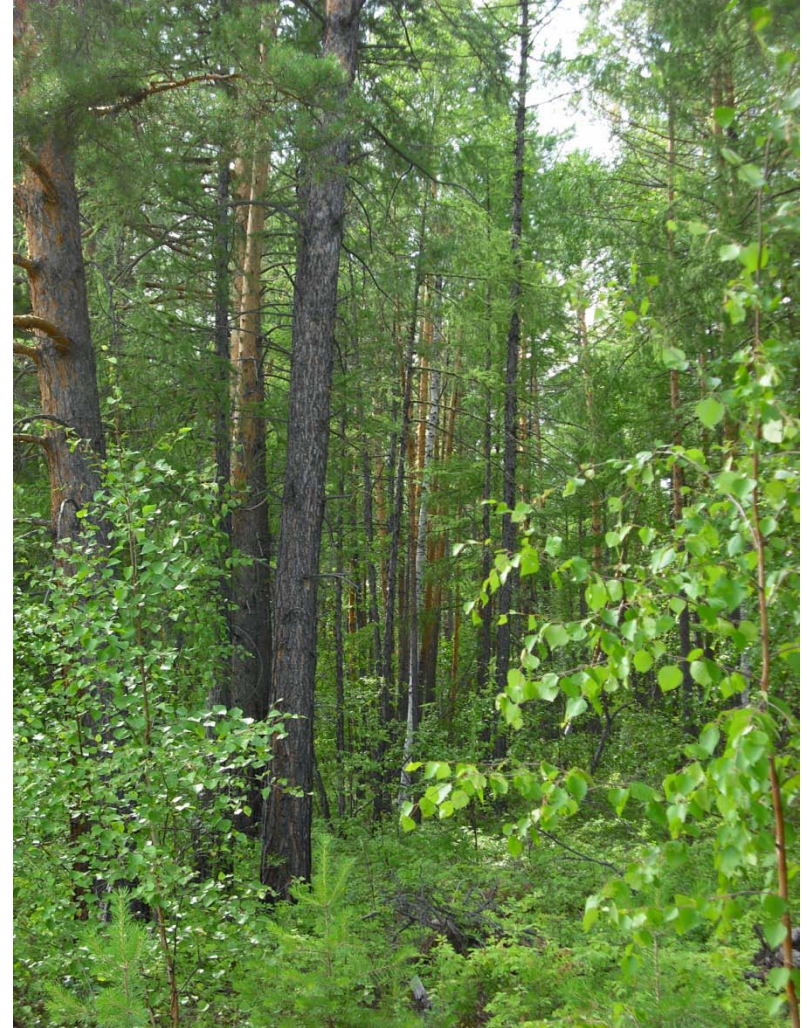




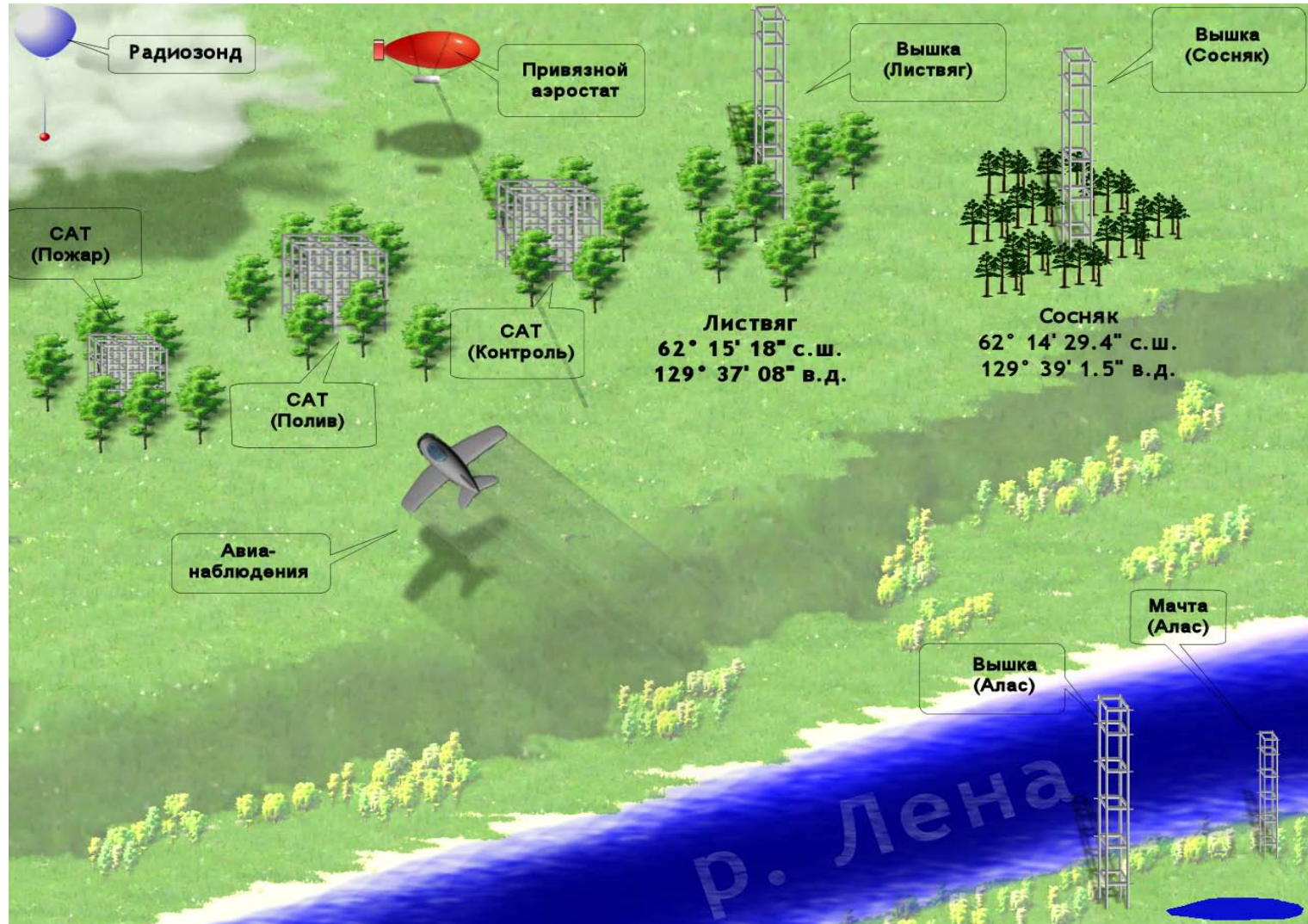
Chokurdakh experimental tundra station, East North Yakutia



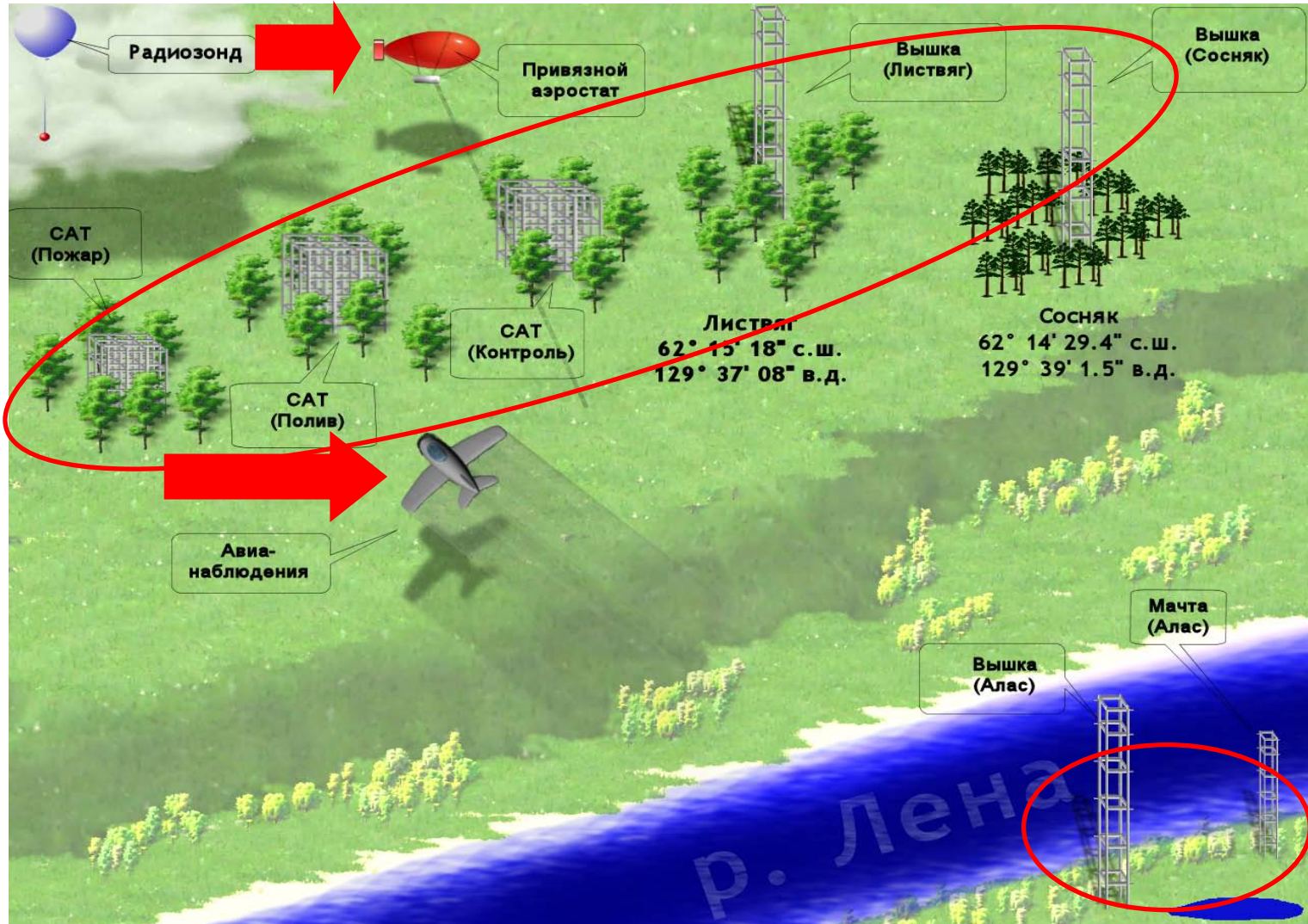
Elgeei experimental forest station, South Yakutia



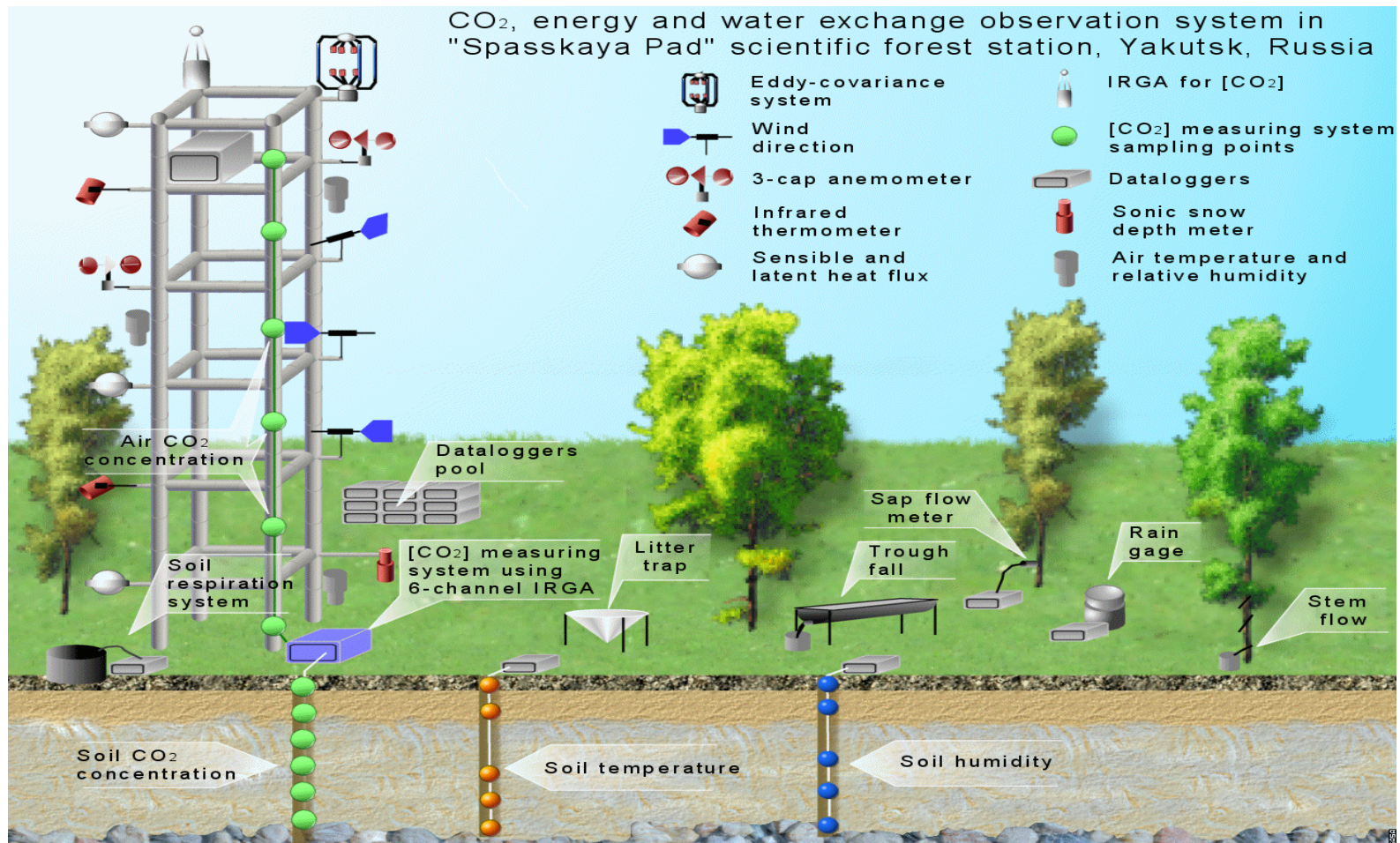
Regional scale of investigations of heat, water and carbon dioxide fluxes in forest ecosystem. Central Yakutia



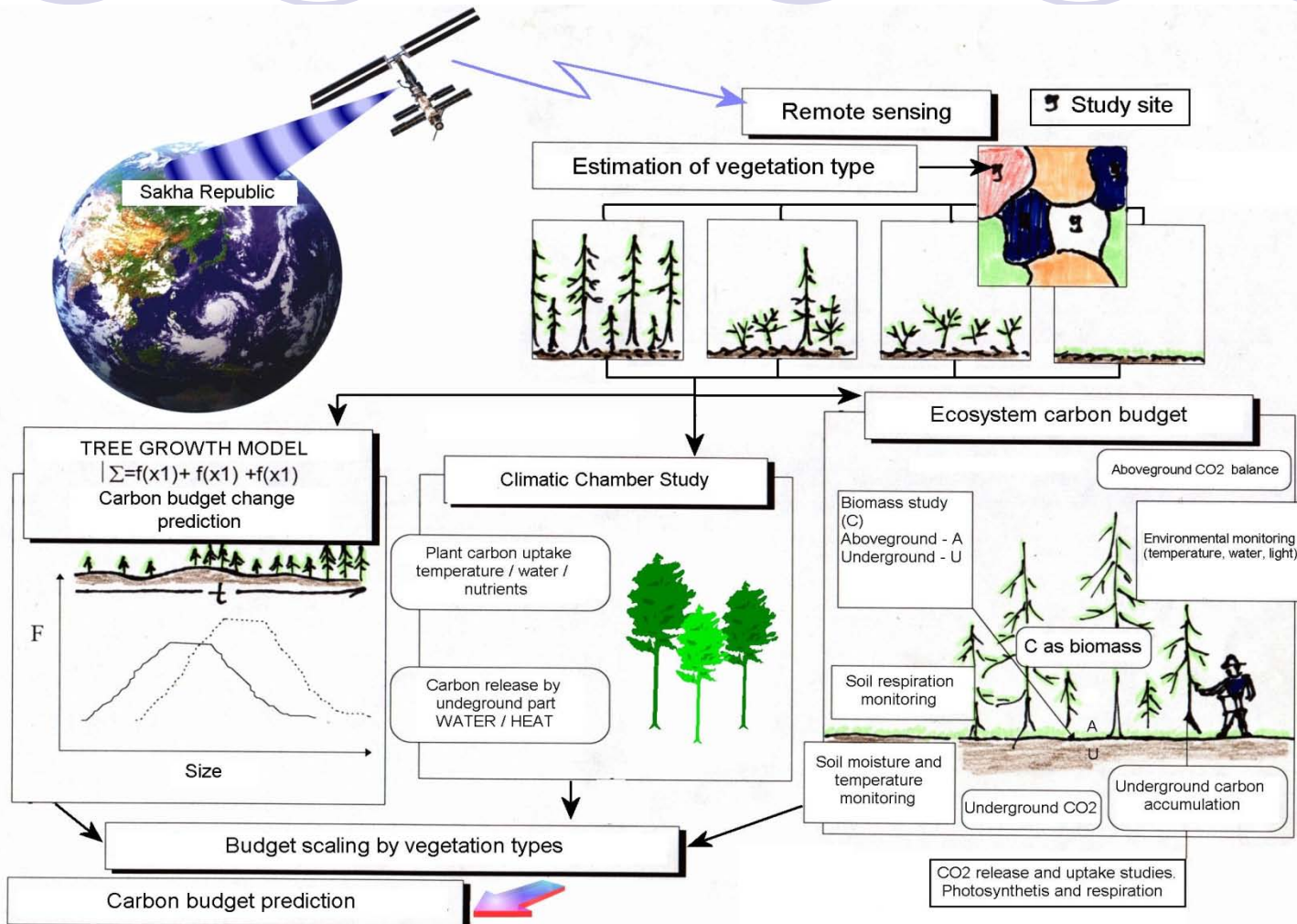
Regional scale of investigations of heat, water and carbon dioxide fluxes in forest ecosystem. Central Yakutia



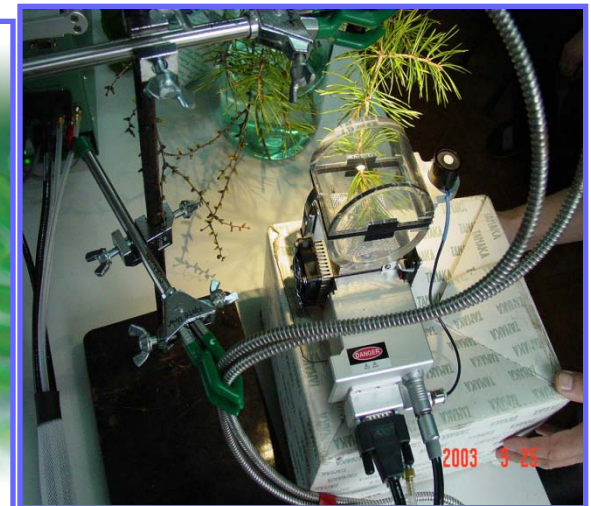
Local FluxNetWork at Spasskaya Pad Forest Experimental Station of IBPC SD RAS. 62°14'29"N, 129°39'2". Central Yakutia



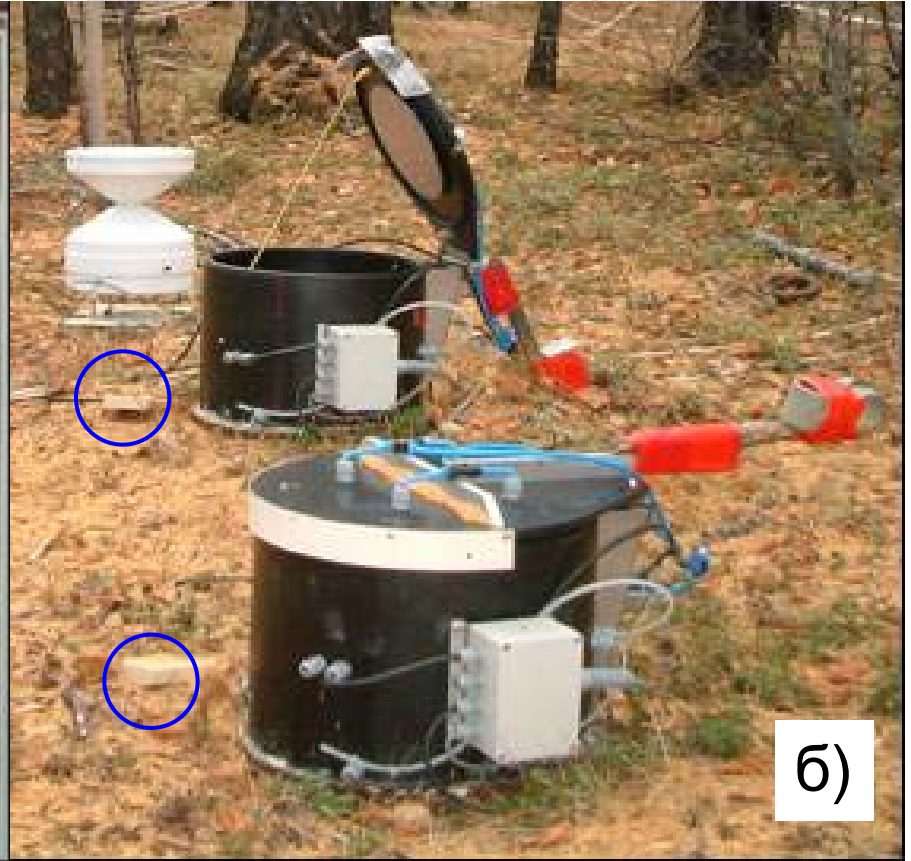
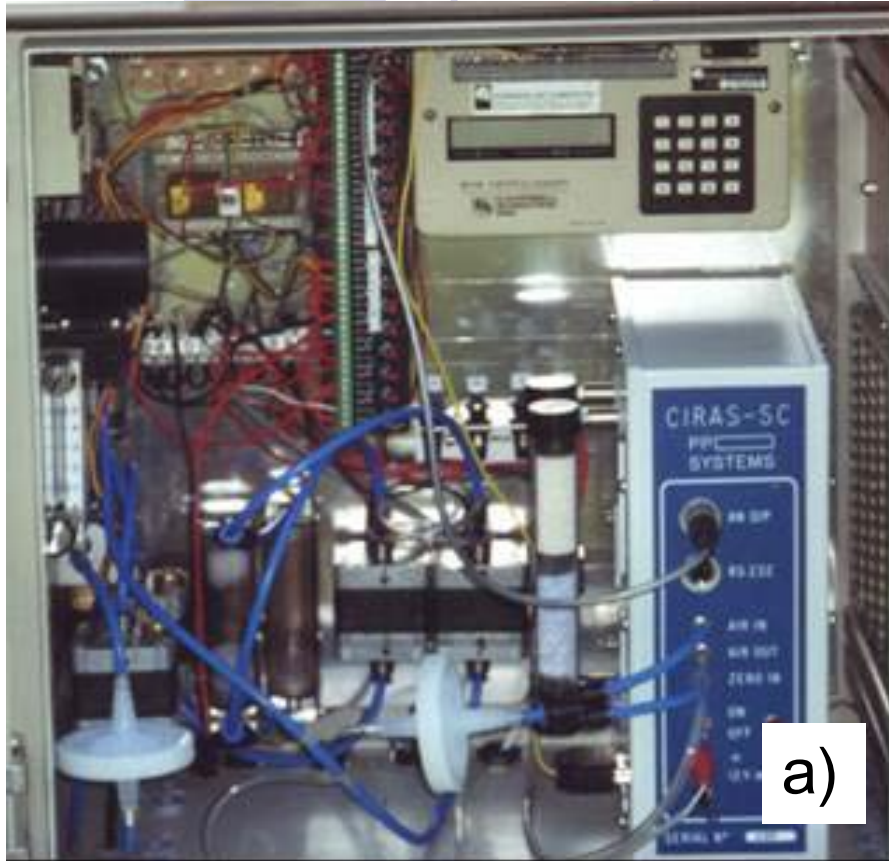
Long term studies on biogeochemical cycles



Chamber measurements. Open and closed chambers



Chamber measurements. Open and closed chambers



a) Control unit with Ciras-SC IRGA; b) Soil chambers

Measured parameters – soil CO_2 flux, T_{soil} , η , p_p , $[\text{CO}_2]$ and $[\text{H}_2\text{O}]$

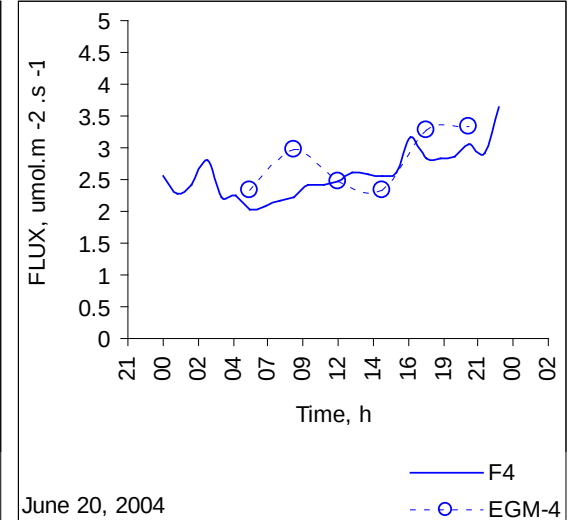
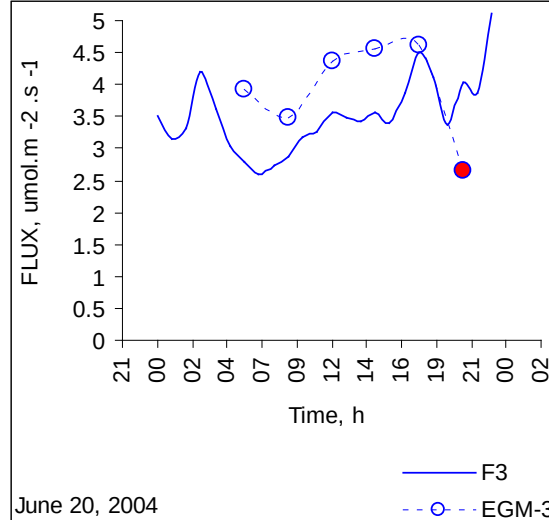
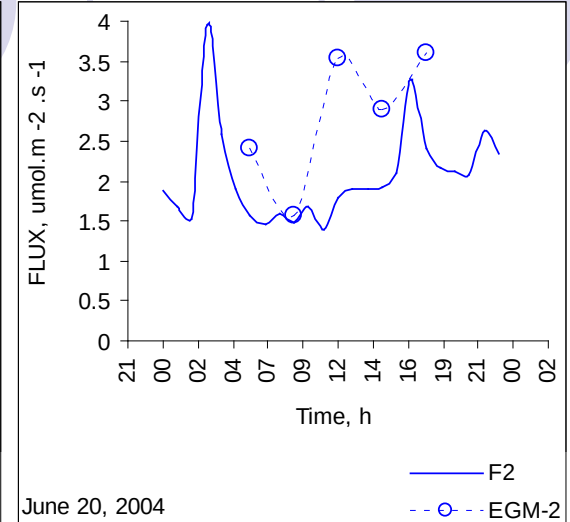
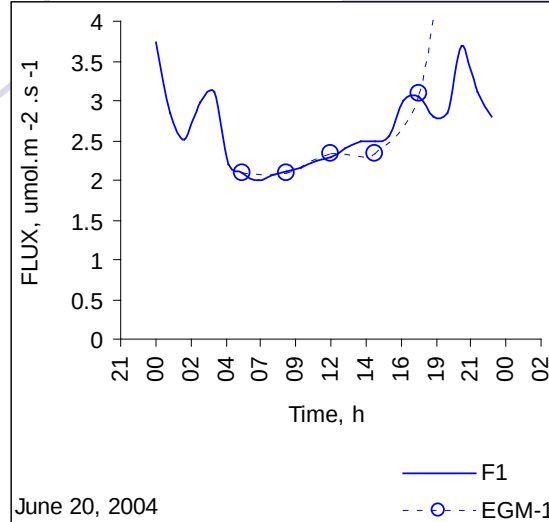
Measurements interval – 1 hour (4 chambers average)

Soil temperature and moisture sensors installation depth – 5 cm

Two methods comparison



EGM-4 (PP Systems, UK)

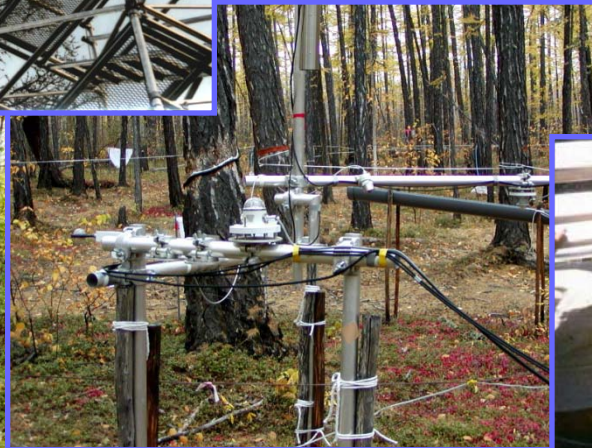
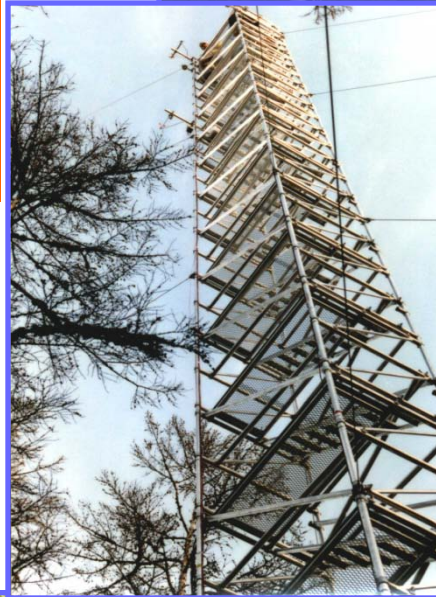


The difference among data obtained by two devices was less than 16%

Eddy covariance (EC) method



Energy, water and carbon fluxtower measurements



EC-measurement for BVOC



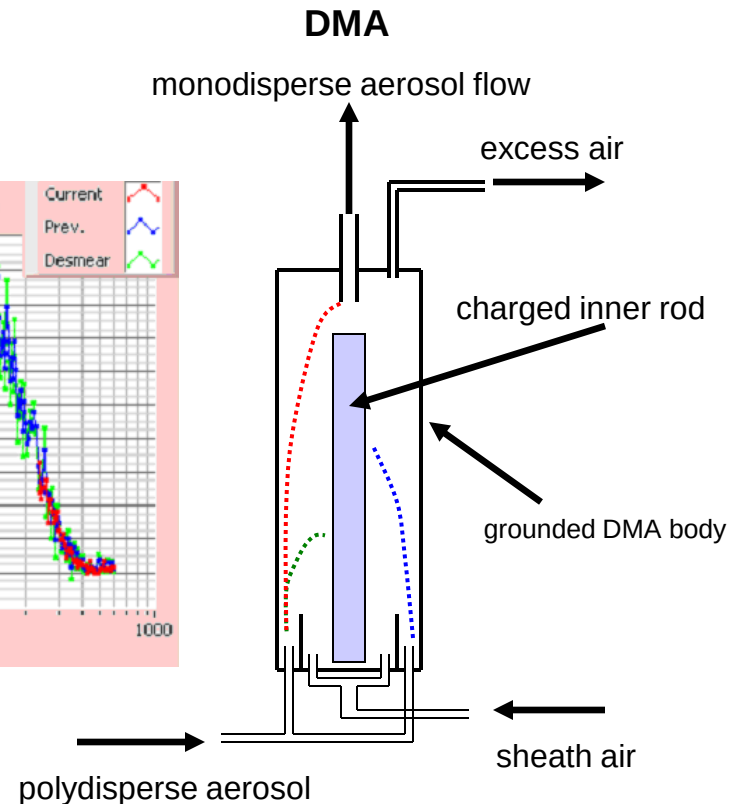
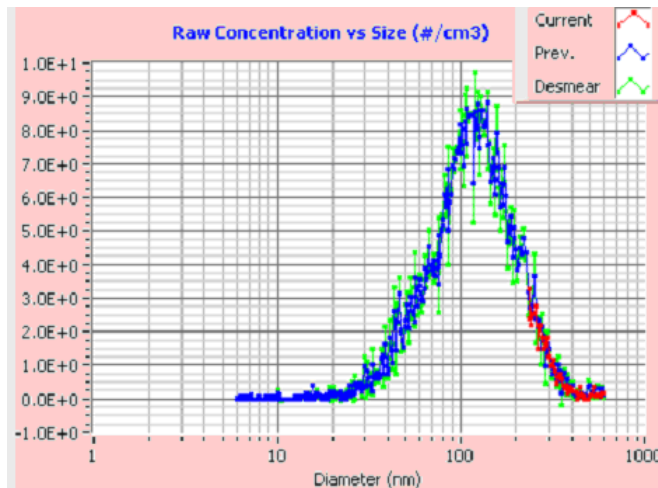
- EC – a combination of:
 - 3-D wind measurements (,sonic‘)
 - fast concentration measurements
- Proton-Transfer Reaction Mass Spectrometry (PTR-MS)
 - PTR-MS uses ,soft Chemical Ionisation (CI)‘, BVOCs in sample air are protonated:
$$\text{VOC} + \text{H}_3\text{O}^+ \rightarrow \text{VOC-H}^+ + \text{H}_2\text{O}$$
 - PTR-MS needs no sample gas conditioning, even mixtures of different BVOC
 - very fast (up to 10 Hz), ,online‘ results
 - can scan for different BVOC in a sequence
 - detection limit: ~50ppt

Aerosol measurements

- Scanning Mobility Particle System (SMPS)
 - ca. 6 – 600 nm particle size distribution
- Air Ion Spectrometer (AIS)
 - ca. 0.4 – 40 nm particle size distribution



SMPS





**The basic strategy
of northern plants: survival and regeneration
to the detriment of high productivity
(NPP ~0.8-1.3 t per ha)**

Homeostatic adjustment

The physiological response



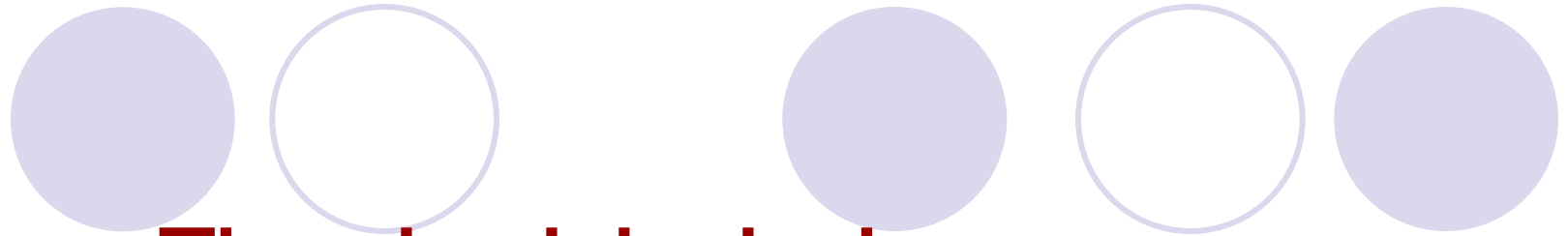
Larch-dominated carbon density difference in Russia

Region	kg C/m ²	kg C/m ³
Mean 29 regions	3.71(100%)	0.52 (100%)
Ust Maya, SYa	4.67 (26%)	0.43 (17%)
Yakutsk, CYa	3.82 (3%)	0.49 (6%)



Homeostatic adjustment

- 1) permafrost (acute continental climate);
- 2) short growing season (less 60 (tundra) and 100 days (forest));
- 3) early preparation and leaving of plants to winter dormancy (buds- mid of July and early August & vegetation all growing season- quick growth, dormancy on time, autumn hardening);
- 4) the high duration of daily photosynthesis (15-16 hours in forest and 23 hours in tundra);
- 5) small celled, xeromorphism;
- 6) low LAI, transpiration and assimilation surface;
- 7) the advanced root system;
- 8) an advancing of growth of roots above growth of an elevated part of plants in the beginning of growing season (1.4 times);
- 9) economy use of water on creation of unit of a biomass of a plant;
- 10) equation in use rain and thawed snow water;
- 11) "self-independent" work powerful plant acceptors (generative organs);
- 12) pathological lack of photosynthates during formation and development generative organs (low starch : sucrose);
- 13) low net primary productivity(less than 3.1 t/ha);
- 14) absence of the big difference between tree species in photosynthesis rates;
- 15) high variability (2.5 times) of ecosystem response (NEE,SR, Photosynthesis,NPP,Cannopy conductance etc)
- 16)???



The physiological response

- 1) high level of transpiration;
- 2) high stomatal conductance;
- 3) high water use efficiency;
- 4) high stability xylem water potential of plants (-1.5 MPa);
- 5) high level of net photosynthesis rate (till $13.5 \mu\text{MCO}_2/\text{m}^2 \text{ s}^{-1}$);
- 6) high variability of photosynthesis rate;
- 7) high daily productivity of photosynthesis at small dark and night respiration expenses;
- 8) high rate of photosynthesis in the initial stages of development of plants;
- 9) high level of deposition and re-assimilation of secondary substances;
- 10) high level growth inhibitors (ABA and phenol substances);
- 11)???

Global Carbon Stocks in Vegetation and Soils

Biome	Area (10 ⁶ km ²)	Global Carbon Stocks (Gt C)			NPP, t C ha ⁻¹ yr ⁻¹
		Vegetation	Soils	Total	
Tropical forest	17.6	212	216	428	11.0 (5.0-17.5)
Temperate forest	10.4	59	100	159	6.3 (2.0-12.5)
Boreal forest	13.7	88	471	559	4.0 (1.0-7.5)
Tropical savannas	22.5	66	264	330	4.5 (1.0-10.0)
Temperate grassland	12.5	9	295	304	3.0 (1.0-7.5)
Deserts & semideserts	30.0	8	191	199	0.05 (0.0-0.1)
Tundra	9.5	6	121	127	0.1 (0.0-0.4)
Wetlands	3.5	15	225	240	0.9 (0.1-3.9)
Croplands	16.0	3	128	131	1.6 (0.2-3.9)
Russuan forest	8.8	33	130	163	3.1 (2.6-3.7)
Yakutian forest	1.1	3	11	14	3.1
Yakutian tundra	0.4	0.1	6	6	0.8
Total	135.6	466	2011	2477	

Carbon pool of Yakutia, *G t C per year*

Plant carbon	2.2 -4.1
Soil carbon	17.1
Annual sequestration	0.28

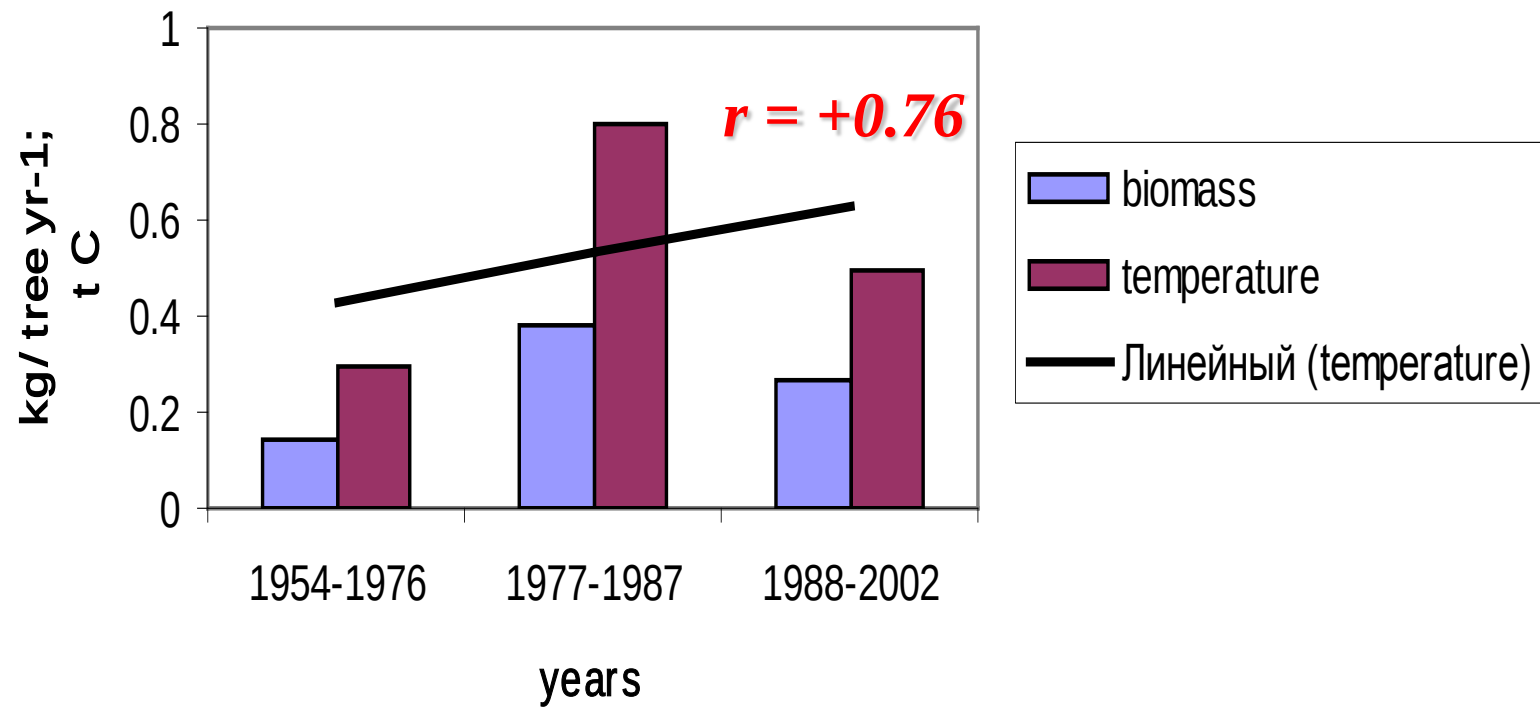
Including: Forest

Area	125.5 <i>M ha</i>
Plant carbon	2.2-4.5
Soil carbon	11.2
<i>Annual sequestration</i>	<i>0.25</i>

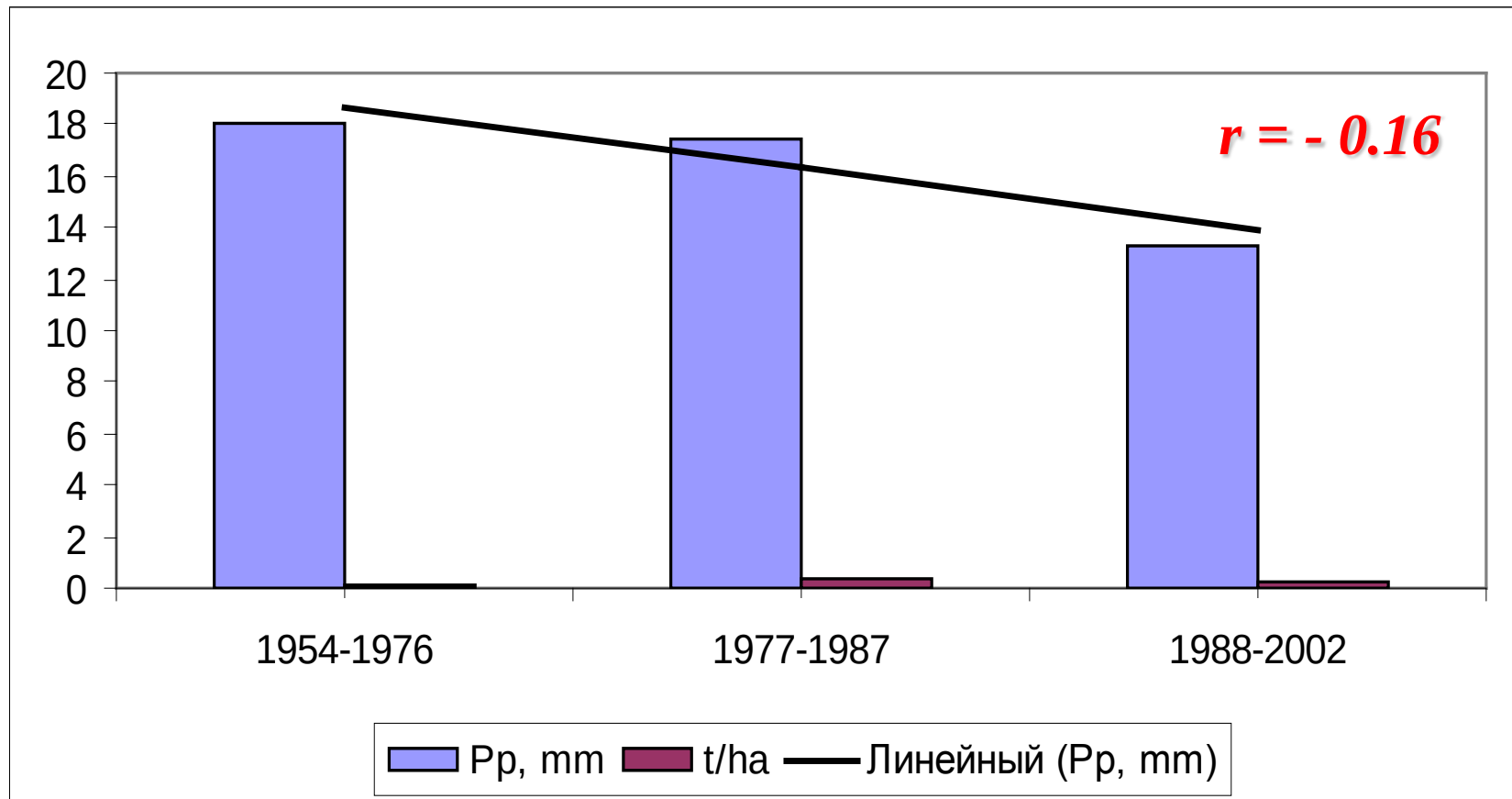
Tundra

Area	37 <i>Mha</i>
Plant carbon	0.053
Soil carbon	5.9
<i>Annual sequestration</i>	<i>0.03</i>

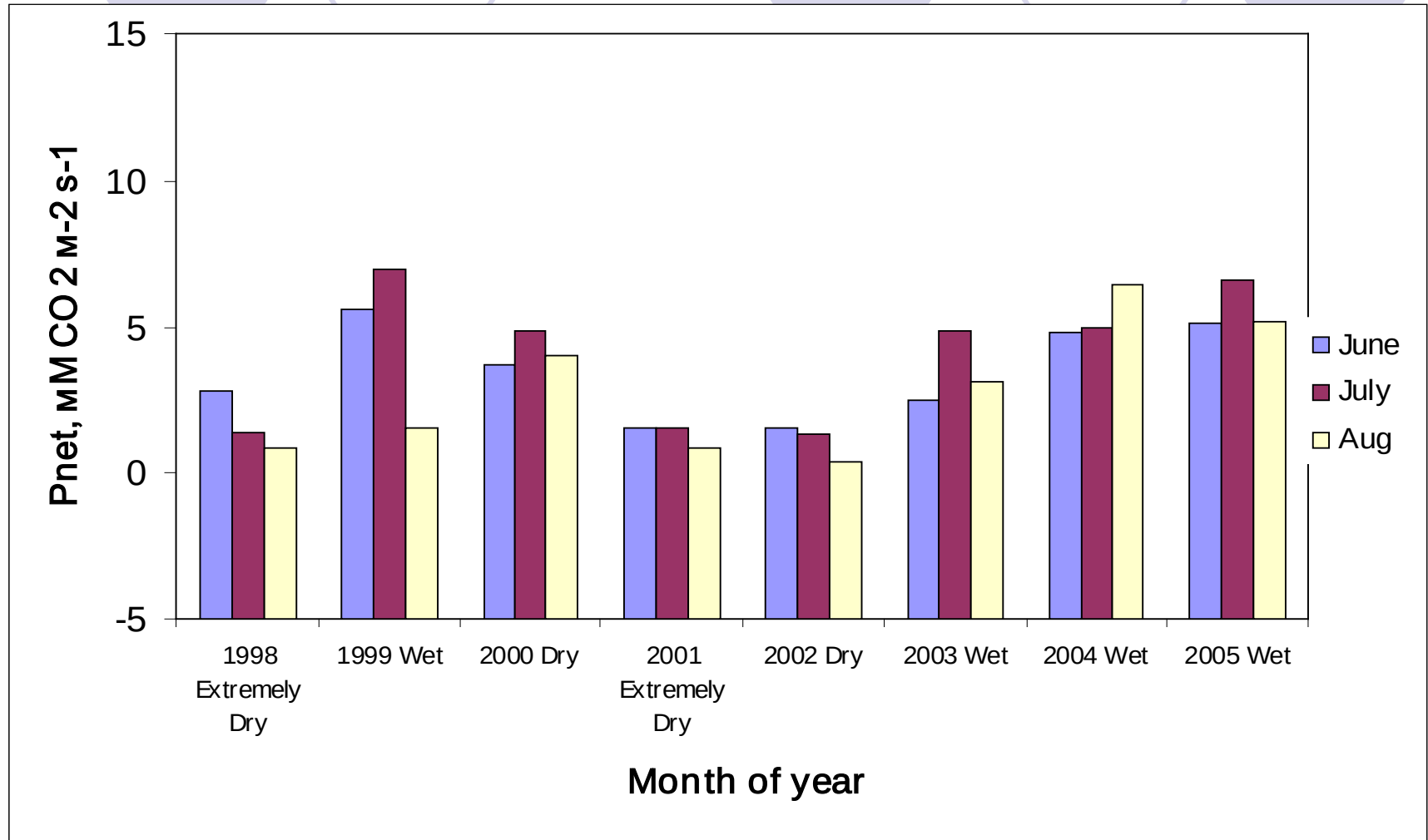
Long term annual growths of *Larix cajanderi* crown biomass and atmospheric temperatures. Spasskaya Pad, 1954-2002



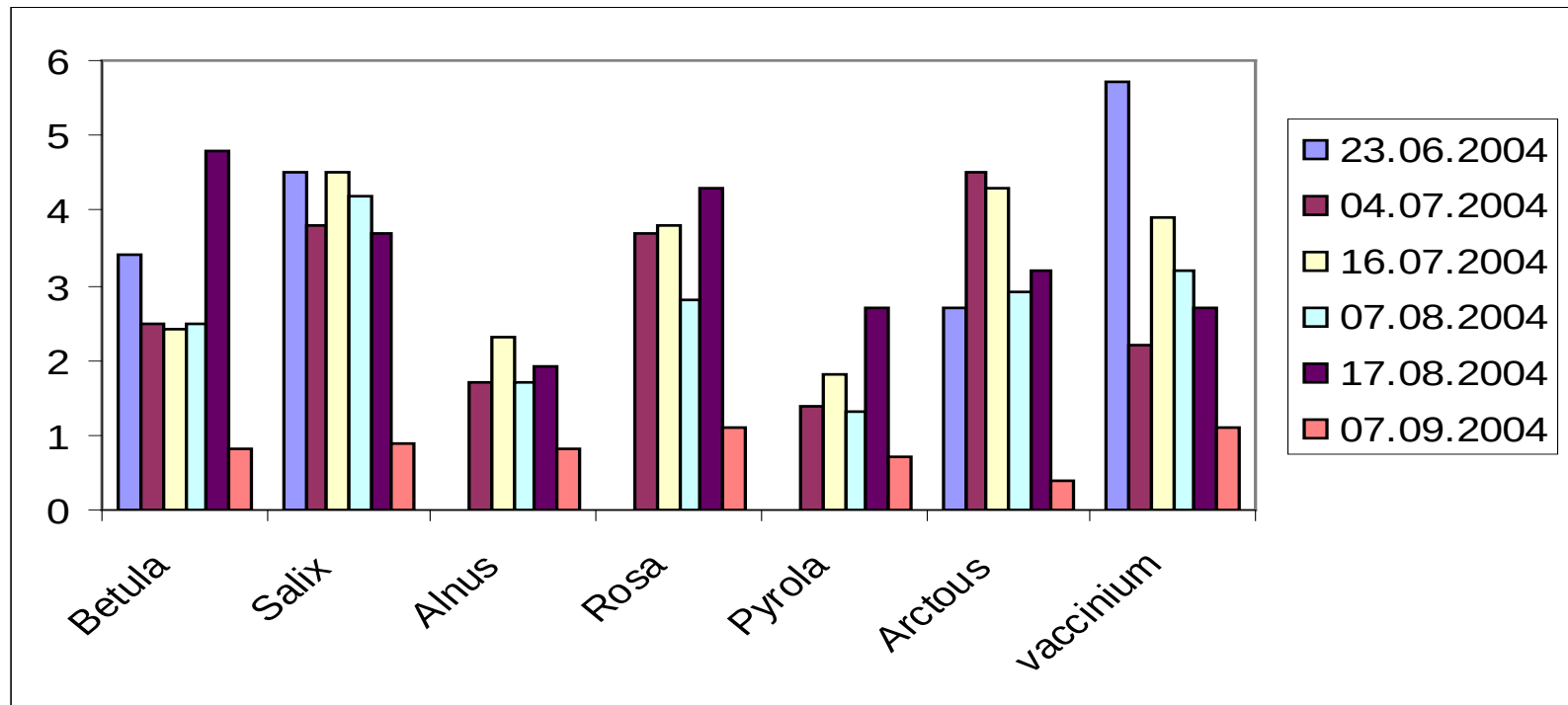
Long term annual growths of *Larix cajanderi* crown biomass and atmospheric precipitation. Spasskaya Pad, 1954-2002



Seasonal changes of net-photosynthesis in *Larix cajanderi*, 1998-2006

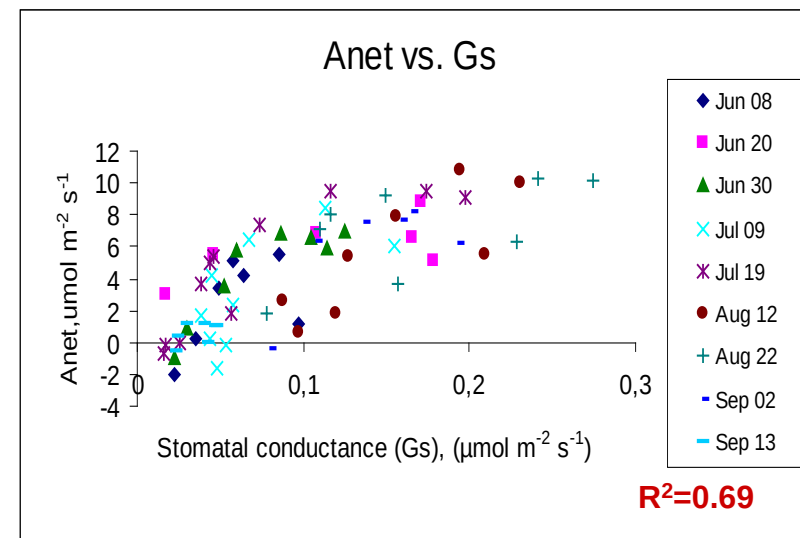
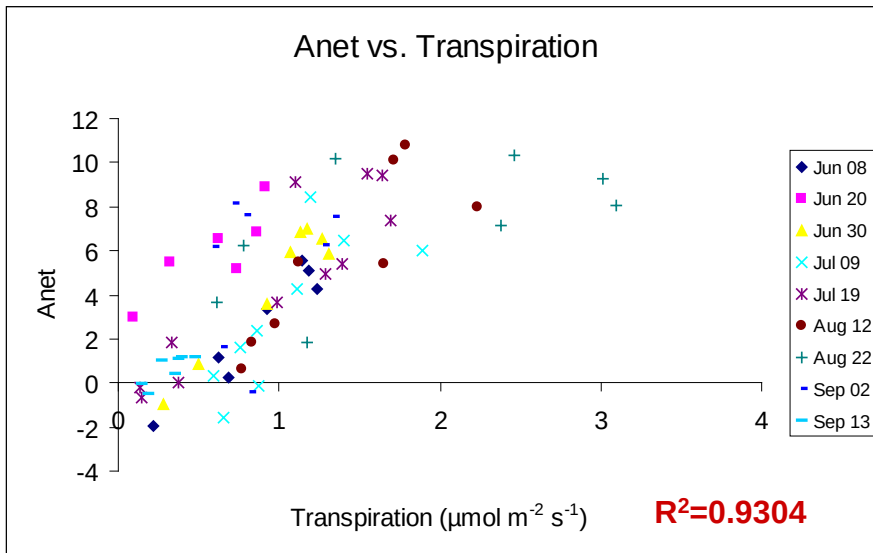
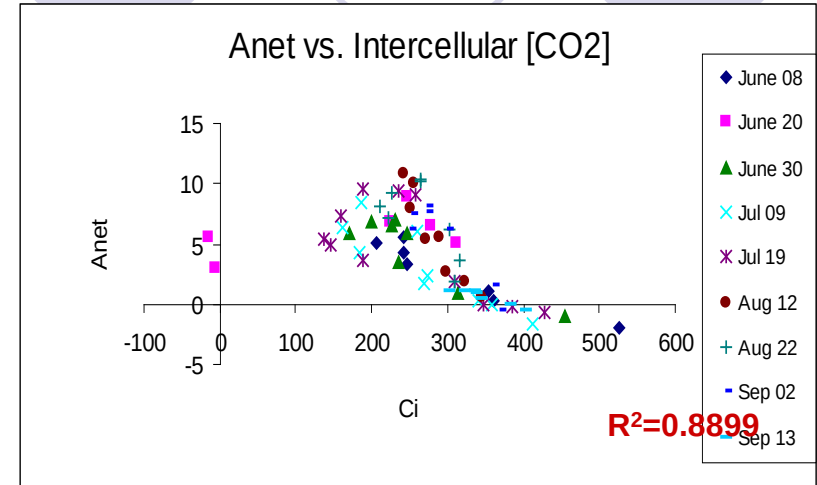
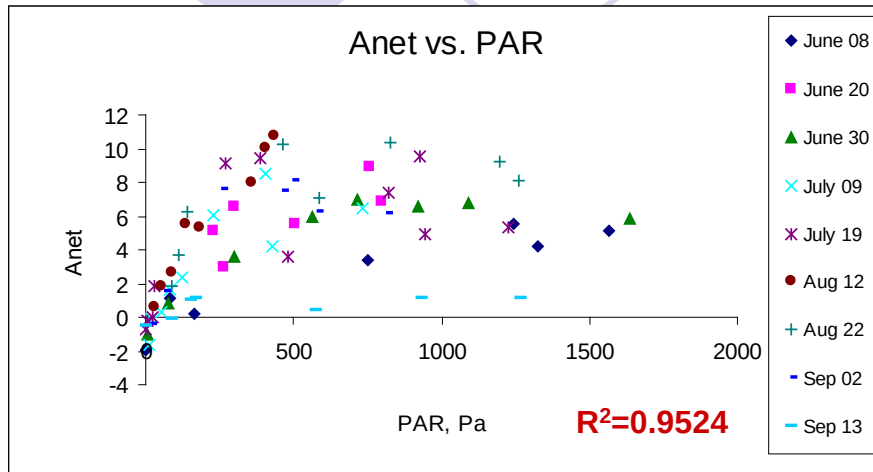


Mean Photosynthesis rate of understorey and floor vegetations, Larix forest, Wet 2004 (n=9)

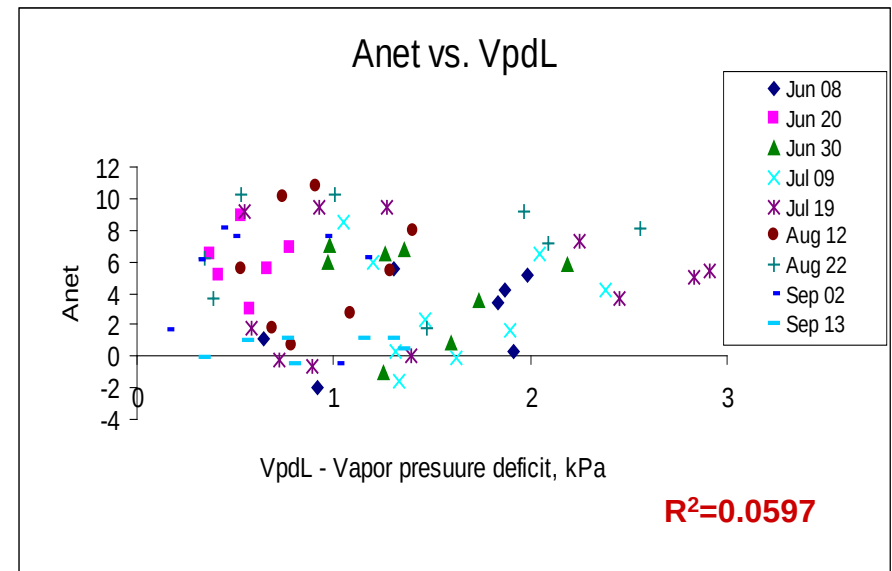
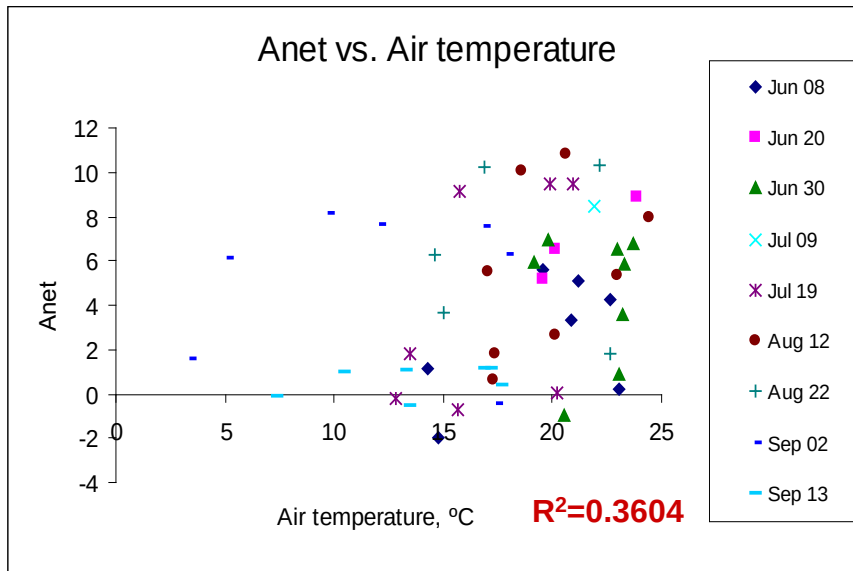


Photosynthesis of Larch	5.2 t C/ha season-1	
Photosynthesis of understorey and floor	3.0	
For the larch ecosystem	4.1	
Photosynthesis for ecosystem	8.2	[100%]
Larch	5.2	63
Canopy	3.0	37

Exogenic and endogenic factors dependency of Larch photosynthesis



Exogenic and endogenic factors dependency of Larch photosynthesis



Maximum values of carboxylation (Vc max) and electron transport (J max) for some tree species

Ecosystem	Vcmax ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)	Jmax ($\mu\text{mol E}_{\text{hv}} \text{ m}^{-2} \text{ s}^{-1}$)	References
Larix gmelinii	45.1	44.5	Korzukhin et al., 2004
Conifer boreal forest	46	123	Baldocchi D.D. Mayers T. 1998
Sparse conifer forest	40	80	Warnant P. и др. 1994
Pinus sylvestris	37,5-117	71-307	Korzukhin et al., 2004
Larix cajanderi	39.9	93.7	Our studies

Monthly and seasonal carbon emission from larch forest soils, t C · ha⁻¹

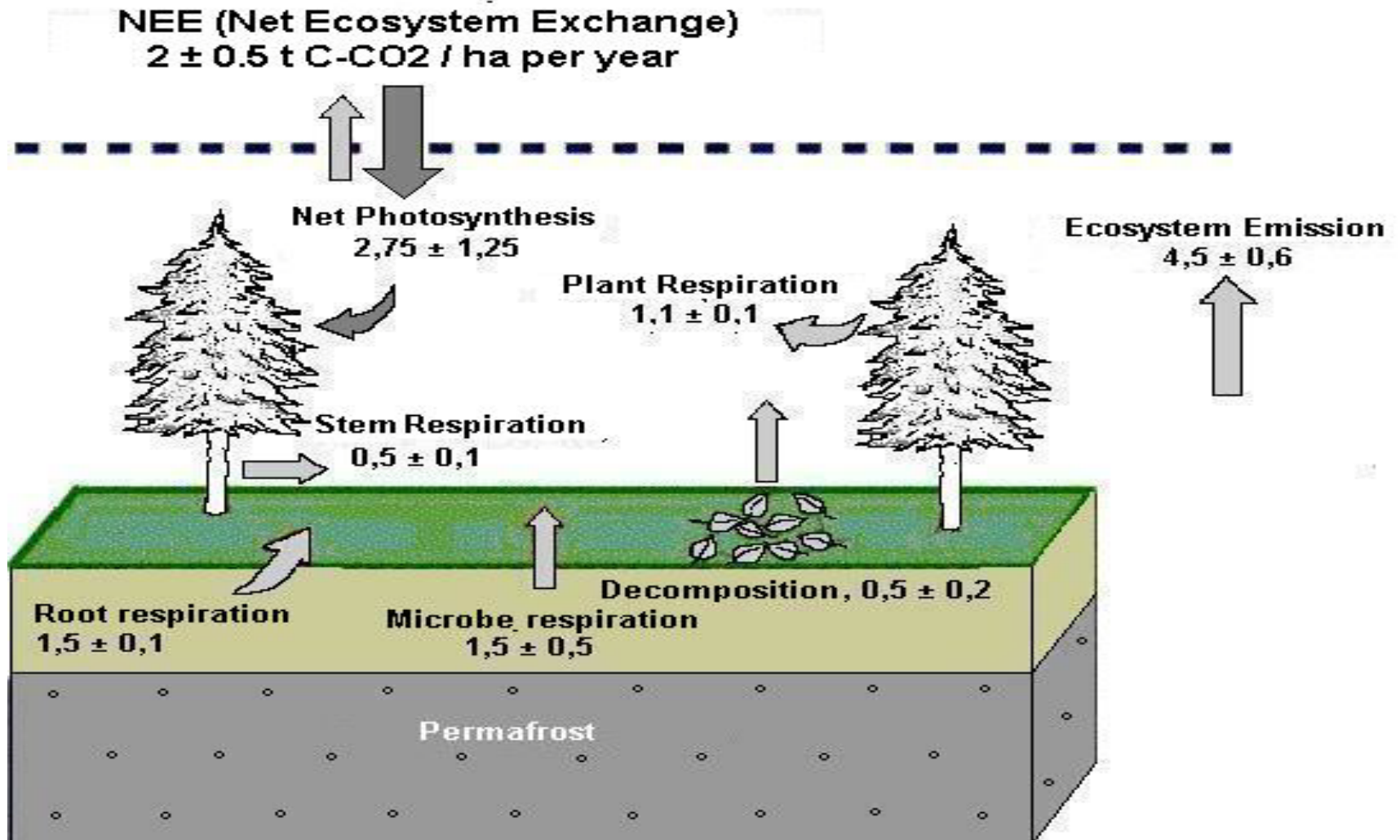
Year	May	Jun	Jul	Aug	Sep	Seasonal sum, t C·ha ⁻¹ ± standard deviation
2001	–	–	$\frac{1,43}{39,5}$	$\frac{1,06}{29,3}$	$\frac{0,26}{7,2}$	3,68±0,08
2004	$\frac{0,41}{12,4}$	$\frac{0,58}{17,4}$	$\frac{0,78}{23,4}$	$\frac{1,13}{33,9}$	$\frac{0,43}{12,9}$	3,23±0,21
2005	$\frac{0,33}{6,71}$	$\frac{0,77}{15,7}$	$\frac{1,56}{31,8}$	$\frac{1,53}{31,2}$	$\frac{0,72}{14,7}$	4,82±0,12
2006	–	$\frac{1,01}{17,3}$	$\frac{2,15}{36,9}$	$\frac{1,84}{31,6}$	$\frac{0,49}{8,4}$	5,56±0,37

Numerator – flux, t C ha⁻¹, denominator – percentage from seasonal cumulative sum

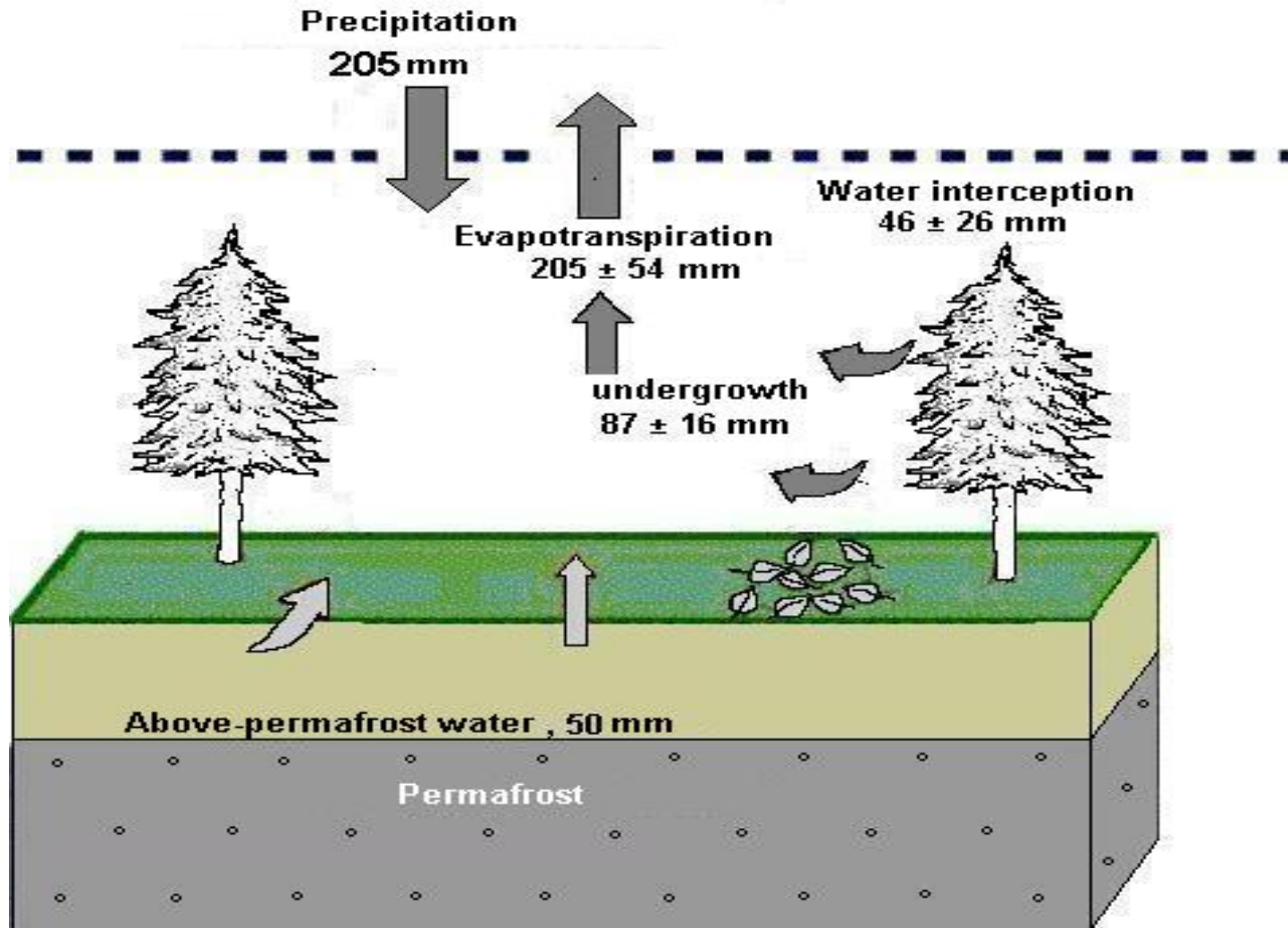
Mean Daily Soil Respiration rate for growing season in different soil climatic zone of Russia

● Zone	$g\ C / m^2\ day^{-1}$
● North Taiga	0.47 - 2.10
● Middle Taiga	0.65 – 2.67
● South Taiga	0.60 – 4.29
● Forest steppe	0.56 – 3.34
● Steppe	0.48 – 2.96
● Permafrost Forest*	2.73 – 3.87
● *our study	

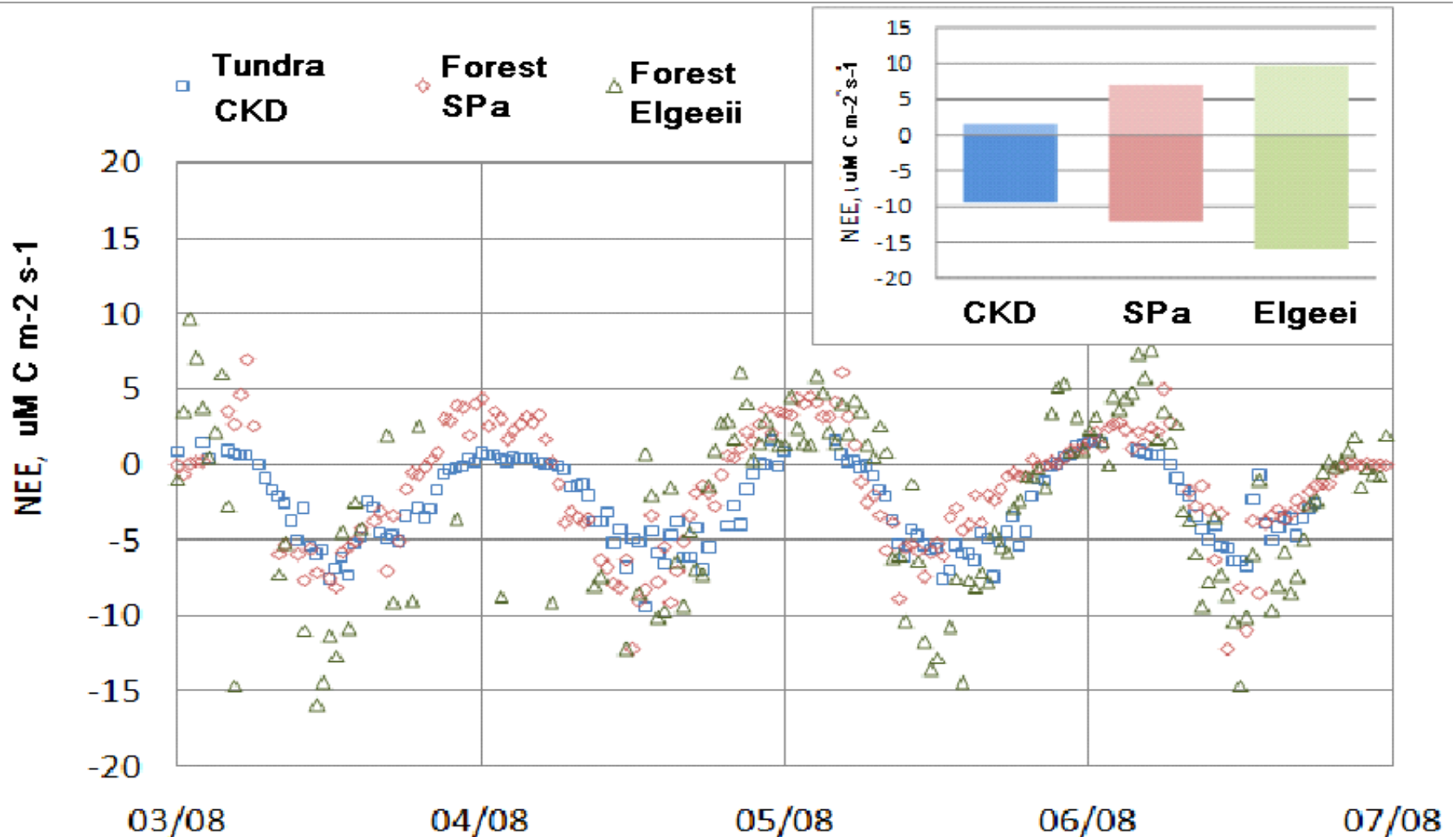
Annual carbon budget of permafrost forest ecosystems, $t\ C/ha\ per\ year$



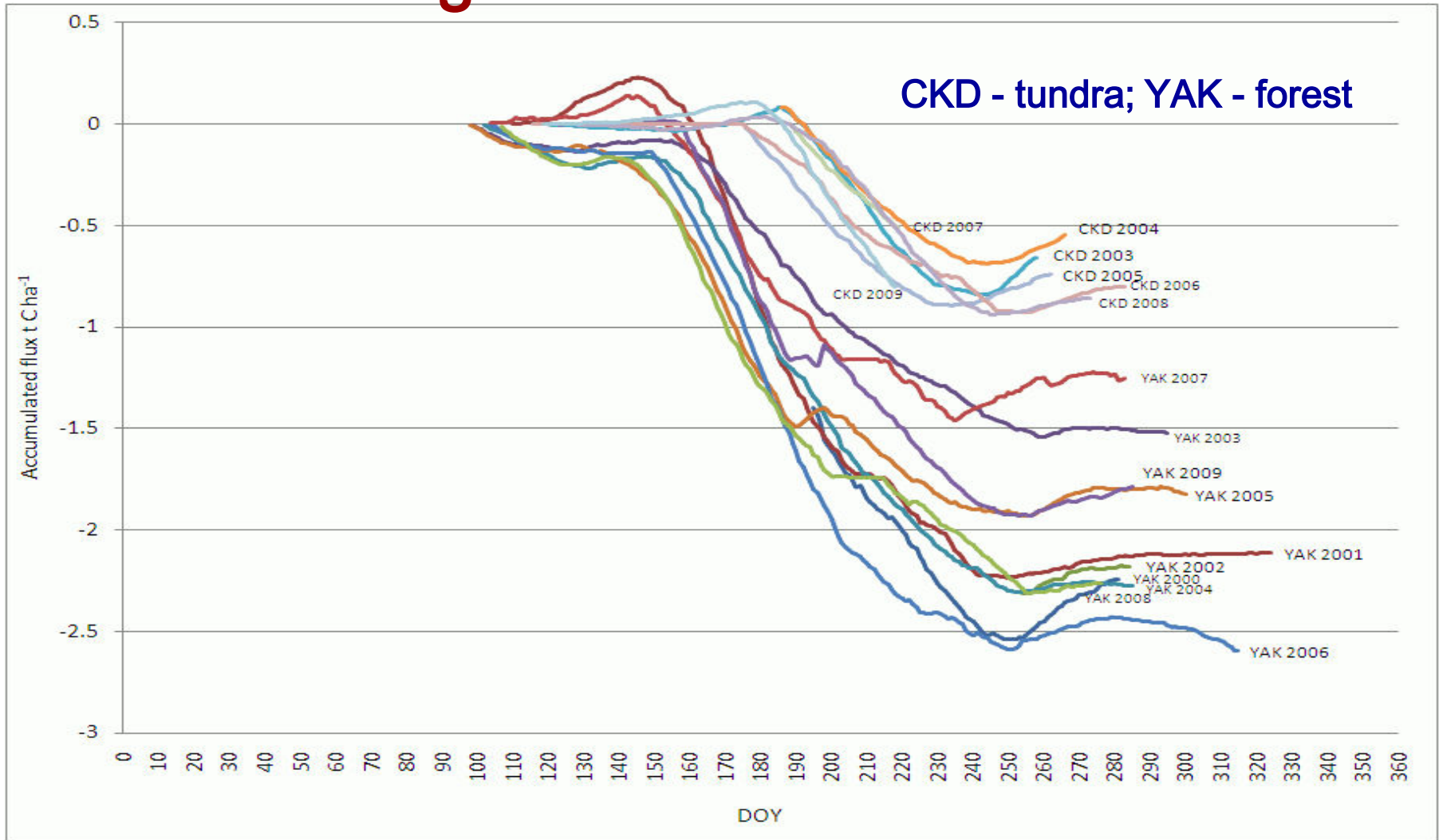
Annual water budget for permafrost forests, *mm per year*



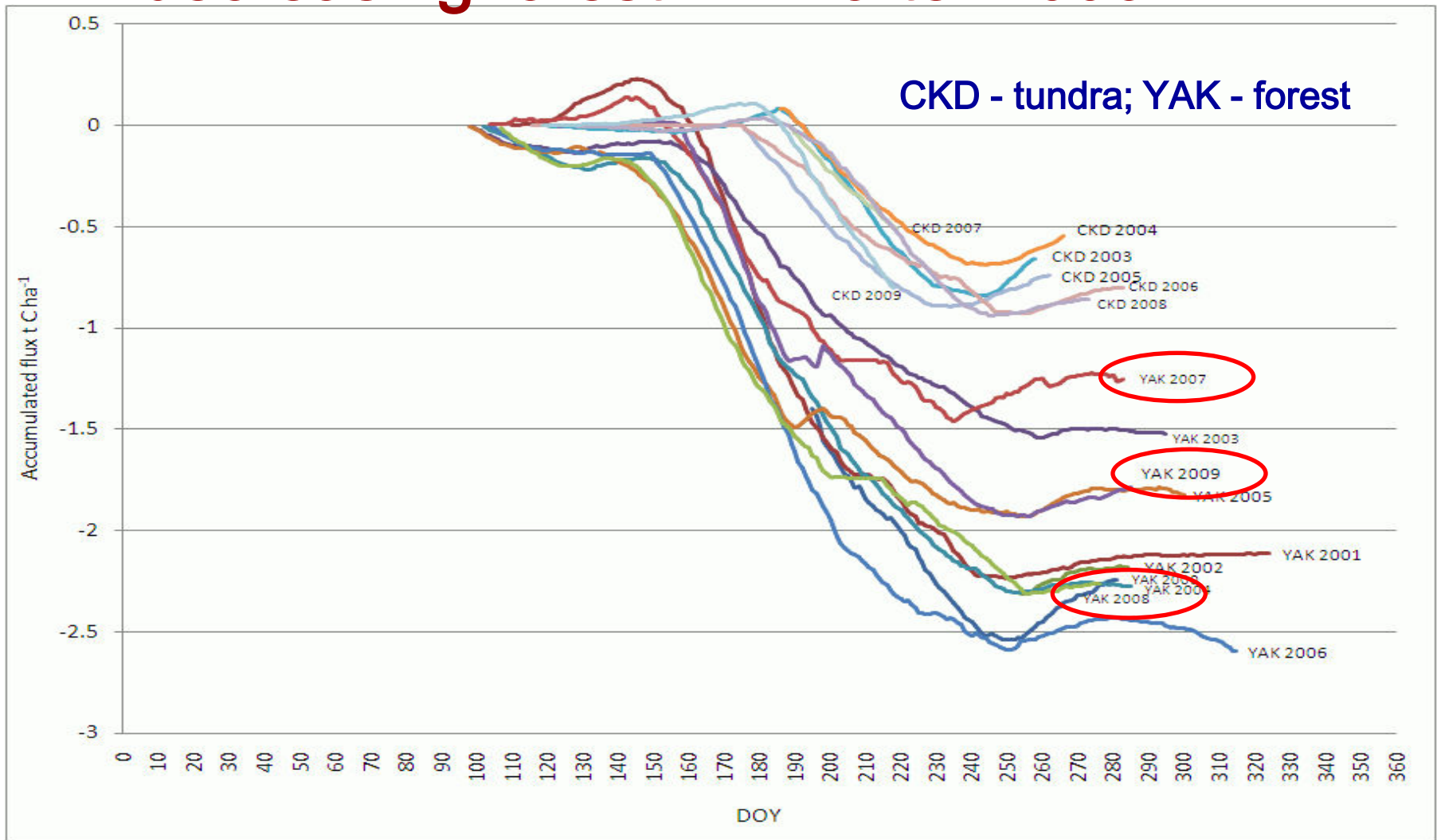
Carbon fluxes comparison between three permafrost-dominated ecosystems



Comparison of carbon sequestration by forest and tundra ecosystems and decreasing forest NEE after 2006



Comparison of carbon sequestration by forest and tundra ecosystems and decreasing forest NEE after 2006





The reasons are,

1. Changing in diversity of vegetations (new successions) during melting of permafrost (subshrubs  grasses)
2. Physiological peculiarity due to plant potential possibility
3. Low rate of decomposition – small nutrients and low fertilization



Summary taiga

- Taiga is an on-off system
- Strong control of humidity
- Relative high rates of NEE in short growing season
- 3 months activity
- Annual uptake 2.0 ton Cha^{-1} (± 0.5)
- June highest uptake



Summary tundra

- Only 50% annual uptake of taiga
- Largest uncertainty in beginning and end (respiration bulge)
- 2 months activity
- How is the lateral exchange through the hydrology?
- How spatially variable is the flux

Annual Siberia Larch carbon budget, *G t C per year*

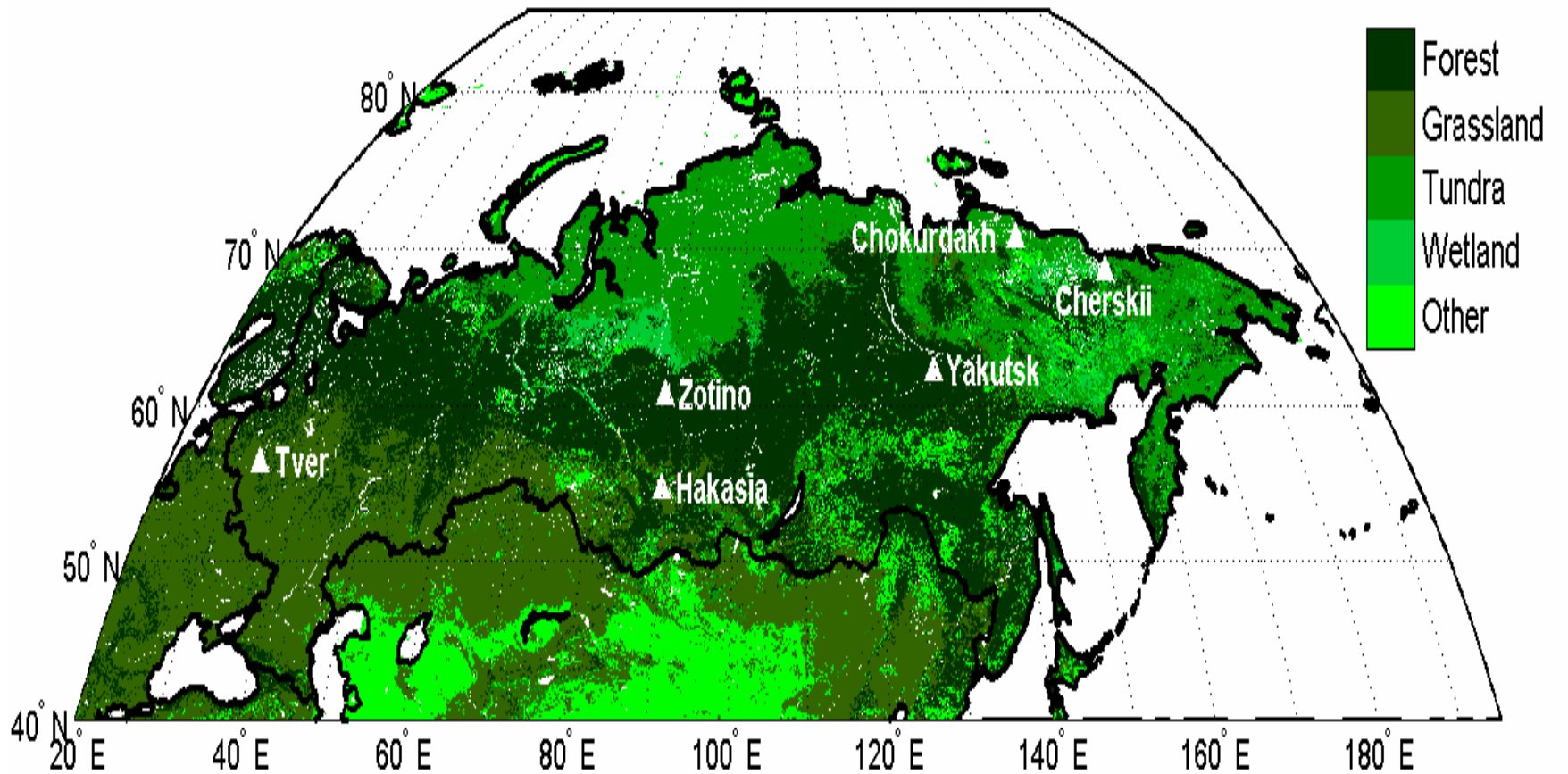
● Uptake by Vegetation		
Siberia*	1.3	[100%]
Siberian Larch	0.4-1.0	54
Yakutian Larch	0.2-0.4	23
● Emission		
Russian soils**	2.6-3.0	[100%]
Siberian Larch	0.8-0.9	27
Yakutian Larch	0.4	12
● NEE Flux		
Russia**	0.82	[100%]
Siberian Larch	0.45	55
Yakutian Larch	0.18	22

* - Schimel et al., 2001; Goodale et al., 2002.

** - Kudeyarov, 2003.

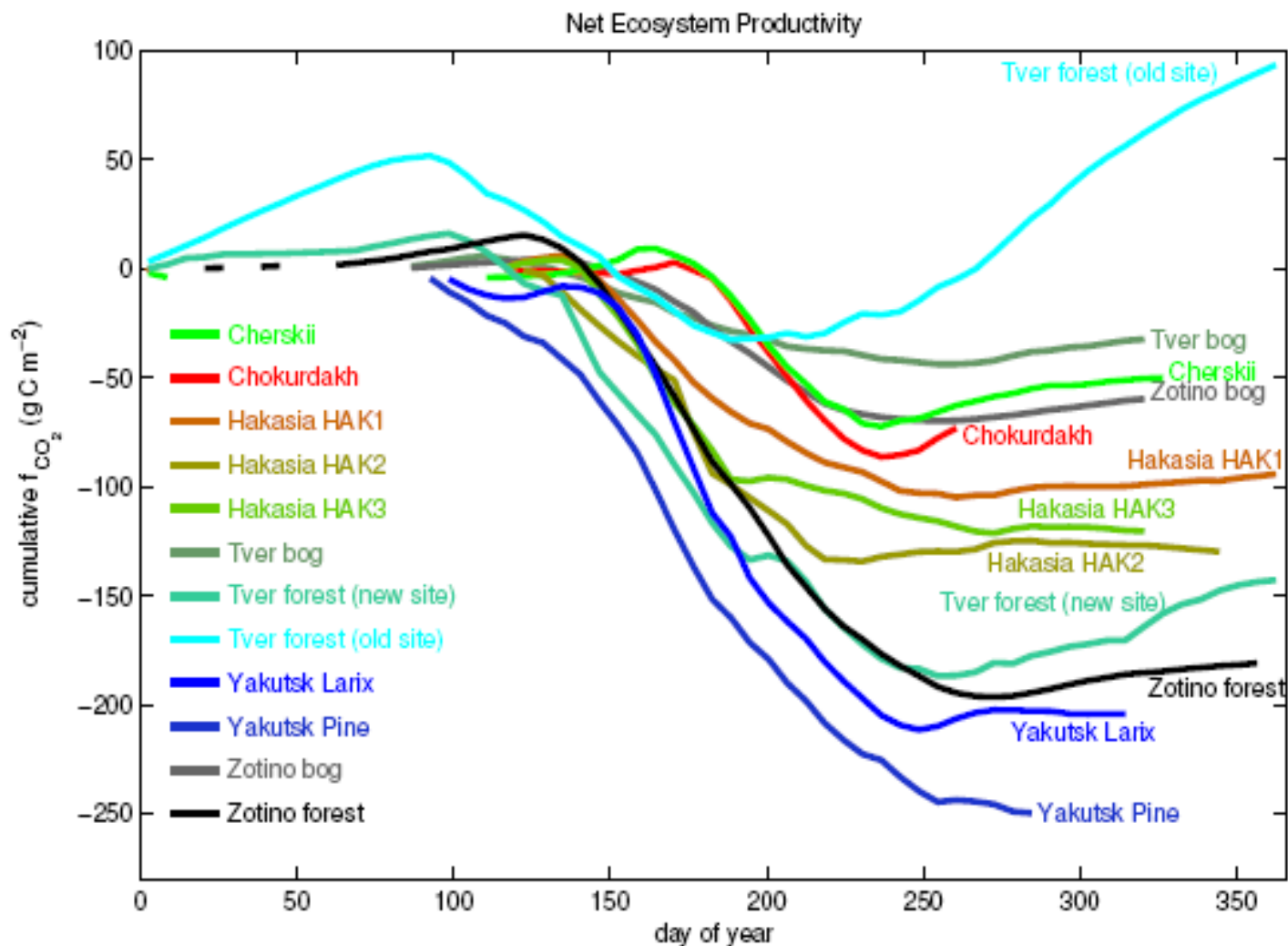
Without marks- Maximov et al.,2005

Land cover map of the Russian Federation and measurement sites



The multi-annual net NEP derived from EC measurement at the 12 sites in Russia

The data are u-corrected and gap-filled



Van der Molen et al, 2006

Annual carbon fluxes in representative biomes of Russian Federation

47 annual dataset from 12 stations on the frame Project TCOS-Siberia (EU-10) and JST CREST (Japan) *www: michiel.van.der.molen@falw.vu.nl*

land cover type	annual flux $\text{g C m}^{-2} \text{ yr}^{-1}$	area 10^{12} m^2	%	annual land cover flux $10^{12} \text{ g C yr}^{-1}$
wetlands	-54 ± 66	4.4	25.9%	-236 ± 338
grasslands	-115 ± 66	2.7	15.7 %	-310 ± 198
Tver forest oldsite	94 ± 66	1.7	49.1%	158 ± 162
forests	-194 ± 66	6.7		-1306 ± 589
other	-104 ± 66	1.6	9.2%	-166 ± 114
total		17.1		-1861 ± 1401

Our estimate of $1.9 \text{ G t C per year}$ or 24% of global emission due to fossil fuel burning (6 G t C per year) and deforestation (2 G t), forest fire (0.19 G t) and river transport (0.020 G t)

Annual budget of carbon of Russian Federation, *GtC per year*

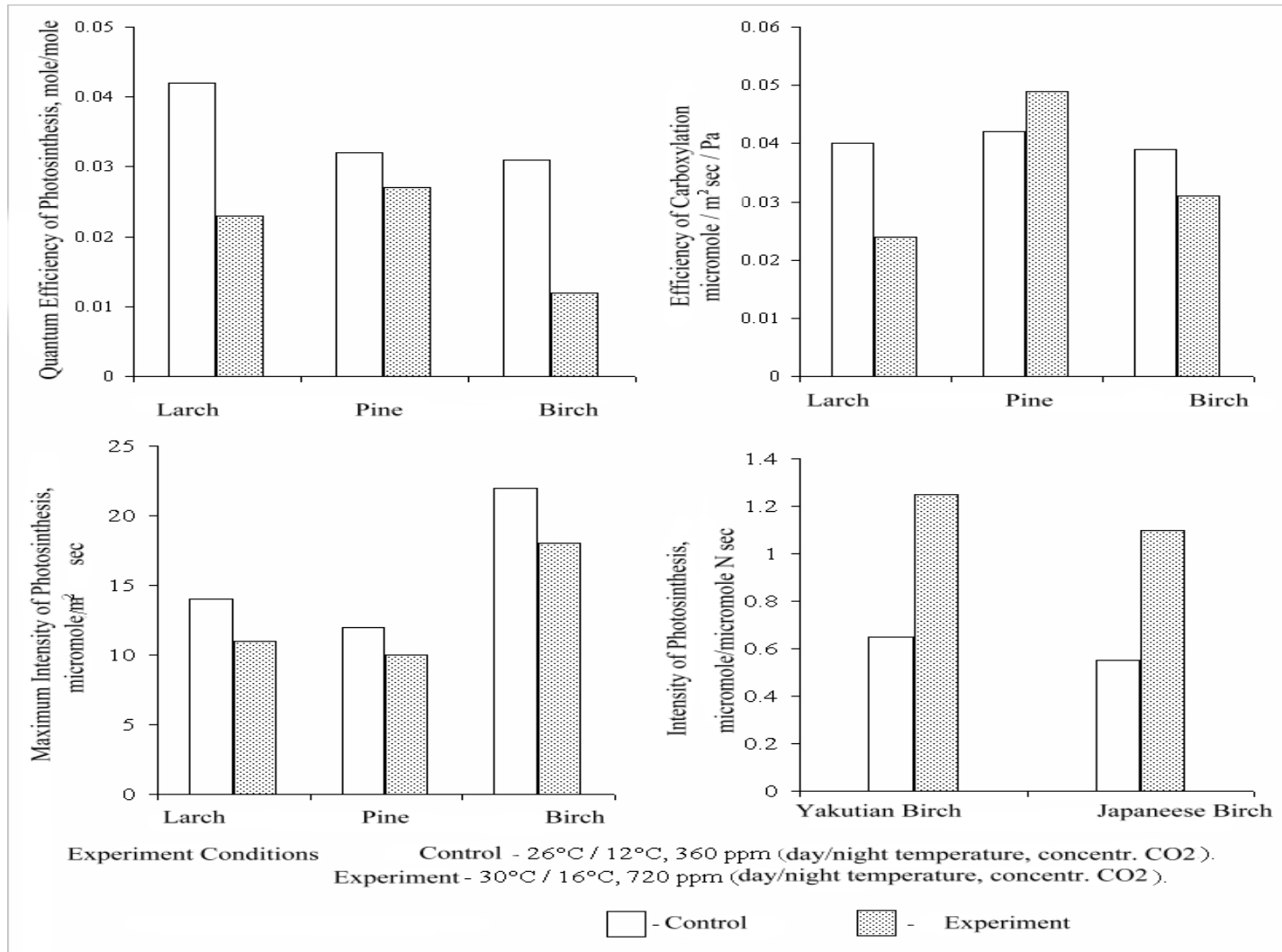
	Method	Value
<i>Schimel et al., 2001</i>	Model	1.3
<i>Goodale et al., 2002</i>	Model	1.3
<i>Kudeyarov, 2007</i>	Istrum	1.0
<i>Shvidenko ,Nilsson, 2003</i>	Model	0.5
<i>Isaev et al., 2005</i>	Model	0.3



The climate warming is sure to cause

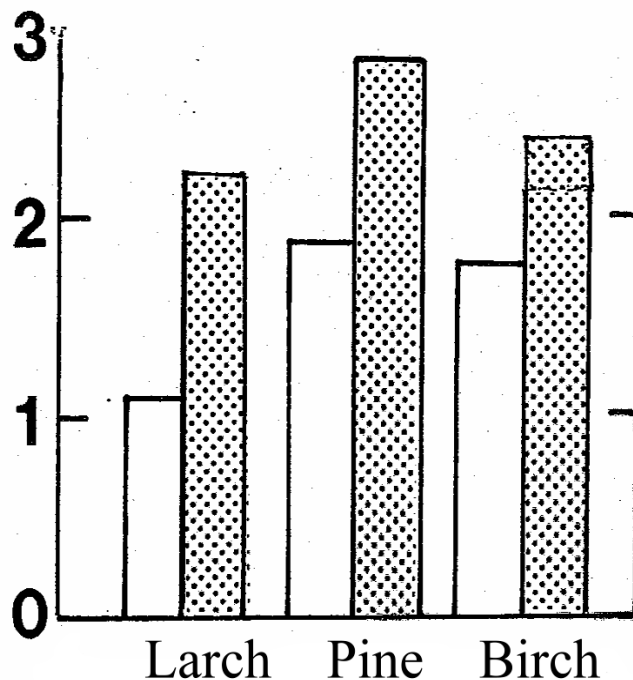
- release of large quantity of nitrogen and carbon resulting from activity of soil microorganisms
- there is a danger that a part of humus and turf horizons rich in organogens may be buried into low layers of the soil profile
- melting of permafrost will cause the wide spread of pedoturbations and mixture of soil mass (Karpachevsky, 1993).
- it may lead to conservation of organic substance and make the main organoges (nitrogen and carbon) come out of the total cycle

Physiological response of coniferous and deciduous species of Yakutia on temperature rise and doubling of CO₂ concentration in the atmosphere

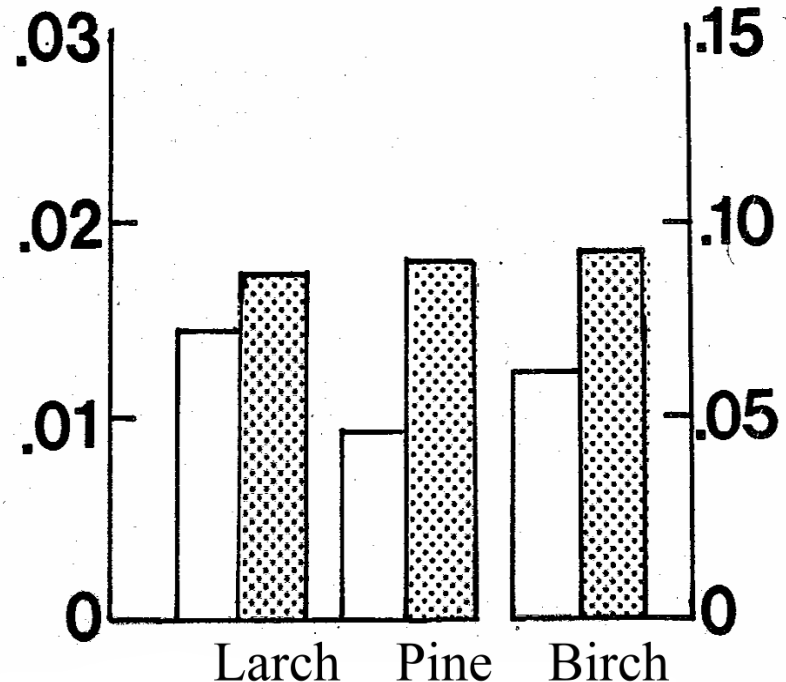


Dependence of activity of the leaf in the process of photosynthesis upon water and nitrogen content

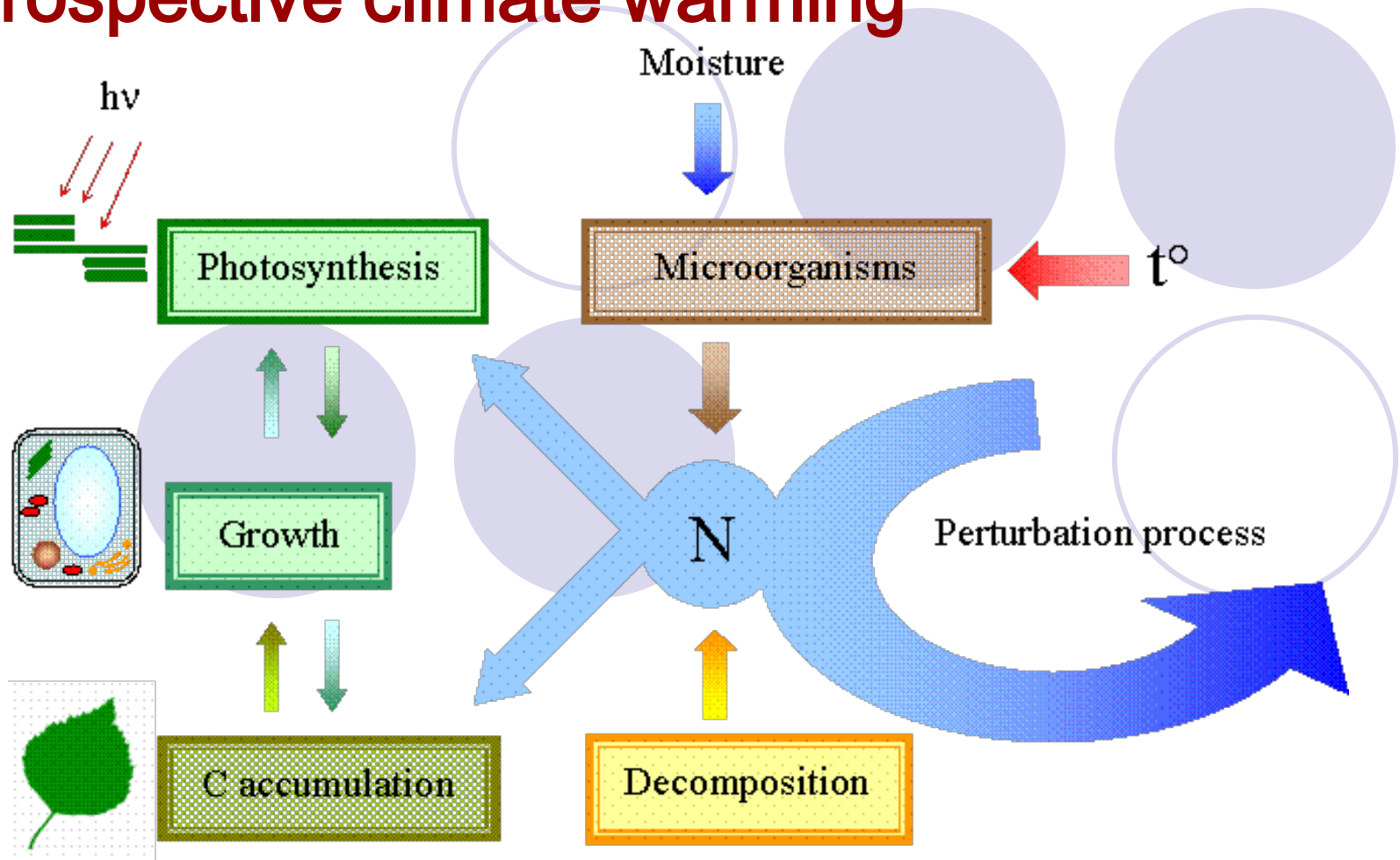
Efficiency of Water Use
micromole / millimole

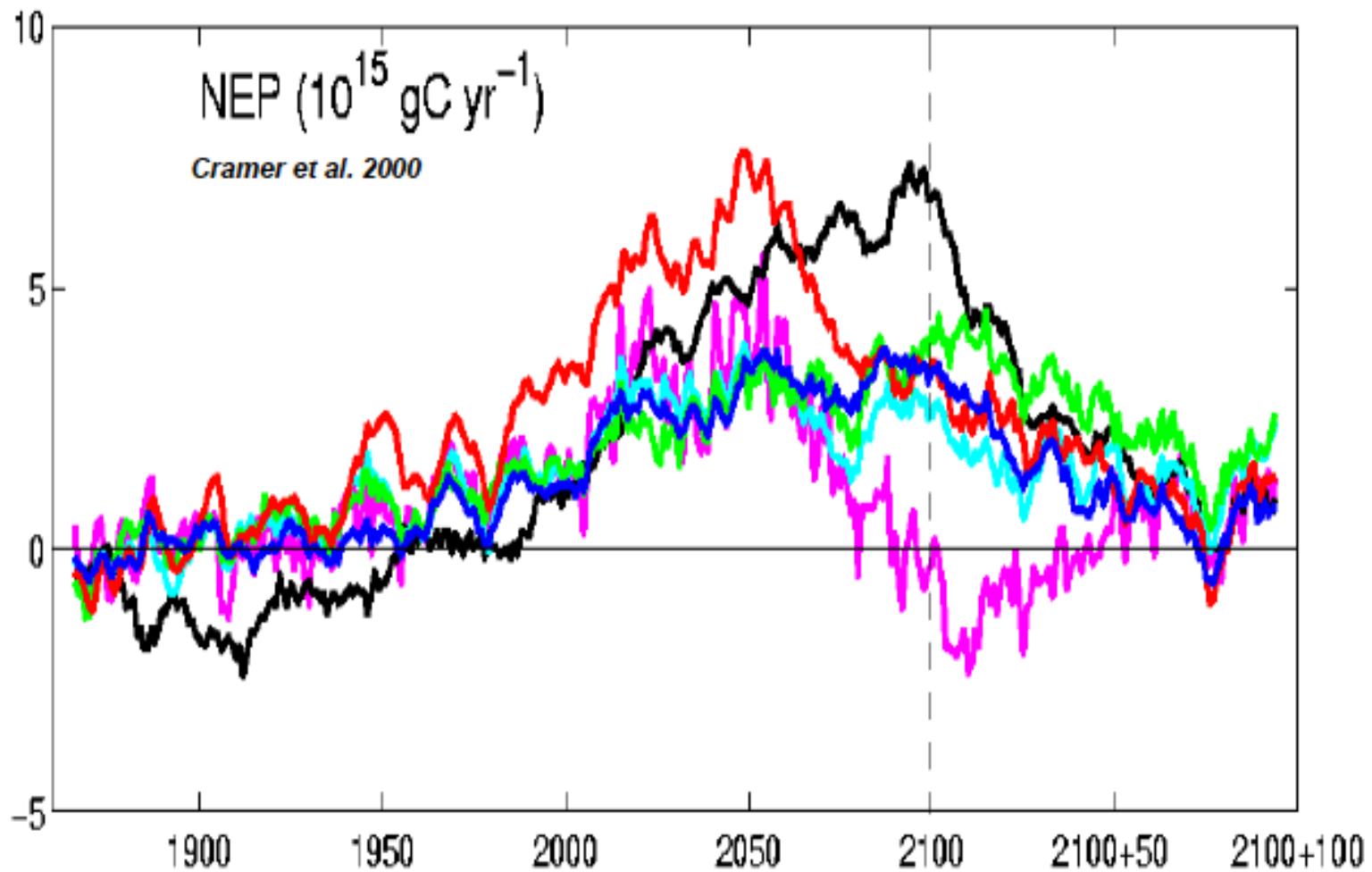


Efficiency of Nitrogen Use
micromole, millimole / N sec



Scheme of supposed physiological response of woody plants of cryolithozone on prospective climate warming



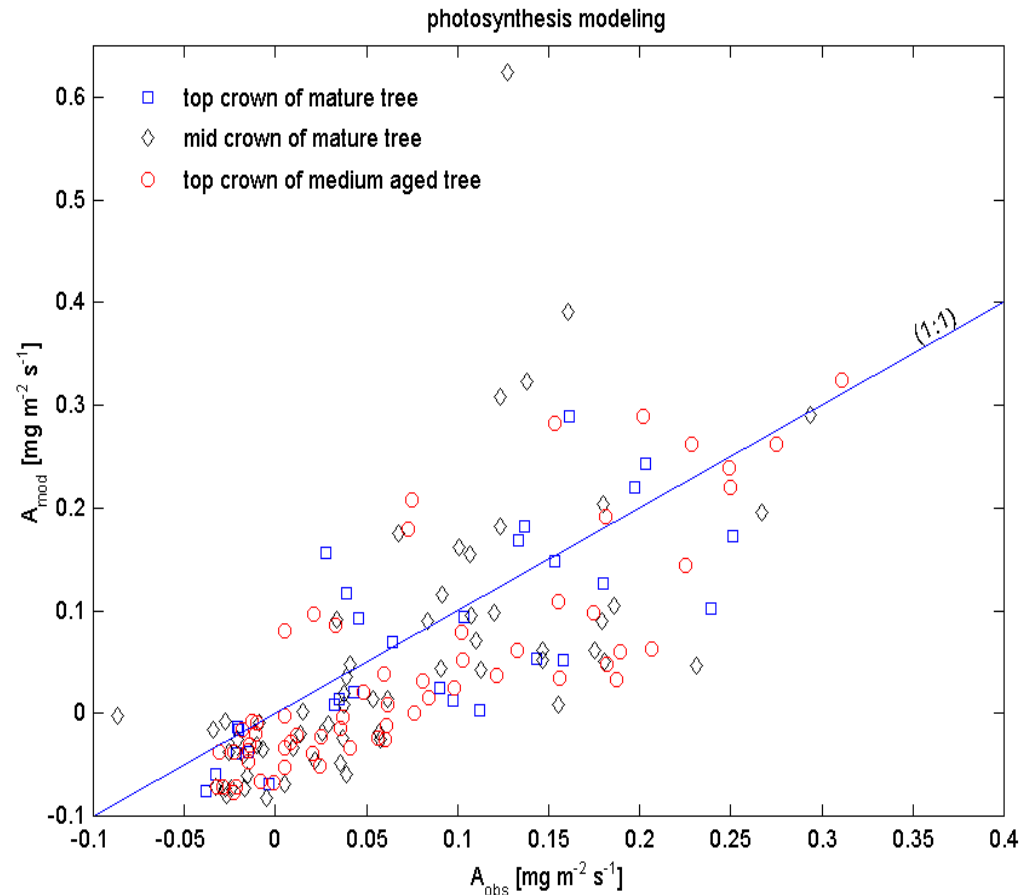


Net Ecosystem Production in various prediction models

Modeling Photosynthesis Spasskaya Pad, Yakutsk

$$g_s = g_{s,\min} + \frac{aAh_c}{C_s}$$

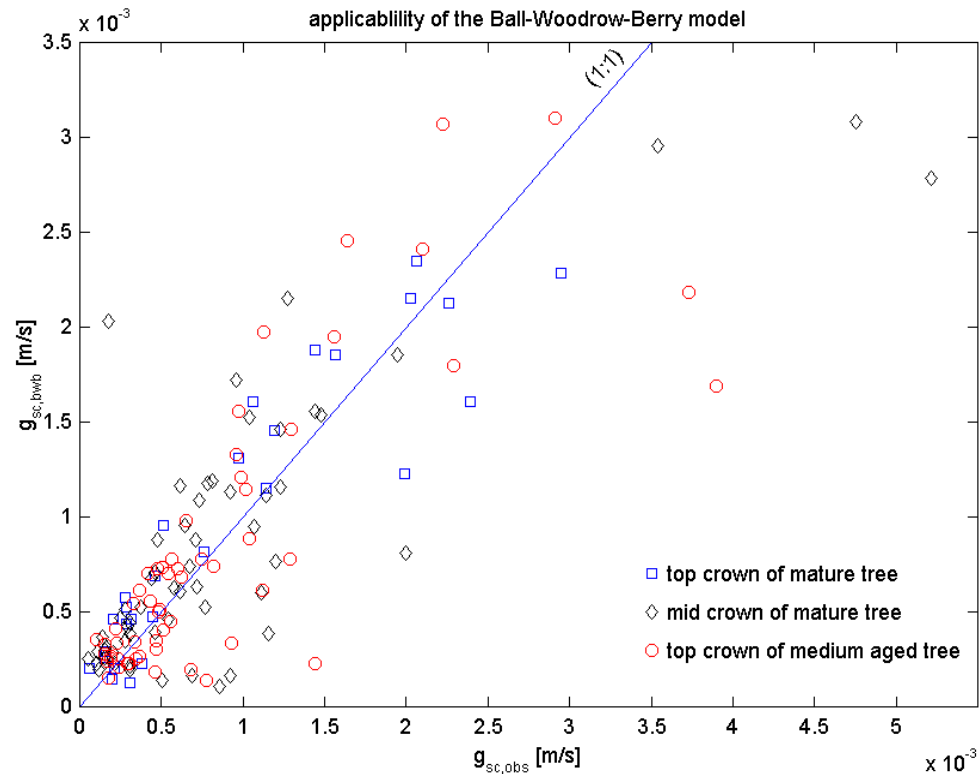
Modeling the
photosynthesis rate
using Ball- Woodrow
Berry - g_s in
combination with a
biochemical model



Modeling Stomatal Conductance Spasskaya Pad

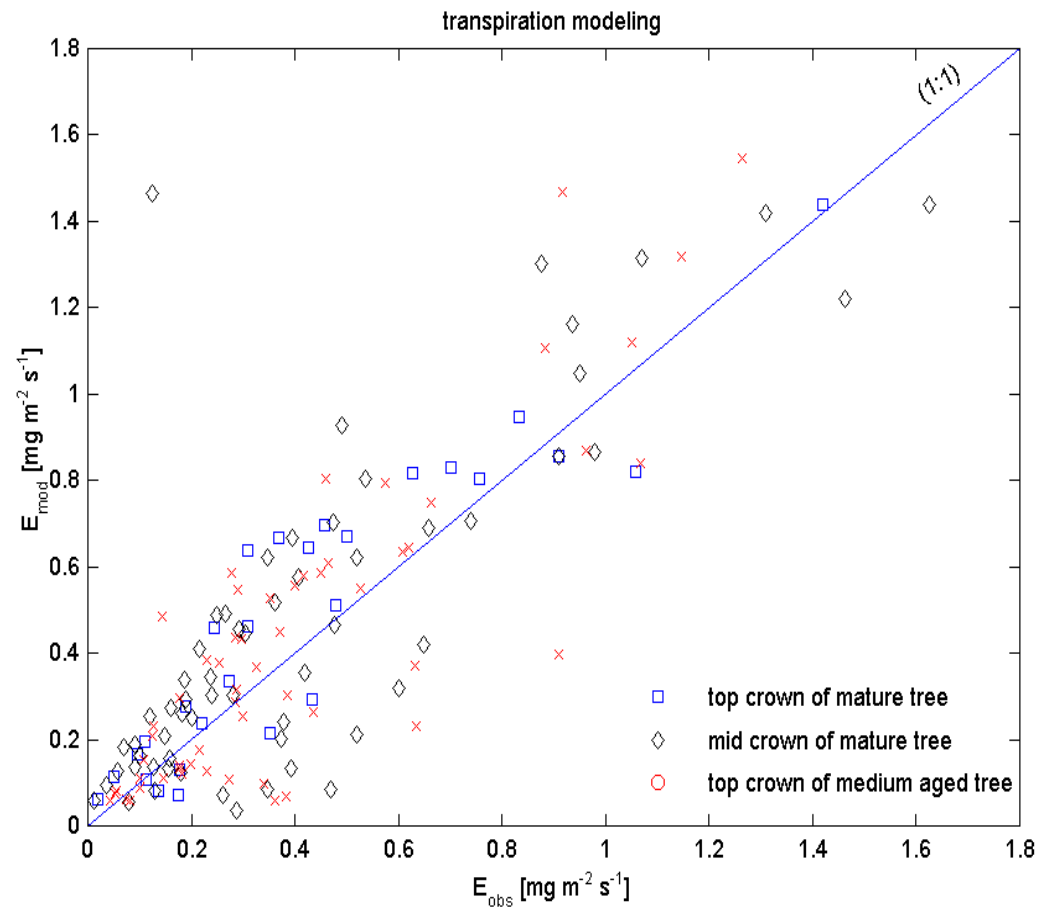
$$g_s = g_{s,\min} + \frac{aAh_c}{C_s}$$

**Ball- Woodrow-
Berry stomatal
conductance
model works well
for all vegetation
levels**



Modeling transpiration Spasskaya Pad

Modeling the
transpiration rate
using BWB- g_s in
combination with
VPD



Simple modeling

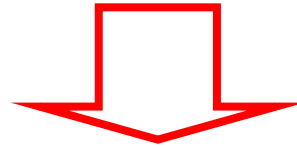
Empirical formulas reflecting dependencies of soil respiration both on soil temperature and moisture

$$2001: \quad F_s = 0.32 T + 0.29 \eta - 3.02 \quad [1]$$

$$2004: \quad F_s = 0.32 T + 0.08 \eta - 0,74 \quad [2]$$

$$2005: \quad F_s = 0.62 T + 0.19 \eta - 4,30 \quad [3]$$

$$2006: \quad F_s = 0.67 T - 0.01 \eta - 0,79 \quad [4]$$



Dry years:

$$F_s = 0,32 T + 0,185 \eta - 1,88 \quad [5]$$

Wet years:

$$F_s = 0,645 T + 0,1 \eta - 2,545 \quad [6]$$

Comparison estimation 3-6%.

Спасибо
за внимание !

