WESTERN-SIBERIAN PEATLANDS AS INDICATOR AND REGULATOR OF CLIMATIC CHANGES

S. Kirpotin

Tomsk State University, Tomsk, Russia

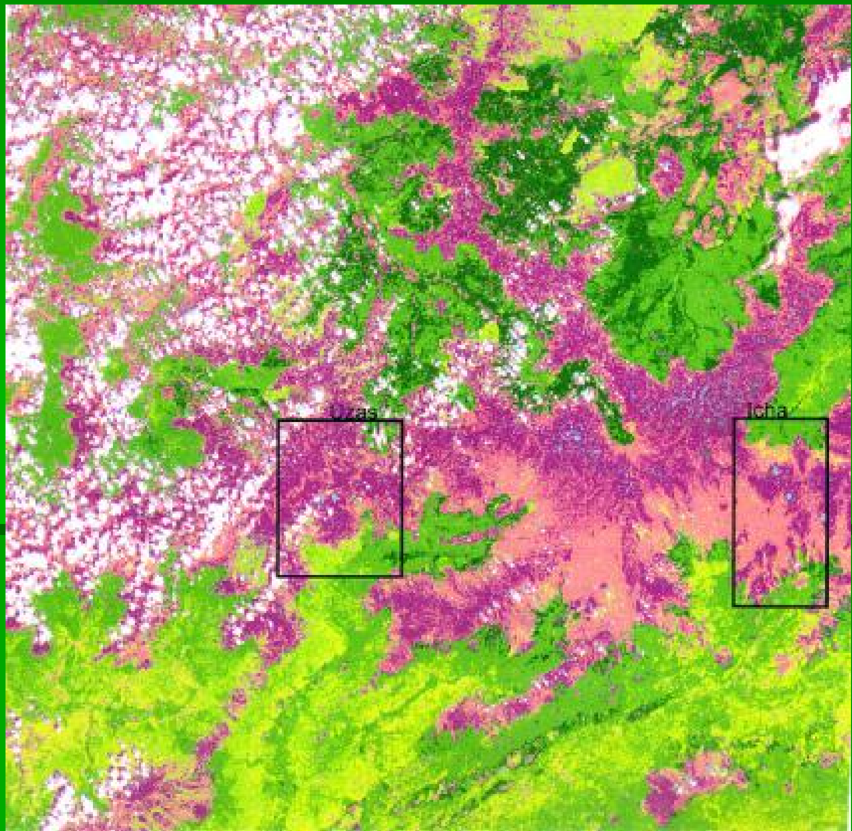
e-mail: kirp@ums.tsu.ru; phone: +7 3822 529644

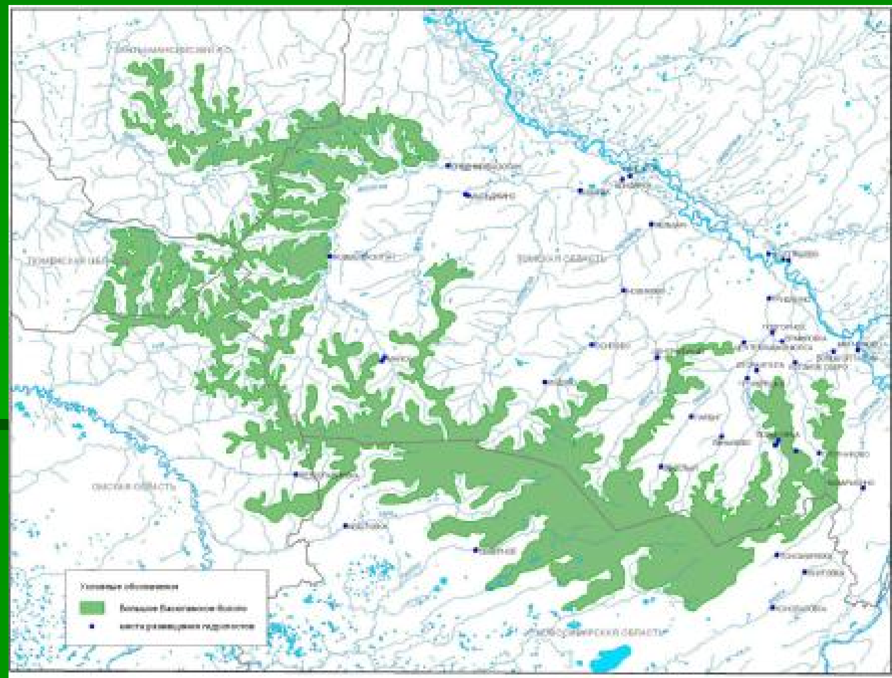
ENVIROMIS-2008

Tomsk Russia

Western Siberia is a unique bog region in the World. About 104 Mha of Russian peatlands are located in Western Siberia, which consists almost completely of pristine peatland ecosystems (photographer S. Kirpotin).

The biggest at the World – Great Vasiugan Mire (total area – 6.78 million hectare [Vaganov etc., 2005] is situated its territory. This unique mire representing the object of a nature of the world value, comparable on the importance and a rank with the lake Baikal. Stocks of peat deposited by this largest bog pool in recalculation on absolutely dry organic substance make almost 18 billion т, and it is not a lot of a little - 16,5 % of stocks of peat of all Western Siberia [Vaganov etc., 2005].





Siberian peatlands have been a major sink of atmospheric carbon since the last deglaciation, but their precise role in the global carbon balance has not yet been quantified
(photographer S. Kirpotin)

- *Yefremov and Yefremova (2001) estimated that in total 51.7 Pg carbon is stored in all Western Siberian peat. Smith et al. (2004) found a total of 70.2 Pg carbon (=70.2 billion tonnes) which is according to highest estimation about 26% of global terrestrial carbon.*

Scheme of West-Siberian plain

The South part of the West Siberian Plain is a typical Siberian taiga with different types of bogs

- Siberian taiga on the left
- ridge-hollow mire on the right

According to investigations carried out by Tomsk University in the Western Siberian Plain, contrasting processes are occurring in the Southern and Northern parts of the region

- In the south, bogs are expanding in the taiga zone and there is progressive swamping which leads to forest death. As a result, in this part of Western Siberia bogs act as a kind of “global refrigerant” due to carbon sequestration in their peat layers.

Northern-taiga and forest-tundra from the helicopter (photographer S. Kirpotin)

However, the situation in the northern part of the Western Siberian Plain is completely opposite

- The bogs there are reducing their area and the forest-tundra zone is being subjected to thermokarst activity and colonisation of bogs by trees [Kirpotin, 1997]. Due to increased thermokarst activity, two contrast processes are observed here - a) increase of lake surface due to melting of lakes' coasts, and - a much more important one - b) decrease of surface area or disappearance of lakes due to water escape downstream the hydrological network [Smith et al. 2005; Kirpotin et al. 2006, Grippa et al., 2007]. This is likely to be connected with the recent climatic changes and, undoubtedly, with global warming.

Global warming is a major environmental issue and is expected to be greatest at high latitudes. Moreover, arctic and sub-arctic landscapes are particularly sensitive to temperature change because of the thawing of the permafrost (photographer S. Kirpotin).

The process of permafrost melting (thermokarst) of the edge of plateaux palsa at the North of Western Siberia (photographer S. Kirpotin)

Vast areas of palsa bogs with great number of lakes on watershed surface in northern taiga and forest-tundra zones (photographer S. Kirpotin)

Colonisation of bogs by trees (photographer S. Kirpotin)

S. Kirpotin1, Yu. Polishchuk2,3, N. Bryksina 4

1Tomsk State University, Tomsk, Russia
e-mail: kirp@ums.tsu.ru; phone: +7 3822 529644
2Ugra State University, Khanty-Mansiysk, Russia
e-mail: Yu_Polishchuk@ugrasu.ru; phone: +7 34671 57669
3Institute of Petroleum Chemistry, SB RAS, Tomsk, Russia
4Ugra Research Institute of Information Technologies, Khanty-Mansiysk, Russia

Disturbance of endogen cyclic succession development on flat palsa-bog complex as a result of thermokarst in the Subarctic region of Siberia using satellite images

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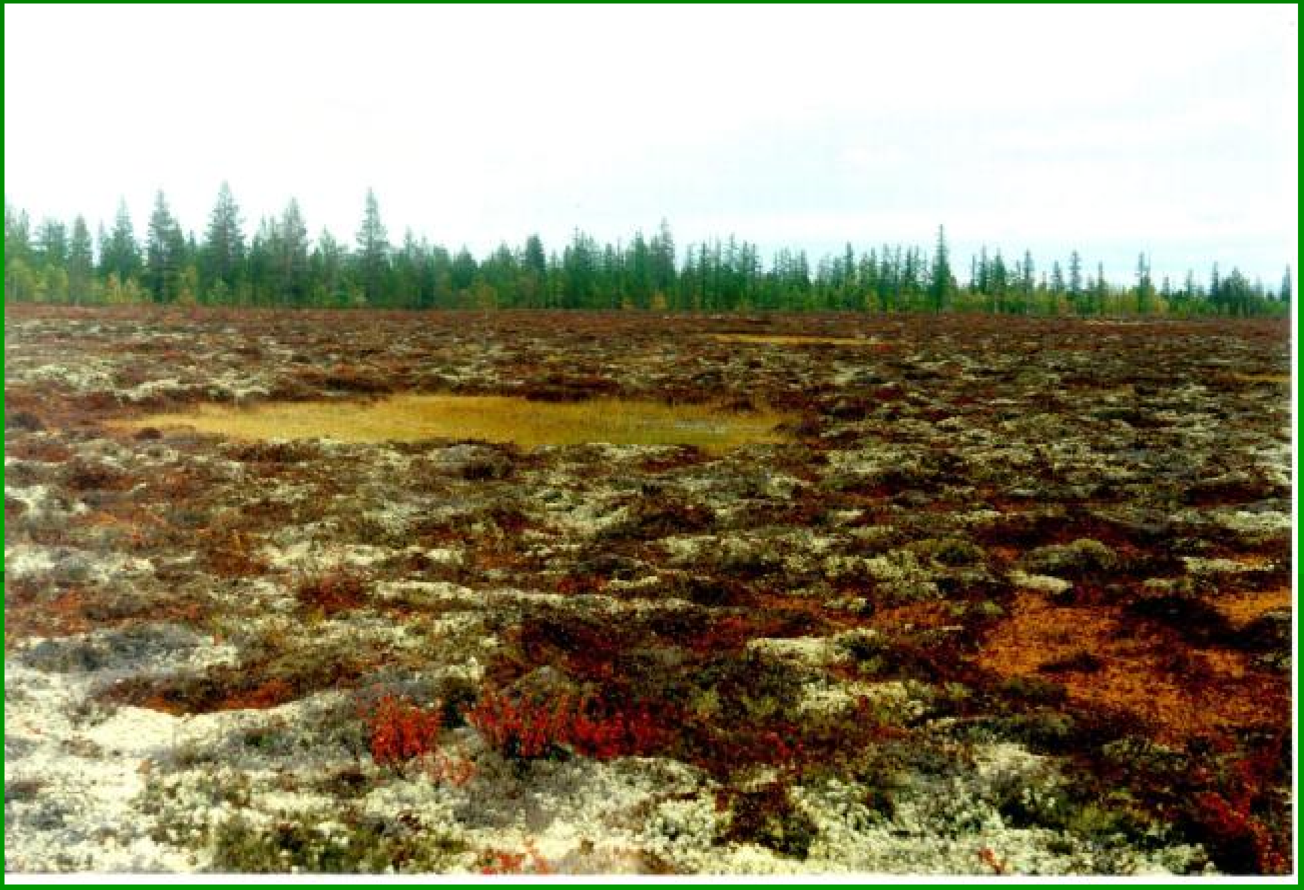
The first stage of permafrost melting (thermokarst) on the palsa bog surface (photographer S. Kirpotin)

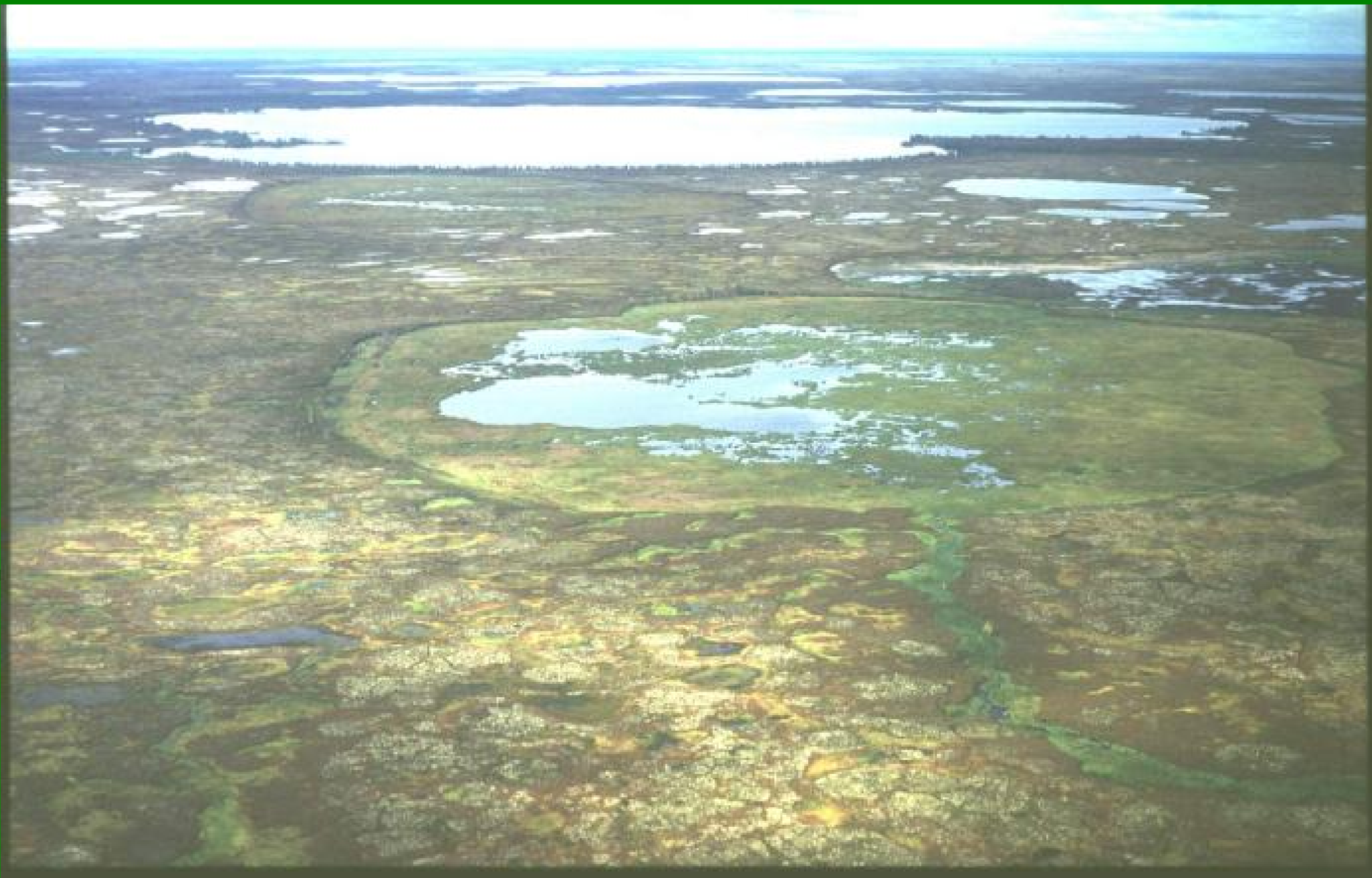
The second stage of permafrost melting (thermokarst) on the palsa bog surface (photographer S. Kirpotin)



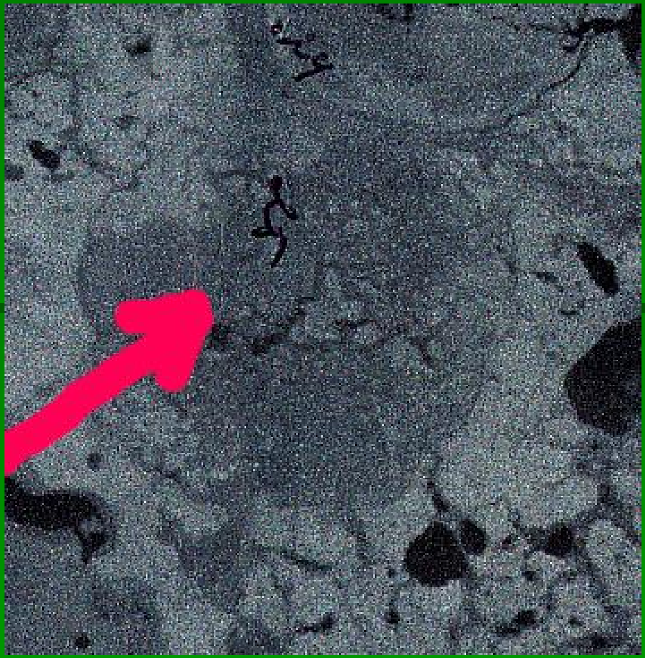
The third stage of permafrost melting (thermokarst) on the palsa bog surface (photographer S. Kirpotin)

Round lakes as a fourths stage of circle succession of permafrost degradation (photographer S. Kirpotin)

Khasyrei - dumped lake, which throw down it's water to another reservoir, as a fifth stage of circle succession of permafrost degradation (photographer S. Kirpotin)

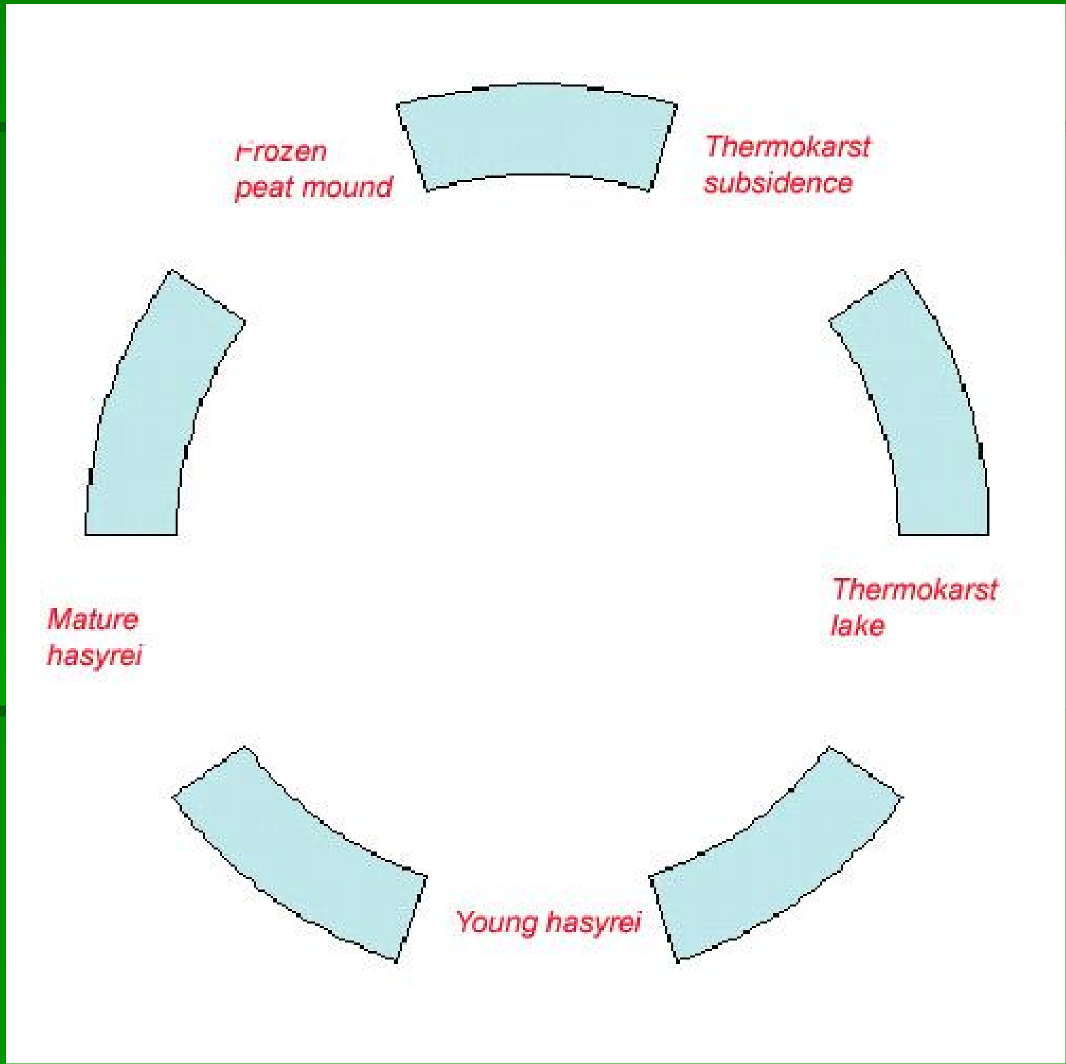


- *Mature khasyrei with yang frozen peat mounds, as a last stage of circle succession of palsa’s dynamics (aerial photo)*



- *Old khasyrei with recovered plateaux peat mounds, as a last stage of circle succession of palsa’s dynamics (aerial photo)*

The scheme of the circle palsa's succession



Fresh thermokarst subsidence. You can see the dwarf shrubs go under water (photographer S. Kirpotin, 2004)

Edges of the big (1 km) lakes (photographer S. Kirpotin, 2004)

Edge (shore-line) of the small thermokarst lake. You can see the dwarf shrubs which go under the water, some of them are still alive (photographer S. Kirpotin, 2004)

Thermokarst processes increase methane emission, especially from yedomas (ice-rich Pleistocene soils with a high labile carbon content). Recent discovery of hot spots of methane emission (bubbling) in Siberian lakes is a strong evidence of this possibility [Walter et al., 2006].

- Methane bubbles in lake ice on the Siberian North (*AP Photo/Nature, Katey Walter*)

Prompt warming of a climate in Western Siberia already today has appreciable economic consequences

- Pylons holding electric wires are being moved from tilting piles driven into the melting permafrost 30 years ago onto more stable horizontal concrete ties.

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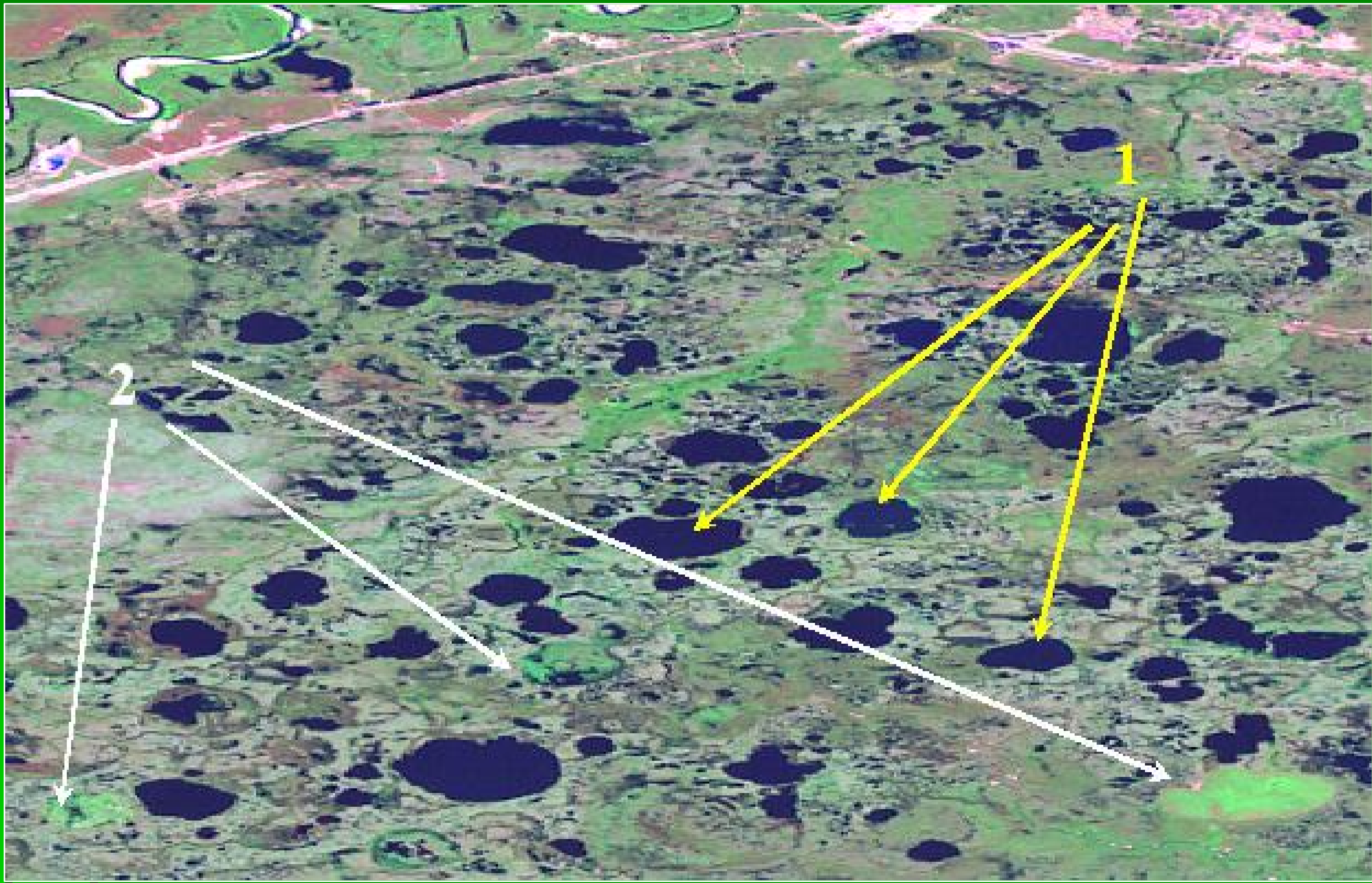
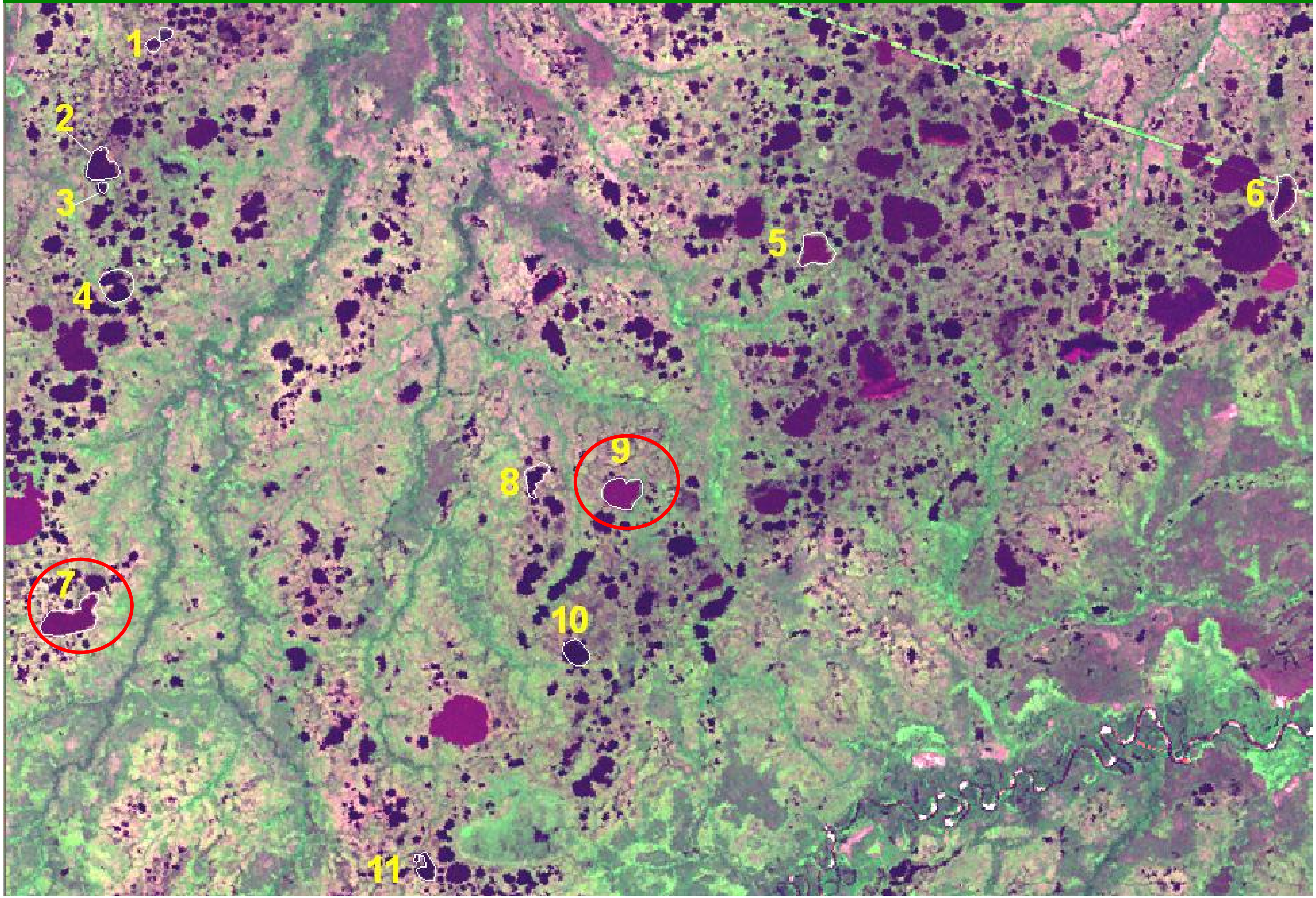
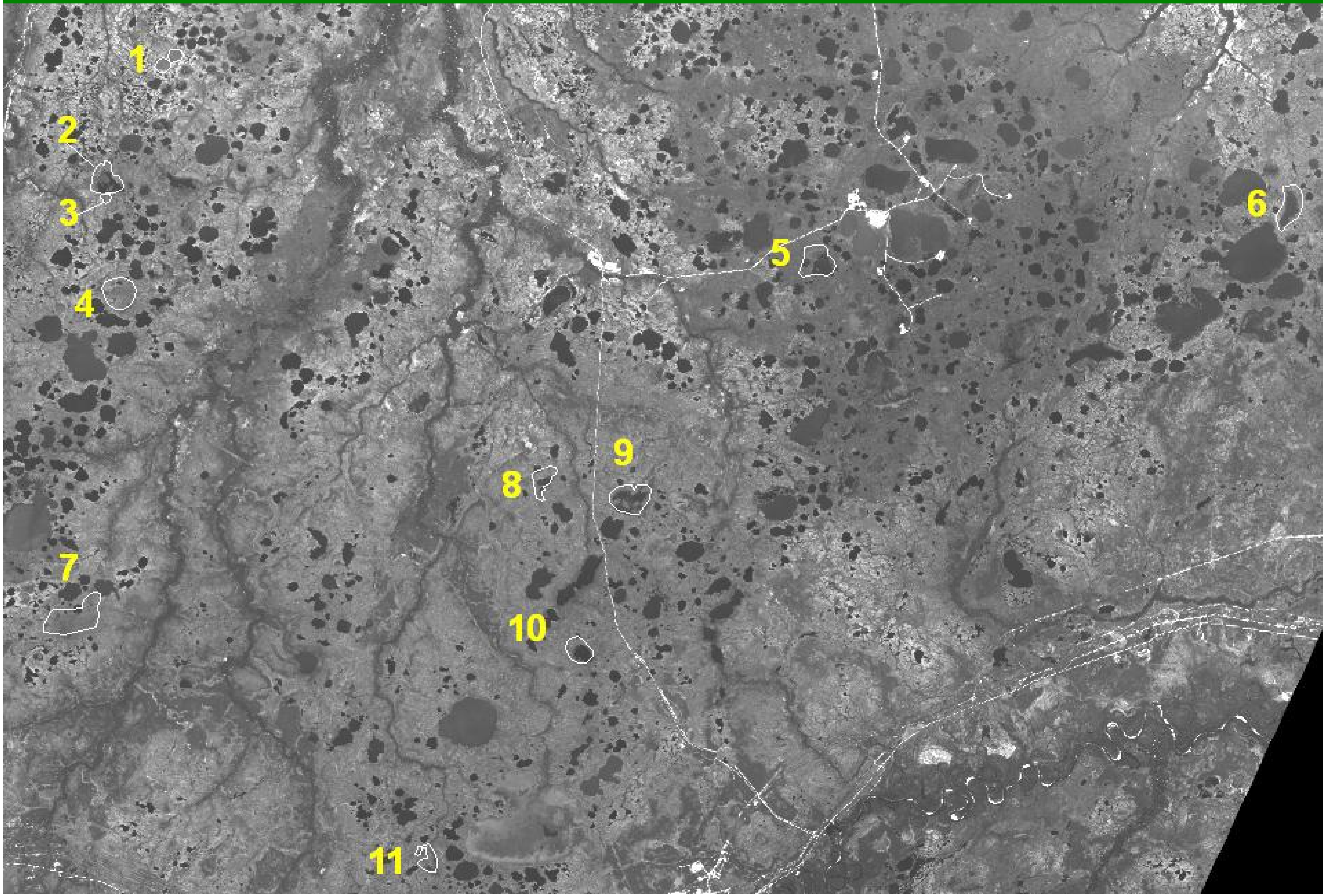
Fragment of space images Landsat-7 (07.08.1999г.), central part of PT-5
Simbols: 1 – thermokarst lakes; 2 – dried lakes



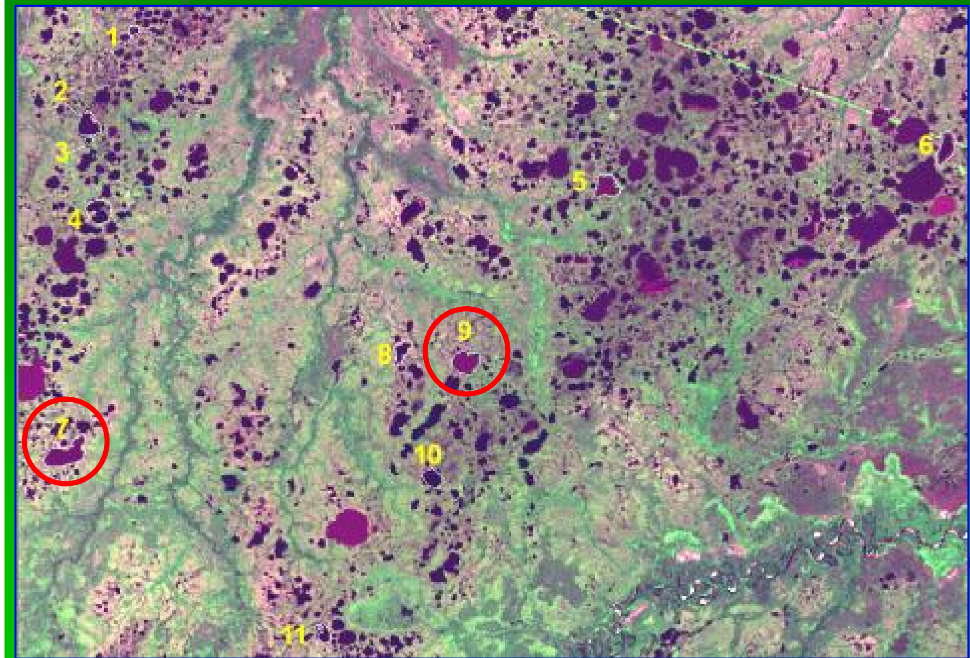
Space image Landsat-1 (10.08.1973) with indicated thermokarst lakes

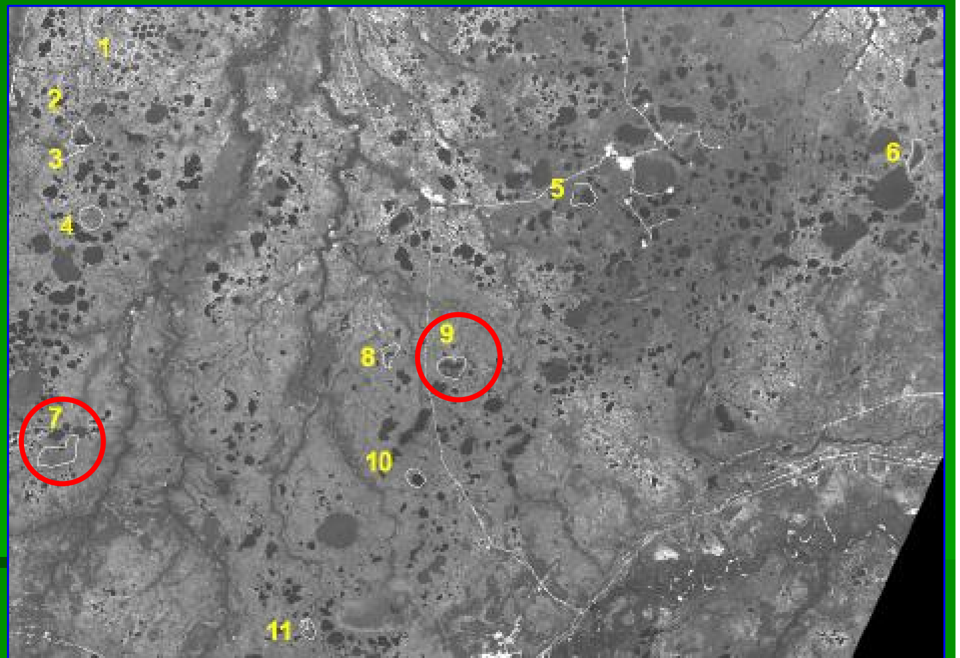


Fragment of space image Spot-5 (20.07.2005)



Comparison of space images Landsat-1 (10.08.1973) and Spot-5 (20.07.2005)



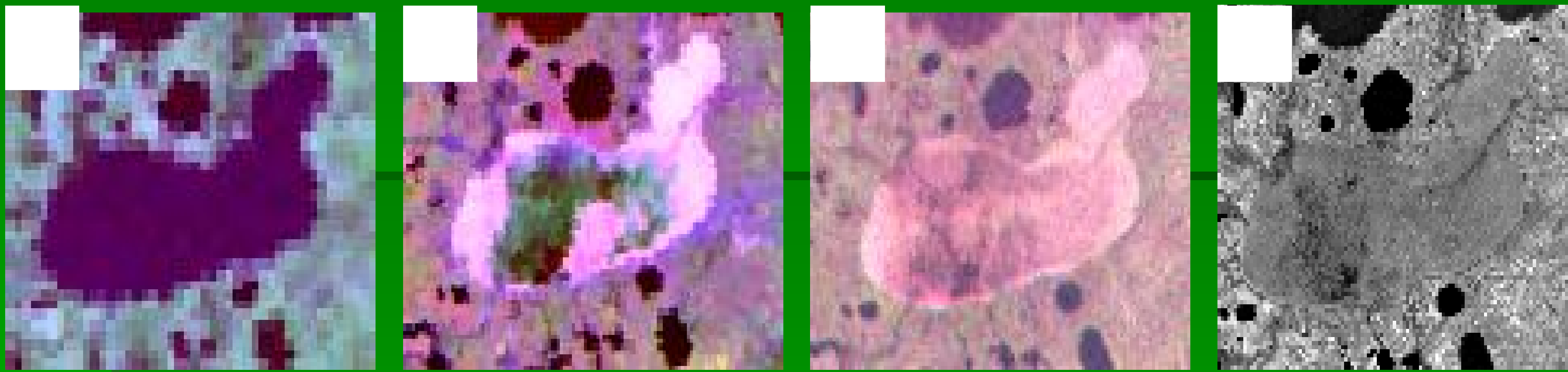


Consequent stages of decrease of lake 9 area

Changes of area of thermokarst lake 9

1973 (a)	1993 (b)	2002 (c)	2005 (d)
112 ha	65 ha	52 ha	47 ha
Landsat-1 (57 m)	Resurs -F2 (10 m)	Landsat-7 (30 m)	Spot-5 (5 m)

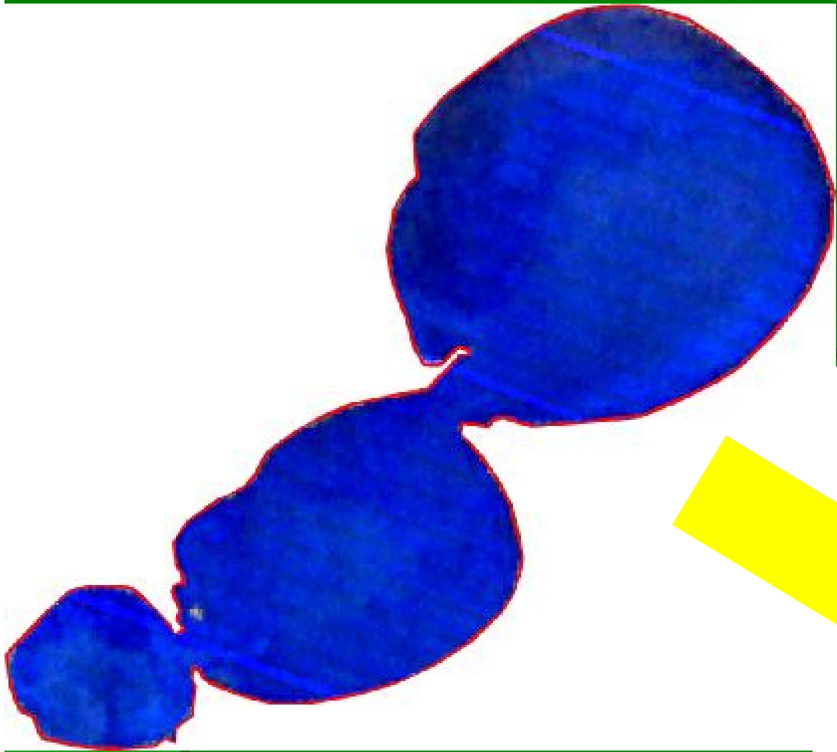
Consequent stages of decrease of lake 7 area



Thermokarst lake 7 areas (red) changes

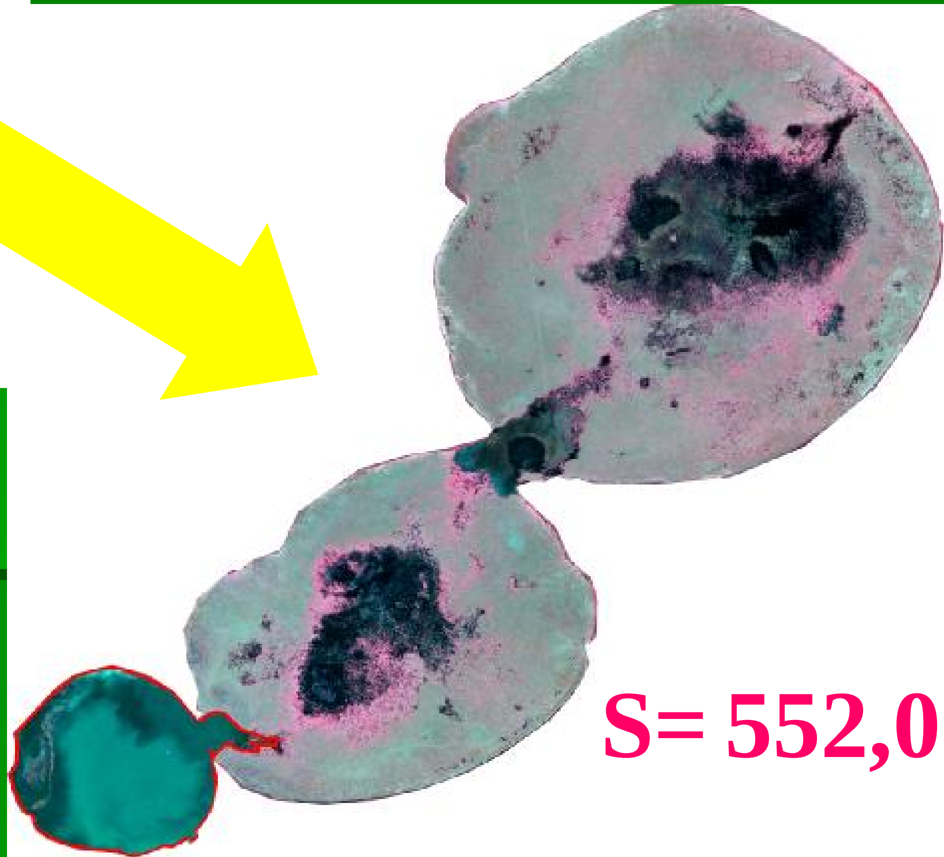
1973 (a)	1988 (b)	1993 (c)	2005 (d)
151 ha	27 ha	3 ha	0
Landsat-1 (57m)	Landsat-5 (30 m)	Resurs -F2 (10 m)	Spot-5 (5 m)

Thermokarst lakes



LANDSAT -1 (1973)

S= 5625,0

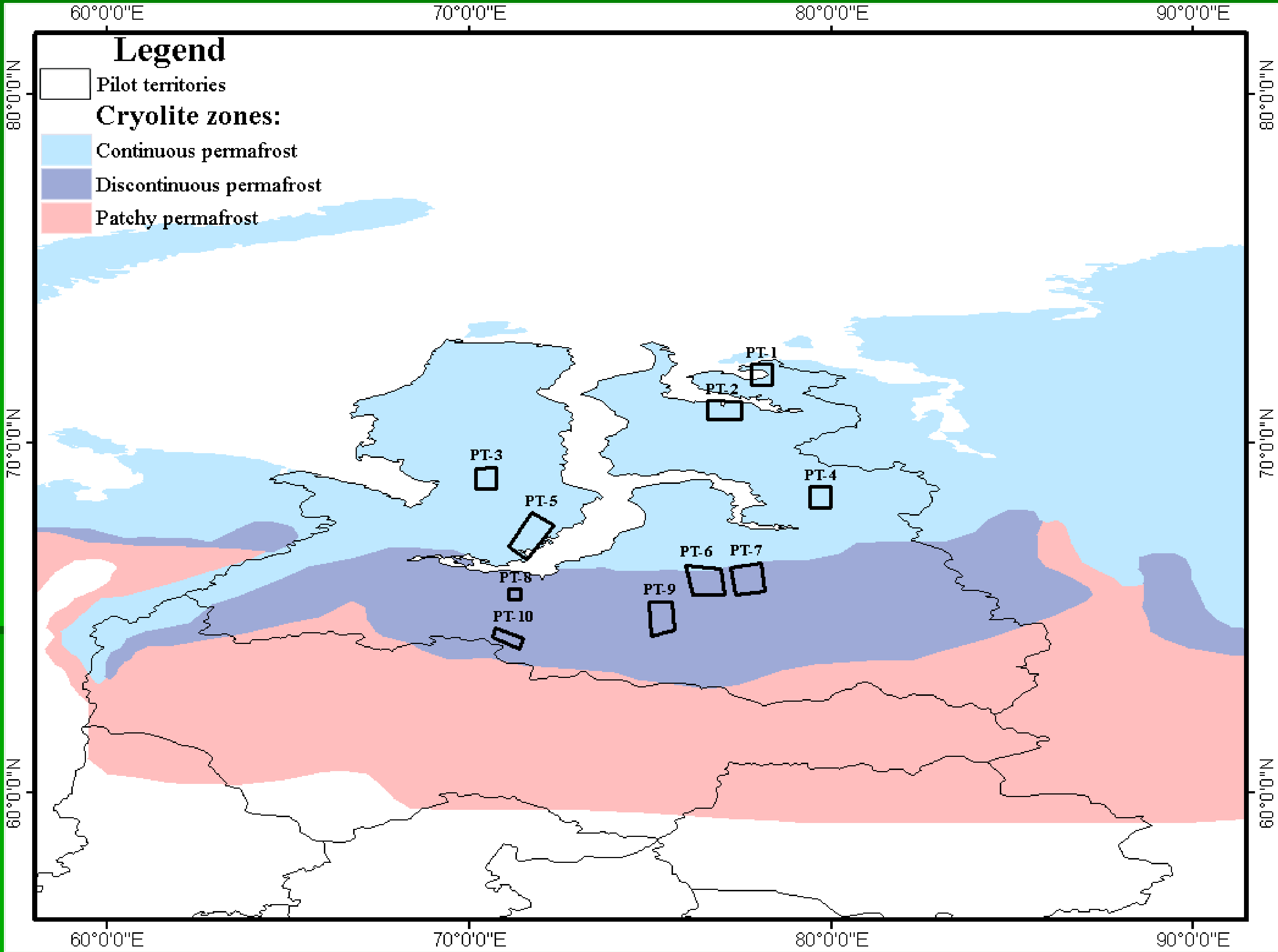


S= 552,0

Озеро Сихтынэмтор сократилось на 90% ALOS (2006)

Selection pilot territories

Location of pilot territories in West-Siberian permafrost



REMOTE SENSING DATA

Landsat - 1 (сканер MSS), 10.08.1973
Landsat - 5 (сканер MSS), 27.07.1984
Landsat - 5 (сканер MSS), 26.06.1988
Landsat - 4 (сканер TM), 01.08.1988
Landsat - 5 (сканер TM), 20.09.1989

Resurs - F2 (сканер МК 4), 14.06.1993
Landsat - 7 (сканер ETM), 07.08.1999
Landsat - 7 (сканер ETM), 03.08.2001
Landsat - 7 (сканер ETM), 03.07.2002
Spot - 5 (сканер HRV), 20.07.2005
ERS - 2 (сканер SAR), 2005-2008
ALOS (AVNIR-2) 2006-2007

Results of Research

Изменение суммарной площади
ермокарстовых озер (га) в прерывистой криолитозо

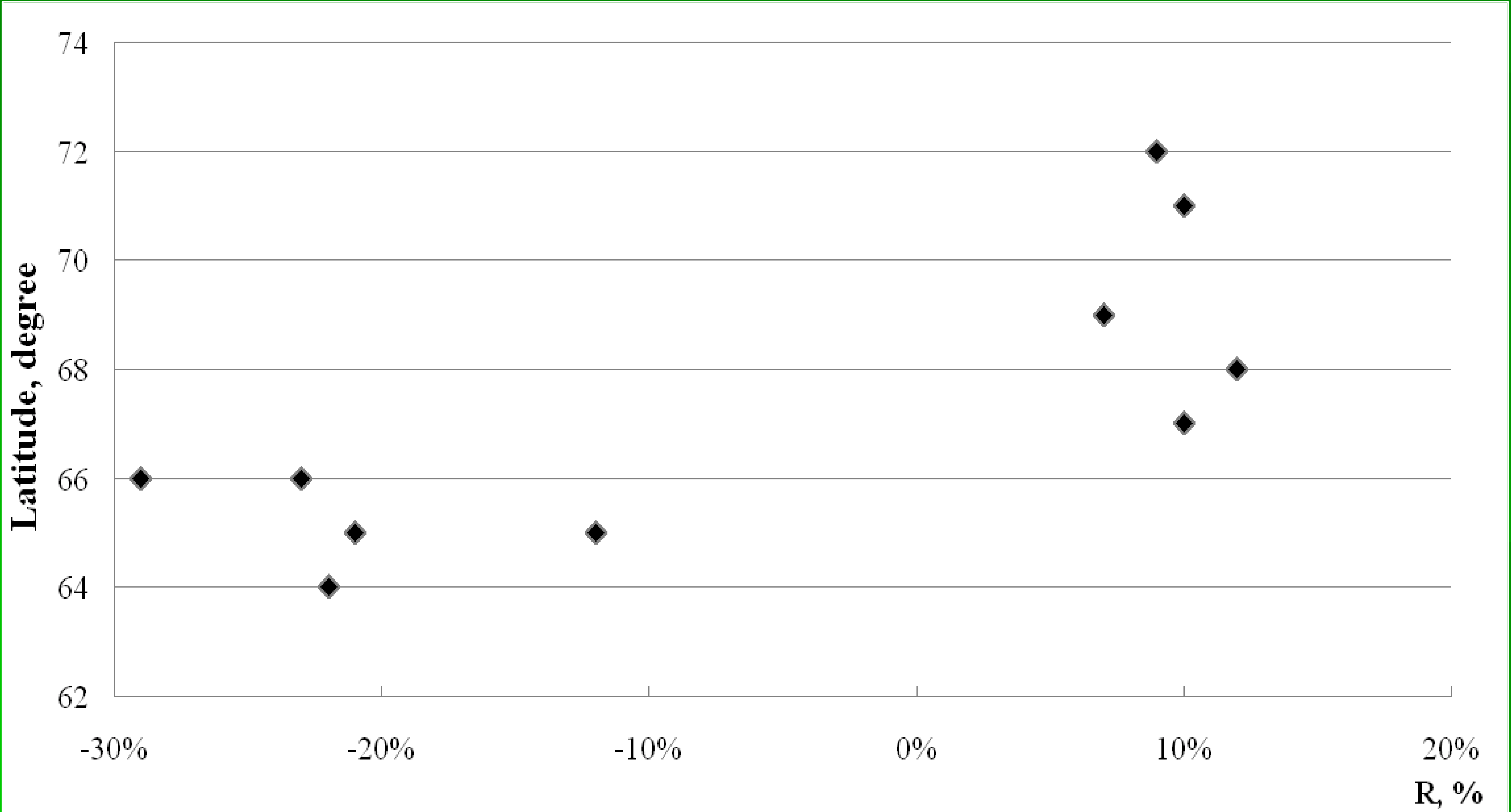
Pilot territories		PT-6	PT-7	PT-8	PT-9	PT-10
Total area of lakes, ha	1973		3864,2	4370,8		2155,1
	1984				3673,2	
	1988	3777,0				
	2000			3453,7		
	2005	2921,7	2759,6		3234,8	1685,5
Volume of sample		40	40	118	40	40
Total area decrease of lakes, ha		-855,3	-1104,6	- 917,1	-438,4	-469,6
R, %		-22,6	-29	-21	-12	-22

R - относительное изменение суммарной площади озер

Изменение суммарной площади рмокарстовых озер (га) в сплошной криолитозо

Pilot territories		PT-1	PT-2	PT-3	PT-4	PT-5
Total area of lakes, ha	1973 1984	6292,7	3421,2	1899,1	3566,9	3611,85
	2006	6965,5	3765,3	2035,0	3998,9	3975,9
Volume of sample		80	40	30	40	60
Total area decrease of lakes, ha		672,8	344,1	135,9	432,0	364,05
R, %		10,7	10	7	12	10

тносительные значения термокарстовы озер в зависимости от широты



Summary and Conclusion

1. Bog landscapes spreading in the permafrost area are most sensitive to temperature alterations because of permafrost melting. Thermokarst lakes are the most convenient object for distant monitoring of the global warming influence on the permafrost rocks state.

2. Study of thermokarst lake’s areas changes in time makes it possible to assess dynamics of kryogenic processes on the basis of space images.

3. The results of investigations carried out may be used for Risk-analysis of oil-gas industry state in northern territory of Siberia as a main oil-gas producing region of Russia.

- Started in 2007 joint French-Russian GDRI project "CAR-WET-SIB Biogeochemical cycle of carbon in wetlands of Western Siberia" is centered on **Carbon in Wetlands of Western Siberia** and will deal with numerous aspects of carbon biogeochemistry of this region, from hydrological regime of wetlands and flooded zones, vegetation production/degradation and dissolved organic matter, to permafrost-affected fluxes and mechanisms of carbon dioxide, methane and metal migration. One of the ultimate goals of this partnership could be creation of multi-level biogeochemical model of carbon dioxide and methane in natural and anthropogenically-affected landscapes of Western Siberia.
- The approach will be based on:
- Combination of "terrestrial"(fieldwork), "spatial" (remote sensing) techniques and numerical modelling approaches to the same objects.
- Simultaneous study, using the same set of techniques, of southern (permafrost-free, Vasugan's plain) and northern (permafrost-affected, thermo-karst lakes region) territories of Western Siberia.

The scientific research of the GDRI will focus on:

- study of variability of hydrological and hydrochemical processes in the wetlands and flooded zones of Western Siberia region at different temporal (from multi-year to seasonal) and spatial (from local, experimental plot level (m^2) to regional, watershed and river basin level) scales through a multidisciplinary approach based on in situ, remote sensing data and numerical modelling;
- investigation of dynamics of pristine and disturbed ecosystems in connection with past, present and future global climatic changes;
- creation a spatial distributed database of Western Siberia Region in the field of environmental dynamics and climatic change for scientific-educational use;
- application of existing satellite remote sensing and numerical modelling techniques, analytical observations, GIS technologies. Their validation, parameterisation and development of new ones for studies and monitoring of environmental conditions of the chosen natural objects;
- effects of climate change on carbon balance, CO2 and methane emissions and biogeochemical cycles of elements at the land – hydrosphere - atmosphere interface;
- analyses and modelling of the primary production processes in different ecosystems in a changing environment;
- analyses and modelling of vegetation pattern and biodiversity at site, local and regional scales within a changing environment;
- development and use of spatial recording techniques to observe, monitor and survey a range of physical and biological parameters of freshwater ecosystems, both under laboratory conditions and in situ;
- identification, enumeration and observation of aquatic microorganisms, their interactions and functional roles within the freshwater ecosystems;
- development of mathematical and computer simulation of environmental and climatic dynamics;
- methodical support for sustainable and environmental-friendly development of extractive industries: oil-gas complex, forestry, hunting, fishing;
- studying and preservation of culture and national features of Siberian indigenous and old believer people;
- protection of natural and semi-natural environments within Western Siberia.

Thank you!