

Изучение динамики термокарстовых процессов на севере Западной Сибири с использованием космических снимков и наземных данных

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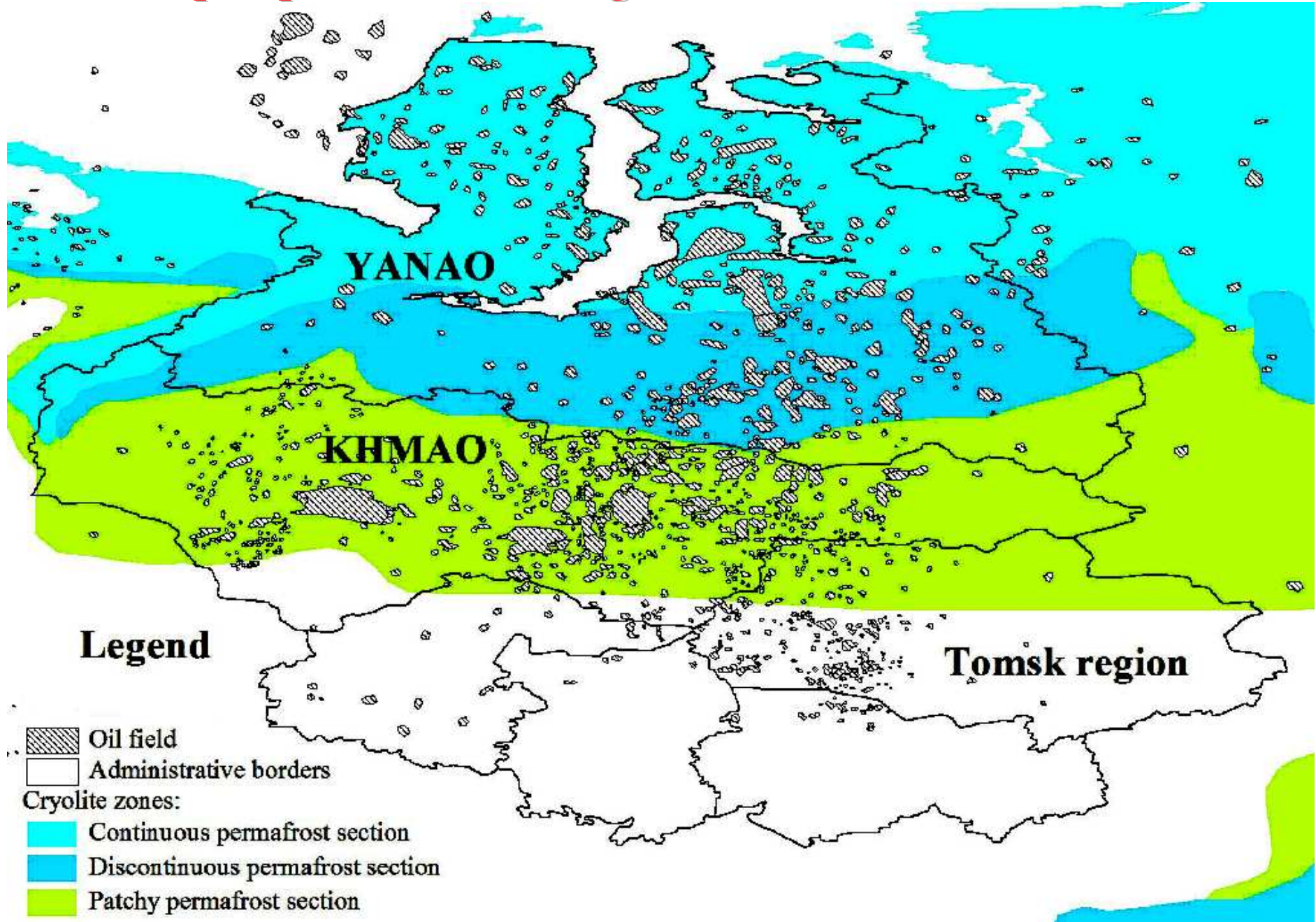
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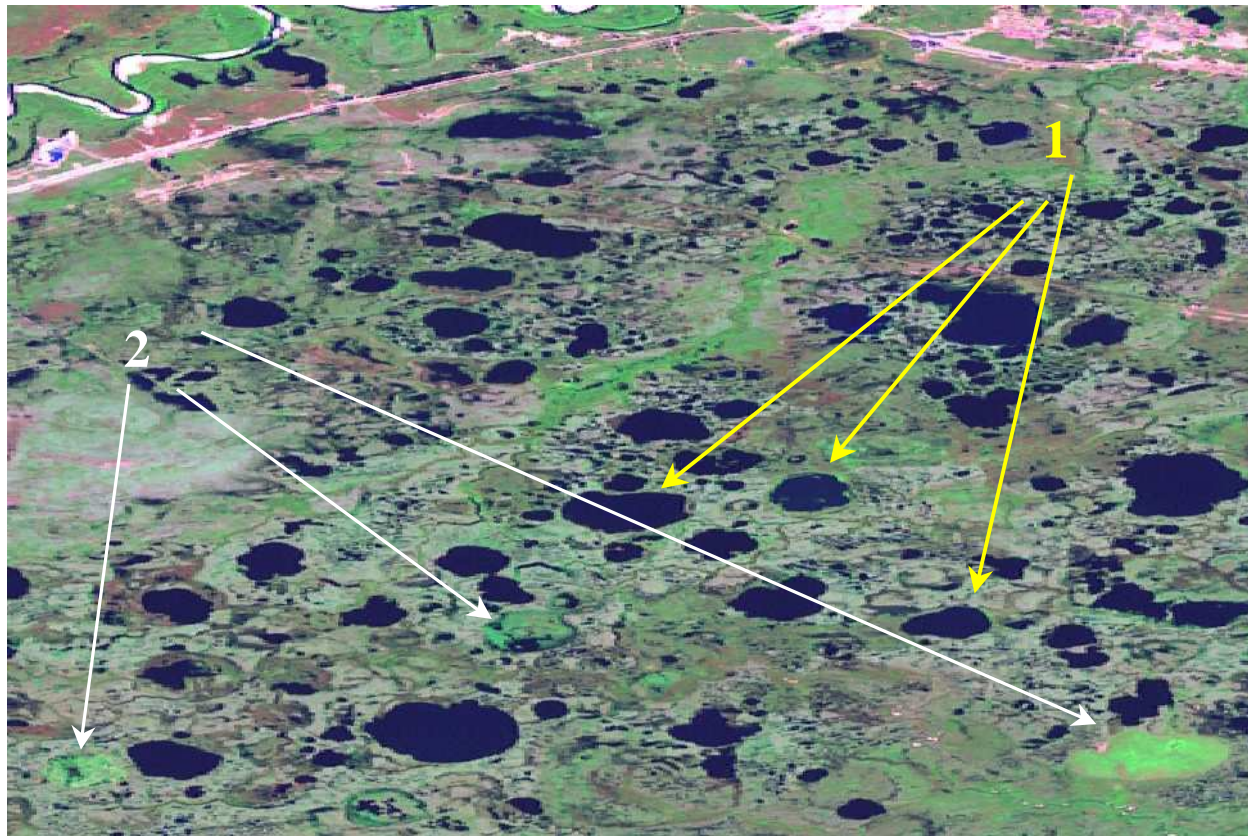
**STUDY OF THERMOKARST STATE CHANGES IN WEST-SIBERIAN
PERMAFROST USING REMOTE SENSING DATA**

Map of permafrost zoning and oil fields in West Siberia



Thermokarst lakes as objects of geocryological studies

The most effective geoindicators of cryogenic changes of permafrost territories under global warming using remote sensing are thermokarst lakes. Below is a fragment of space image Landsat-7 (07.08.1999г.) with indicated objects of geocryological studies:
1 - thermokarst lakes; 2 – drained lakes (khasyreys)



Climatic data

Long-term time numbers of mid-annual values of **air temperature, quantity of atmospheric precipitation** and other climatic parameters, received at **156 meteorological stations** in West-Siberian territory for the period **1955 - 2006 years** have been analyzed.

Remote sensing data

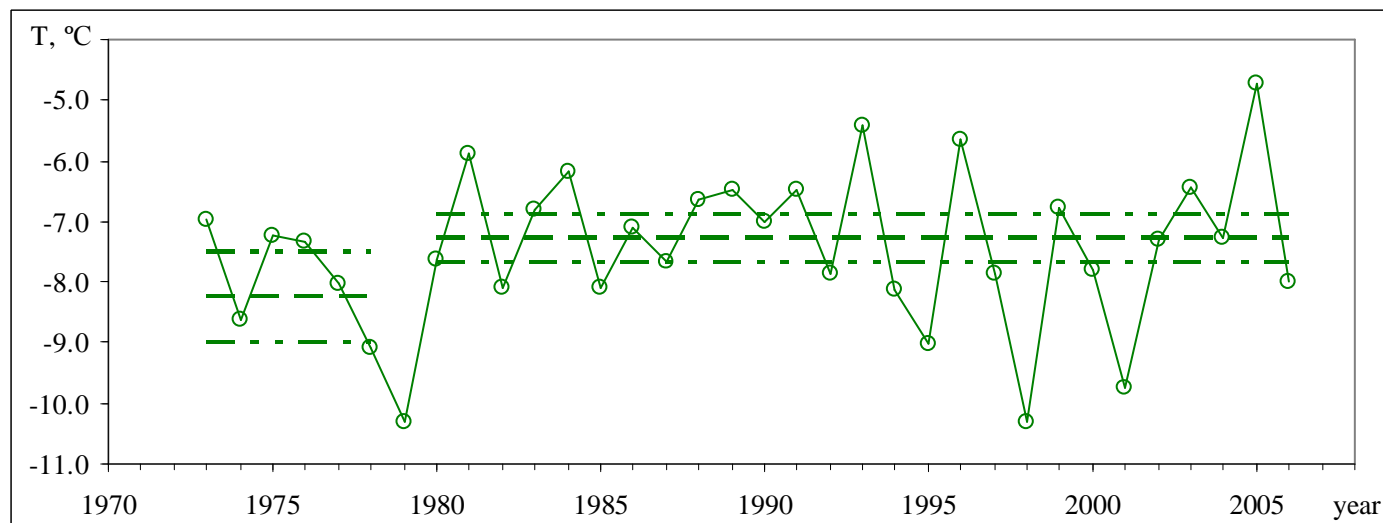
Collections of space images of 1973-2006 years

Landsat - 1 (scanner MSS), 10.08.1973
Landsat - 5 (scanner MSS), 27.07.1984
Landsat - 5 (scanner MSS), 26.06.1988
Landsat - 4 (scanner TM), 01.08.1988
Landsat - 5 (scanner TM), 20.09.1989
Resurs - F2 (scanner MK 4), 14.06.1993
Landsat - 7 (scanner ETM), 07.08.1999
Landsat - 7 (scanner ETM), 03.08.2001
Landsat - 7 (scanner ETM), 03.07.2002
Spot - 5 (scanner HRV), 20.07.2005
ERS-2 – 2005, June – 2006, September

**Методические вопросы
анализа геокриологических
изменений**

**Methodical questions
of analysis
of geocryologic changes**

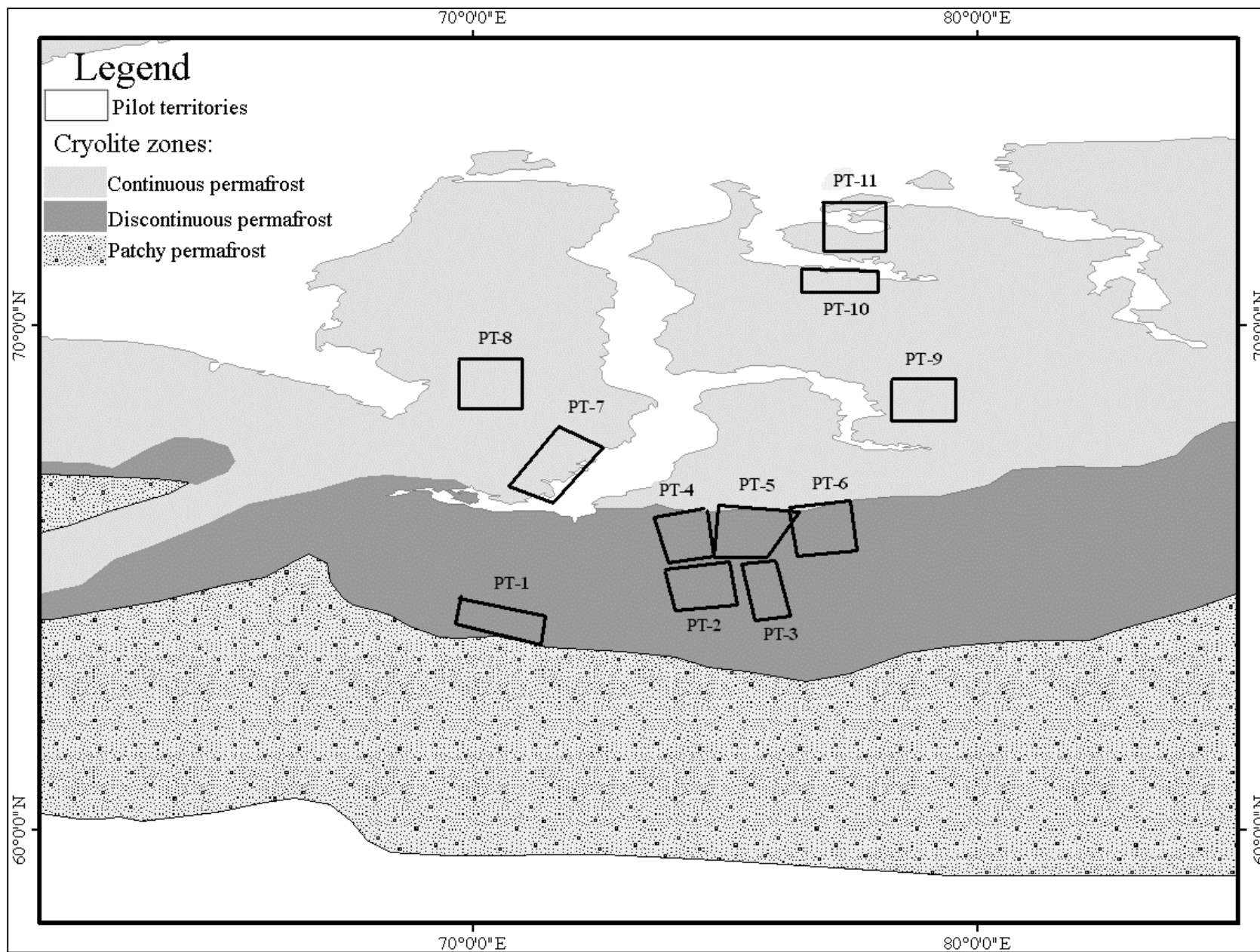
Temperature change in territory of Continuous and Discontinuous permafrost section (Yamal-Nenets region)



Mid-annual air temperature in the second period (1980-2006 years) in comparison with the period of 1973-1979 years has increased 0,96 °C

- Mean value
- confidence limit for 90 % confidence probability

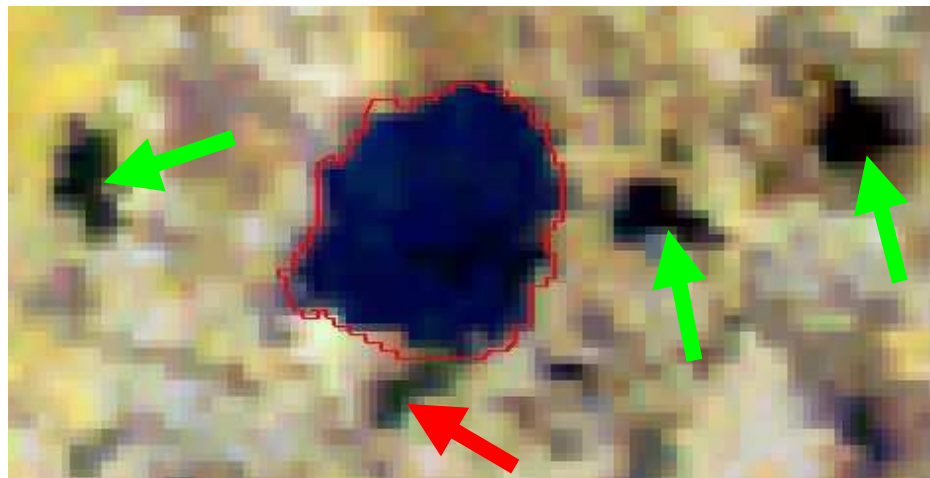
Map of West-Siberian permafrost zoning and pilot territories



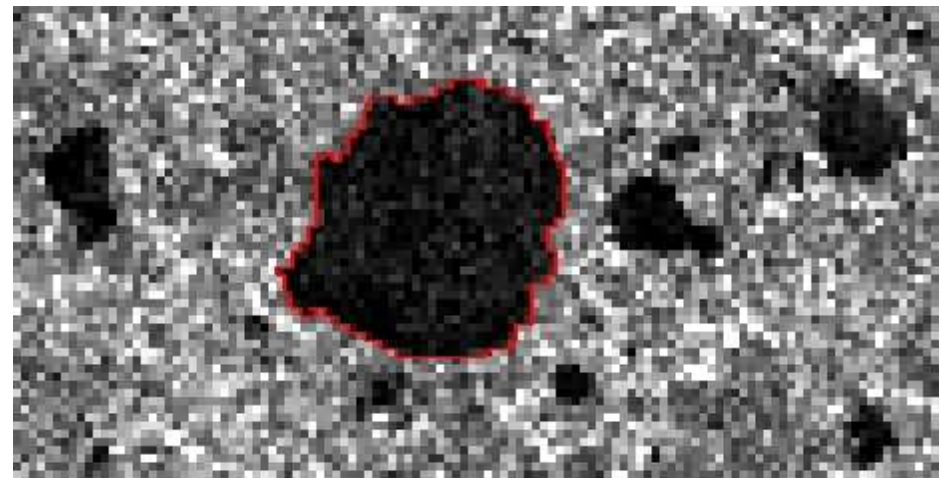
Сопоставление разновременных снимков

Big Shirokoe Lake surrounded by small lakes: red arrow – drained lake, green arrows – lakes ready to drain

1984



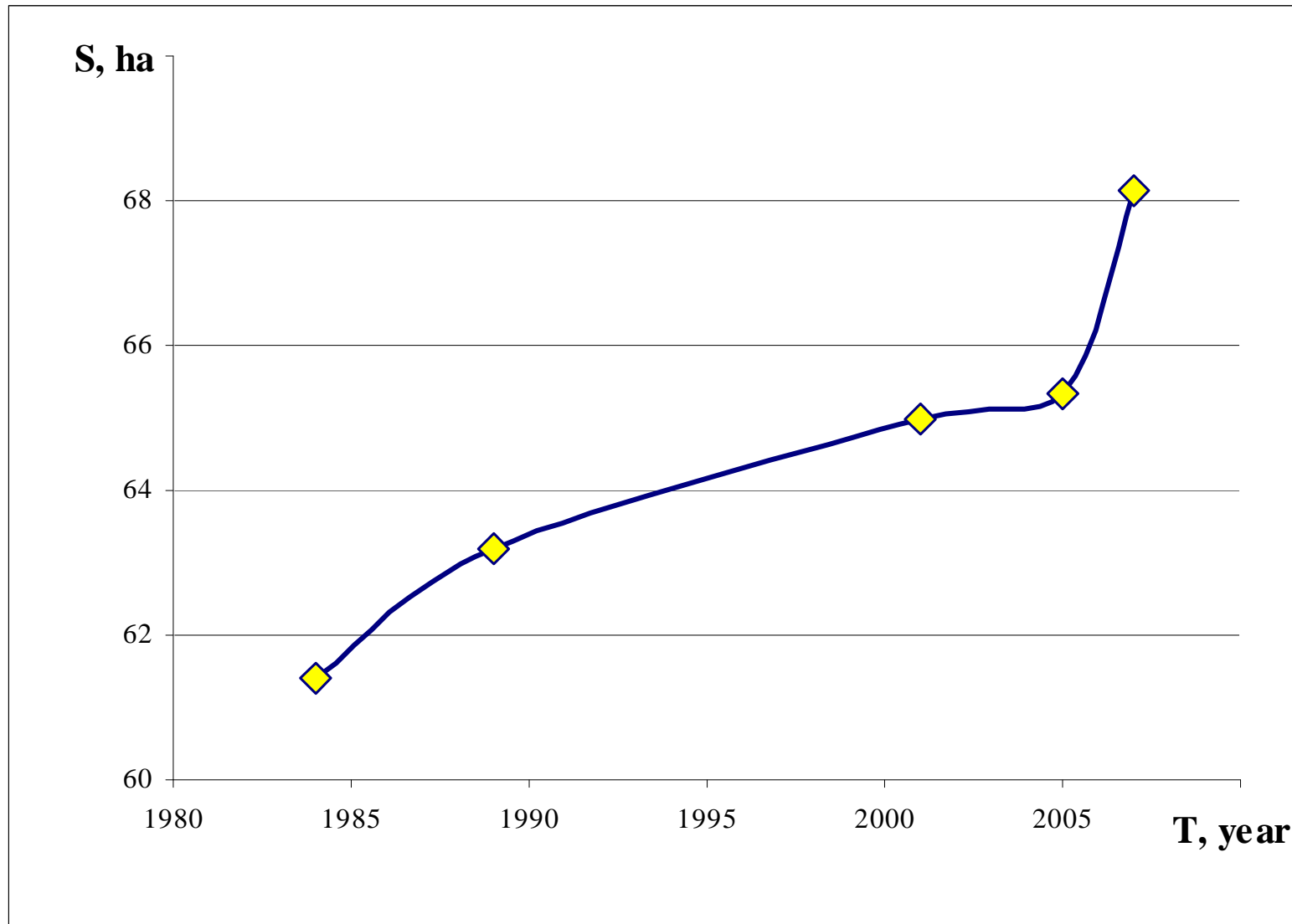
2007

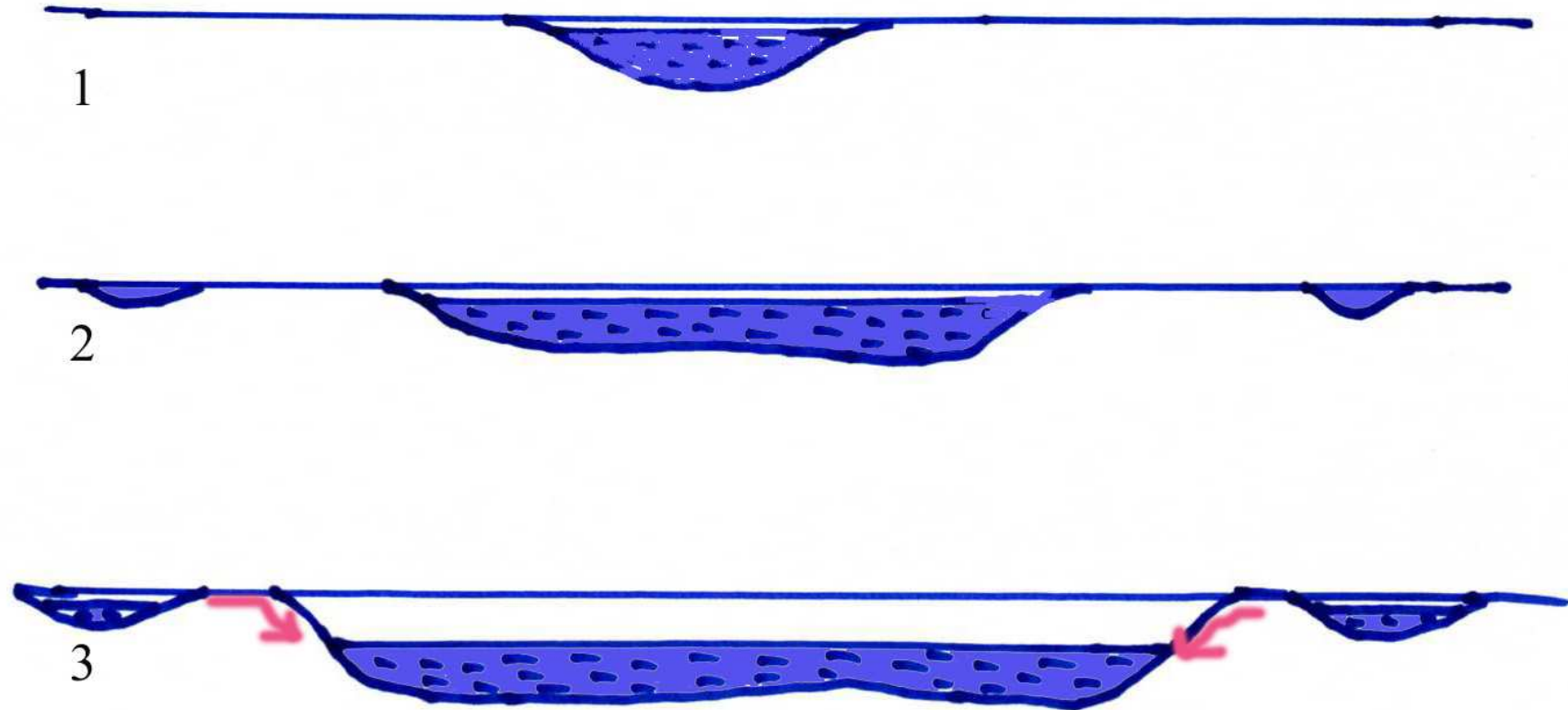


Динамика изменений площади озера (га)

27.07.1984	20.09.1989	03.08.2001	27.07.2005	18.07.2007
61,4	63,1	64,9	66,7	68,1
Landsat-5	Landsat-5	Landsat-7	ERS-2	ERS-2

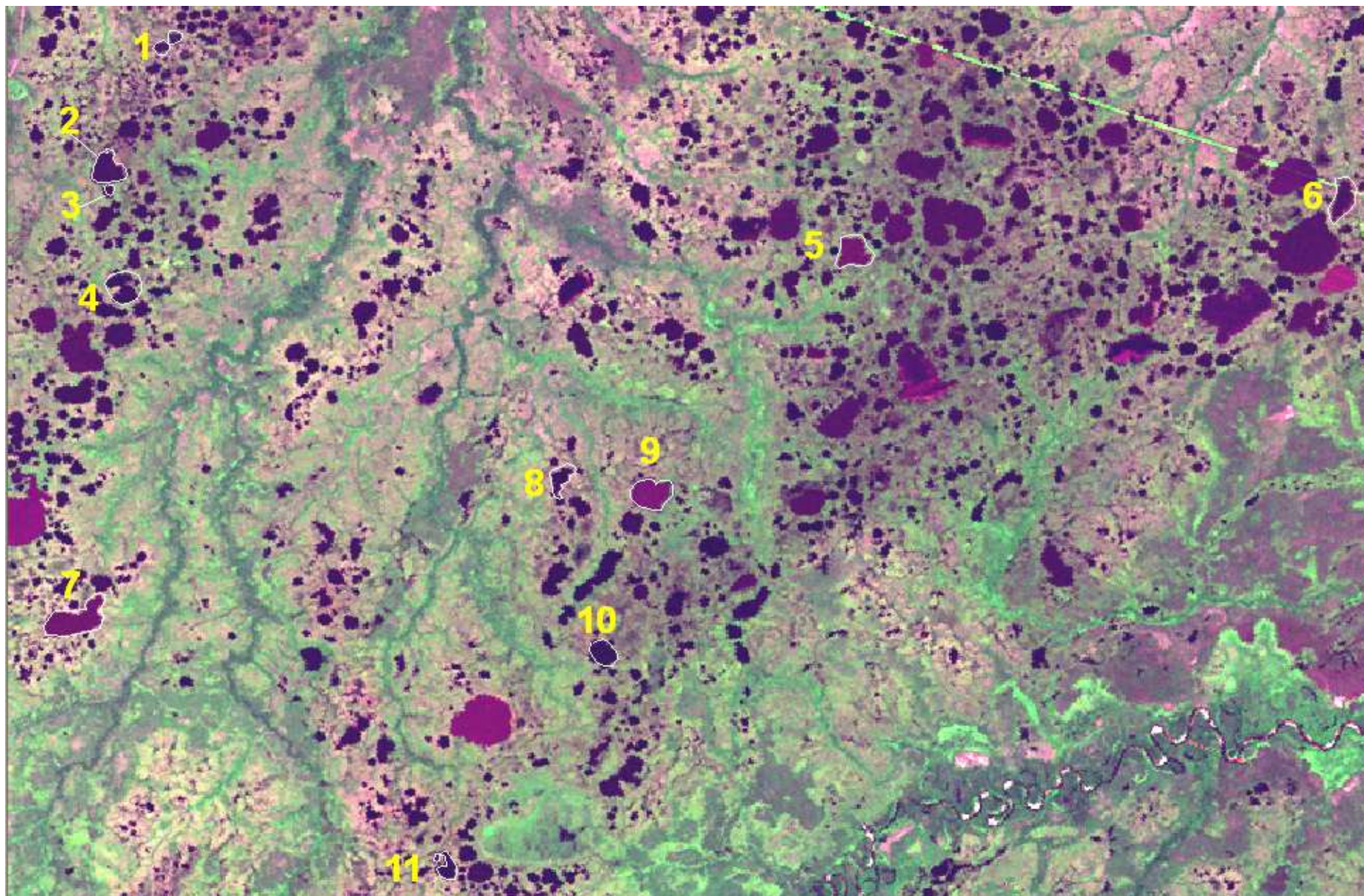
Динамика изменения площади озера



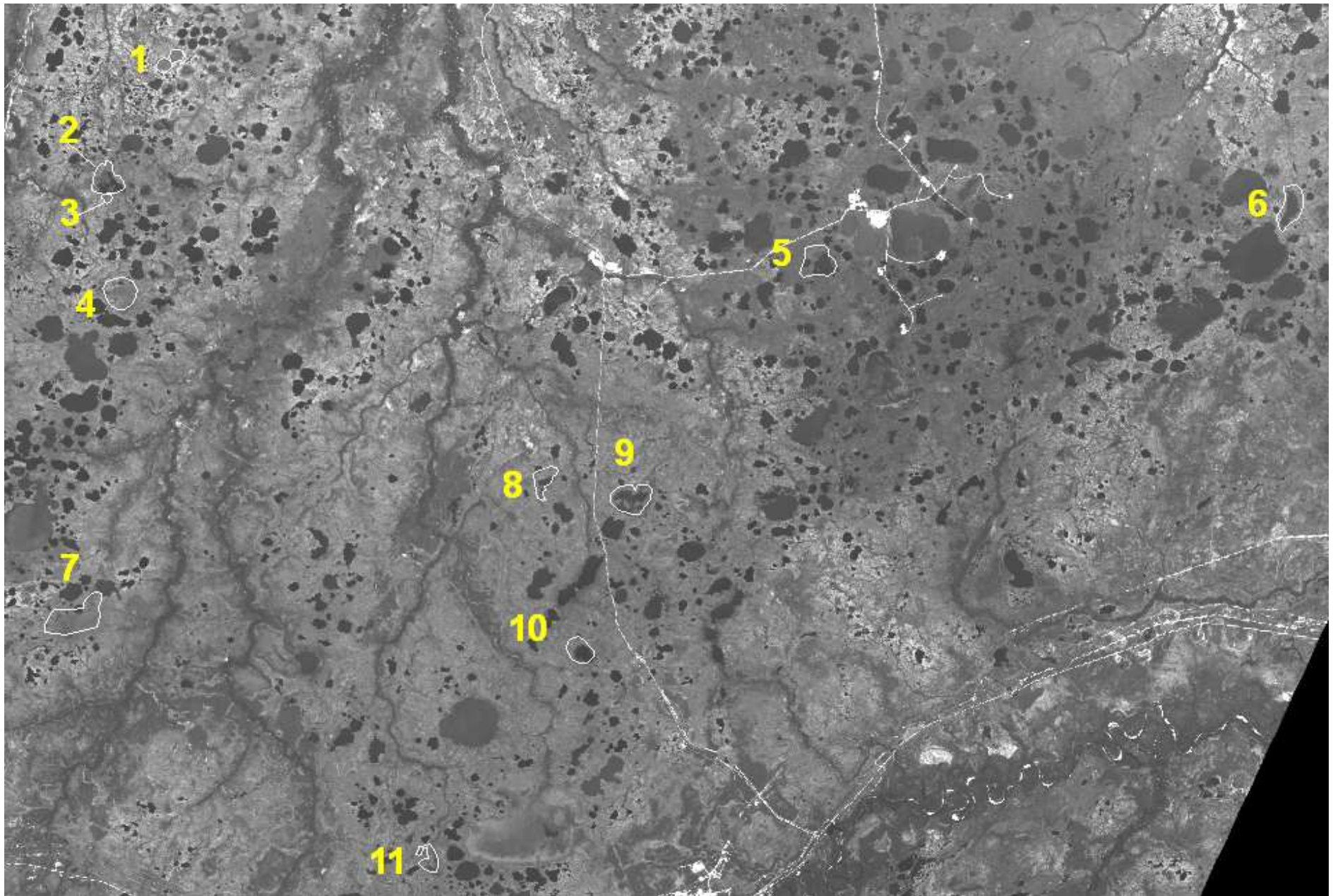


- **Model of thermokarst lakes drainage: (1) appearance of thermokarst lake; (2) growing of the thermokarst lake and appearance of small lakes in their neighbourhood; (3) the thermokarst lake takes a critical mass enough for subsidence of the lake bottom, drain flows from the small lakes are forming**

Fragment of initial space image Landsat-1 (10.08.1973) with indicated thermokarst lakes

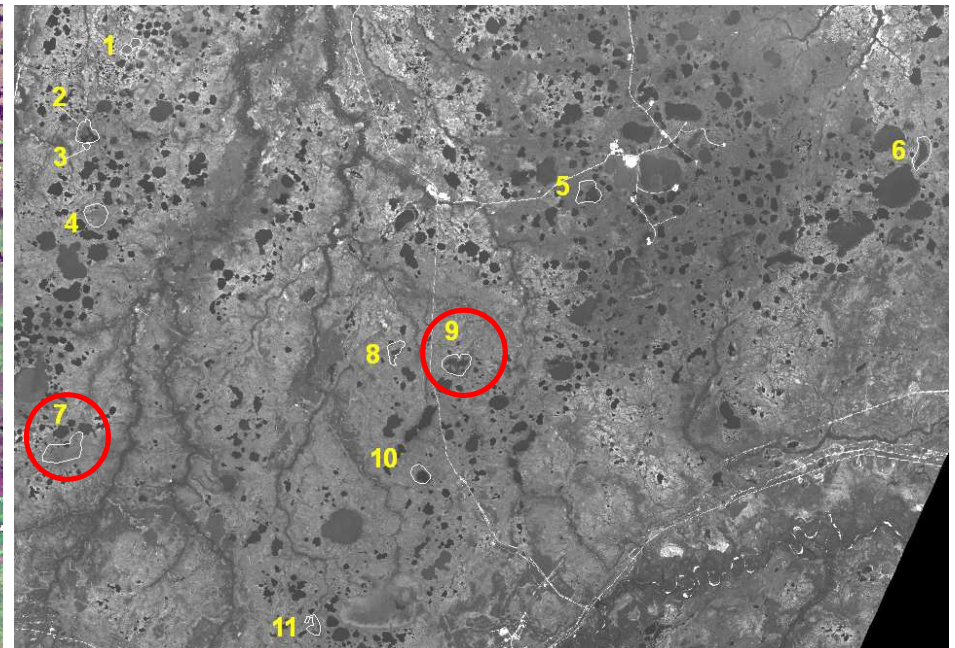
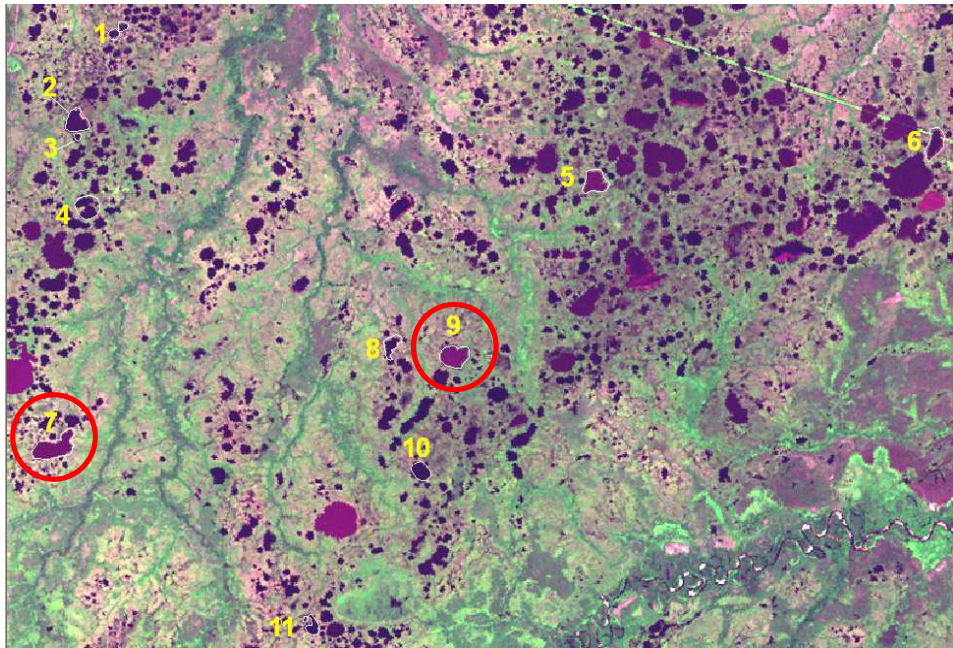


Fragment of final space image Spot-5 (20.07.2005)

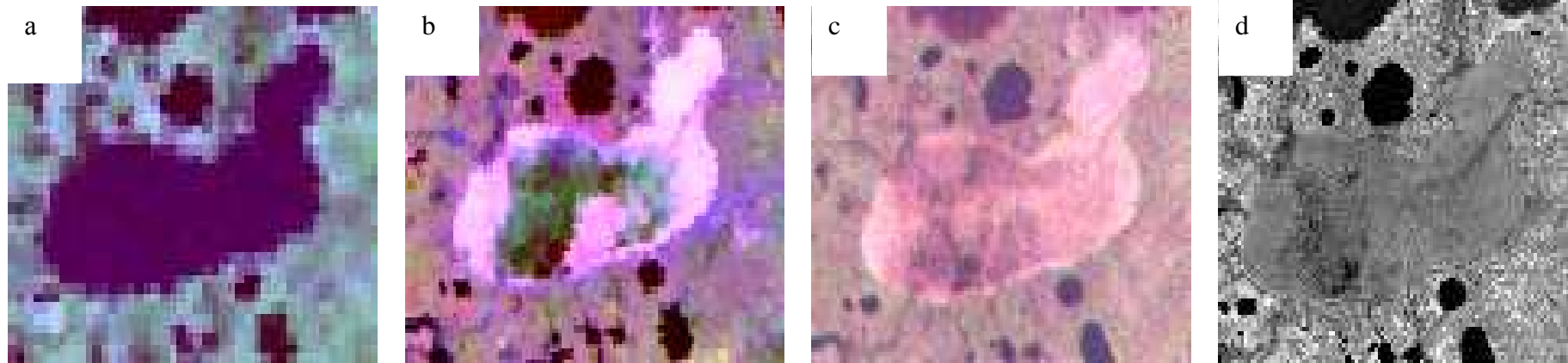


Comparison of initial and final space images

PT-1, Landsat-1 (10.08.1973) and Spot-5 (20.07.2005)



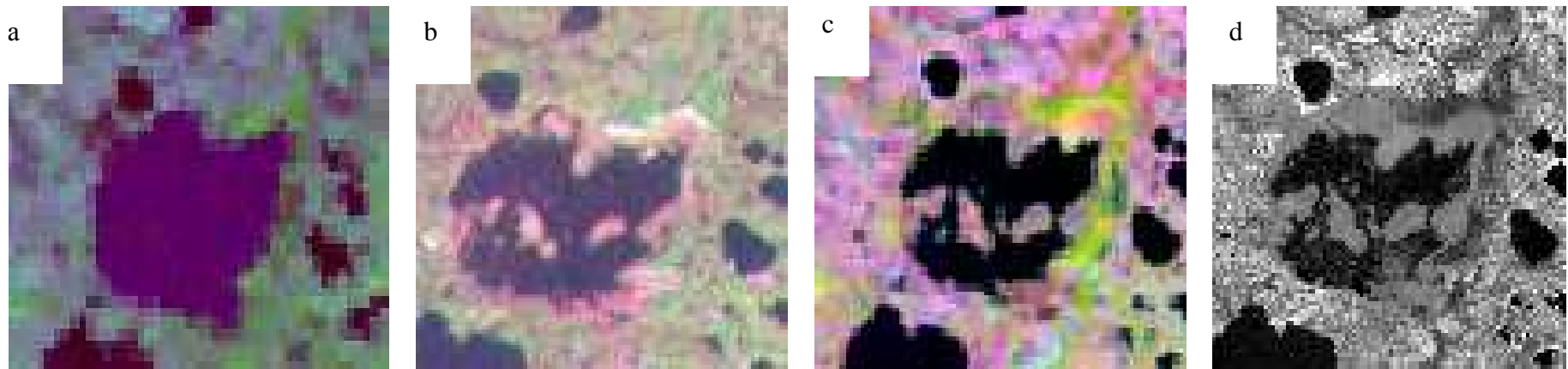
Consequent stages of decrease of lake 7 area in PT-1



Thermokarst lake 7 areas (red) changes

1973	1988	1993	2005
151	27	3	0
Landsat-4 (57m)	Landsat-5 (30 m)	Resurs -F2 (10 m)	Spot-5 (5 m)

Consequent stages of decrease of lake 9 area in PT-1



Changes of area of thermokarst lake 9 (red)

1973 (a)	1993 (b)	2002 (c)	2005 (d)
112 ha	65 ha	52 ha	47 ha
Landsat-4 (57 m)	Resurs -F2 (10 m)	Landsat-7 (30 m)	Spot-5 (5 m)

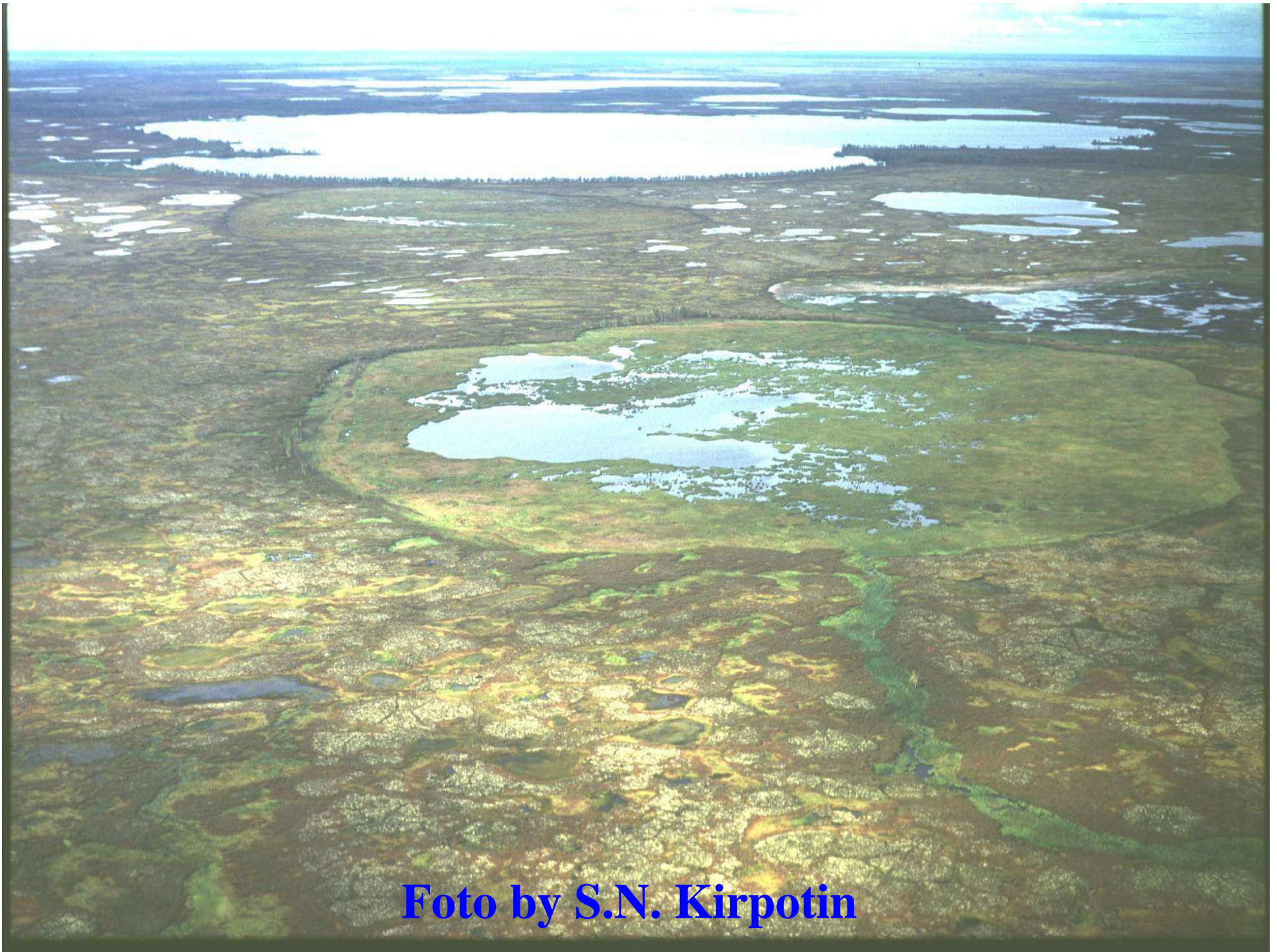


Foto by S.N. Kirpotin

Analysis of lakes area changes in PT-1

- Decrease of lake area
- Increase of lake area
- No changes

Total area of lakes :

1973 - 2155,1 ha,

2005 - 1902,2 ha.

**Total area decrease of lakes in
PT-1:**

$S(1973) - S(2005) = -469,6$ ha

**Normalized total area decrease
 $k = -22\%$**

Lake number	1973	1988	2002	2005
1	26	13	0	0
2	90	80	69	31
3	14	12	3	0
4	61	27	2	0
5	76	58	49	47
6	55	53	45	39
7	151	27	0	0
8	43	22	14	13
9	112	68,3	52	47
10	66	57	36	30
11	50	25	6	0
12	65	61,5	61,7	65
13	34,7	33,5	33,3	33,4
14	68,5	66,8	65,6	54,9
15	25,3	22,7	24,2	24,8
16	9,8	12,6	13,4	14,1
17	52,9	56,4	57,3	57,3
18	46,8	51,3	51,3	51,2
19	65	65,8	65,5	66,5
20	118,2	121,4	121,8	122,8
21	52,2	55,8	57,4	48,6
22	21,7	26,8	27,7	27,1
23	68,4	72,7	75,7	76,2
24	33,2	34,8	35,7	35,1
25	25	25,1	26,5	28,2
26	162,8	167,4	171,5	170,2
27	22,2	24,1	24,7	24,9
28	36,9	41,5	41,3	41,6
29	8	9,7	10,3	10,2
30	17,5	22,9	21,7	21,9
31	42,4	42,7	46,2	46,5
32	29,3	32,5	32	31,6
33	49,6	50,4	50,6	49,7
34	14,9	16,2	17,6	17,6
35	33,1	34,1	38,2	39,8
36	14,1	15,9	16,5	16,9
37	11,9	13	14,6	15,4
38	32,7	35,9	35,6	36,3
39	94	94,6	100,2	100,3
40	273,2	273,2	273,1	273,2

Change of summarized area of thermokarst lakes in discontinuous permafrost zone

Pilot territories		PT-1	PT-2	PT-3	PT-4	PT-5	PT-6
Total area of lakes, ha	1973 1984 1988	2155,1	3673,2	2664,1	3777,0	3165,7	3864,2
	2001 2005	1685,5	3234,8	2644,7	2921,7	2892,4	2759,6
Total area decrease of lakes, ha		-469,6	-438,4	-19,4	-855,3	-273,3	-1104,6
k, %		-22	-12	-1	-23	-9	-29

k - Normalized total area of lakes decrease

Samples of lakes areas changes in continuous permafrost zone Arctic tundra, PT-10, PT-11

PT-10

Total area of lakes :
1984 – 3421,2 ha,
2006 – 3765,3 ha.

Total area increase of lakes in PT-10:

344,1 ha

**Normalized total area
increase
k = 10%**

PT-11

Total area of lakes :
1984 – 3463,5 ha,
2006 – 3761,0 ha.

Total area increase of lakes in PT-11:

297,3 ha

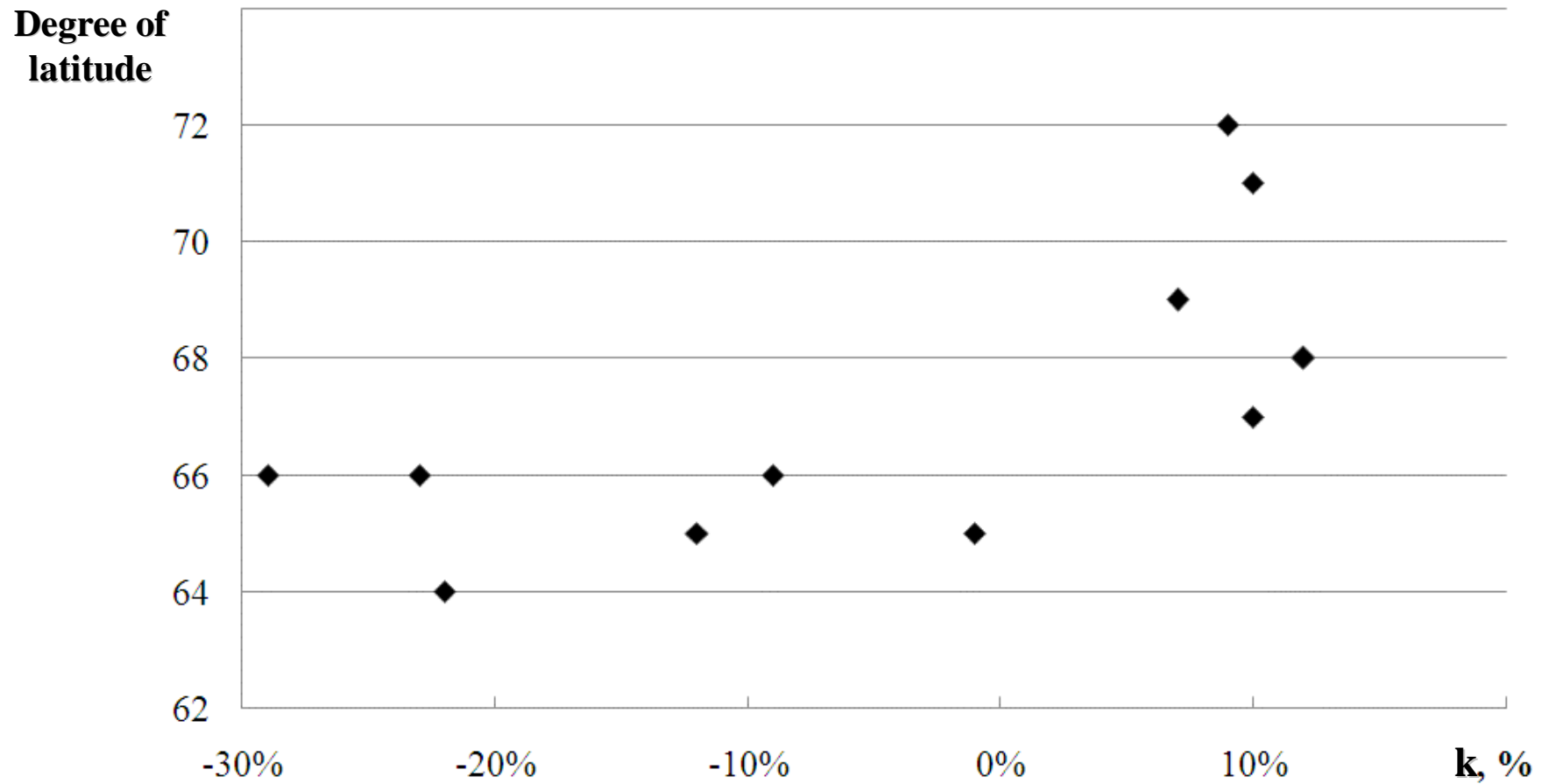
**Normalized total area
increase
k = 9%**

Changes of summarized area of thermokarst lakes in continuous permafrost zone

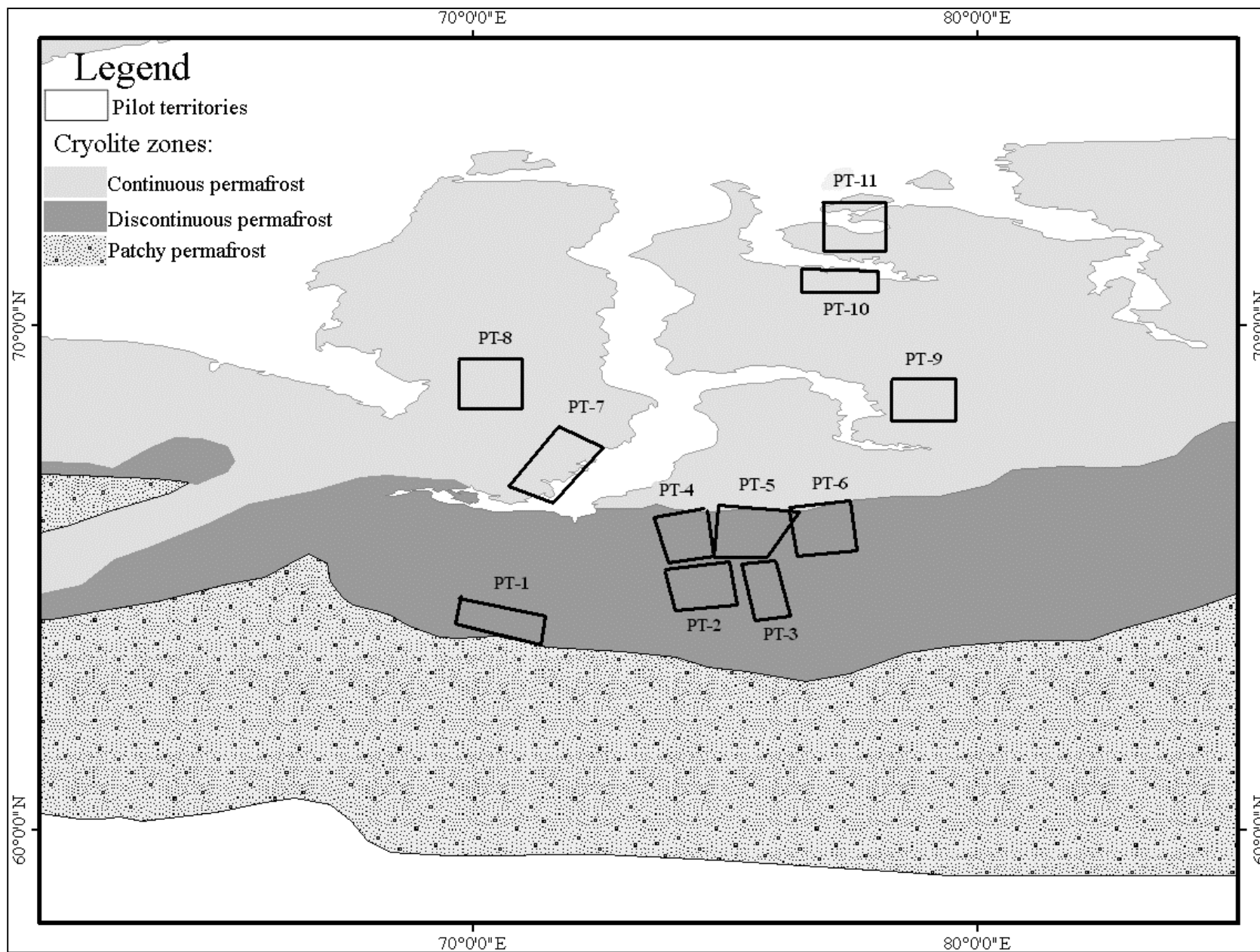
Pilot territories		PT-7	PT-10	PT-8	PT-9	PT-11
Total area of lakes, ha	1973 1984	6292,7	3421,2	1899,1	3566,9	3611,85
	2006	6965,5	3765,3	2035,0	3998,9	3975,9
Volume of sample		80	40	30	40	60
Total area decrease of lakes, ha		672,8	344,1	135,9	432,0	364,1
k, %		10,7	10	7	12	9

k - Normalized total area of lakes increase

Normalized value of thermokarst lakes areas depending on degree of latitude



Map of West-Siberian permafrost zoning and pilot territories

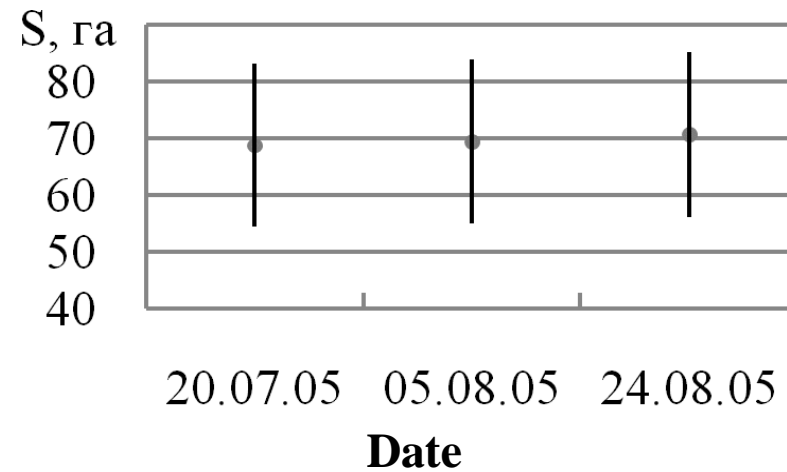
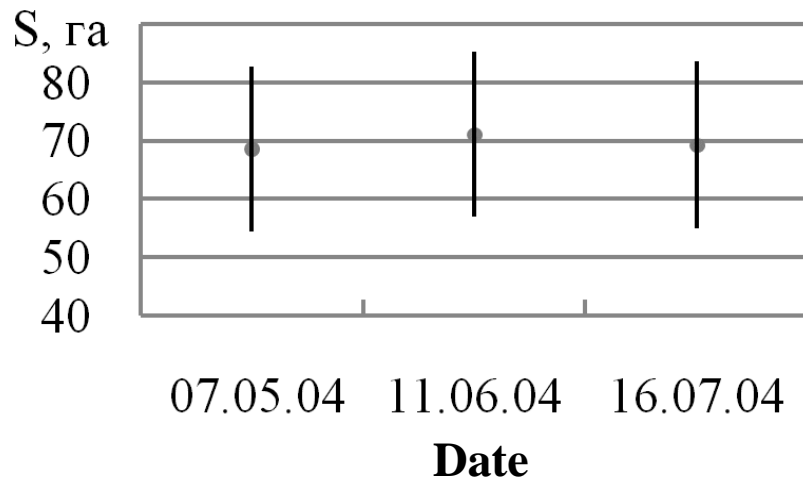


**Analysis of influence
of intraseasonal
geocryologic changes**

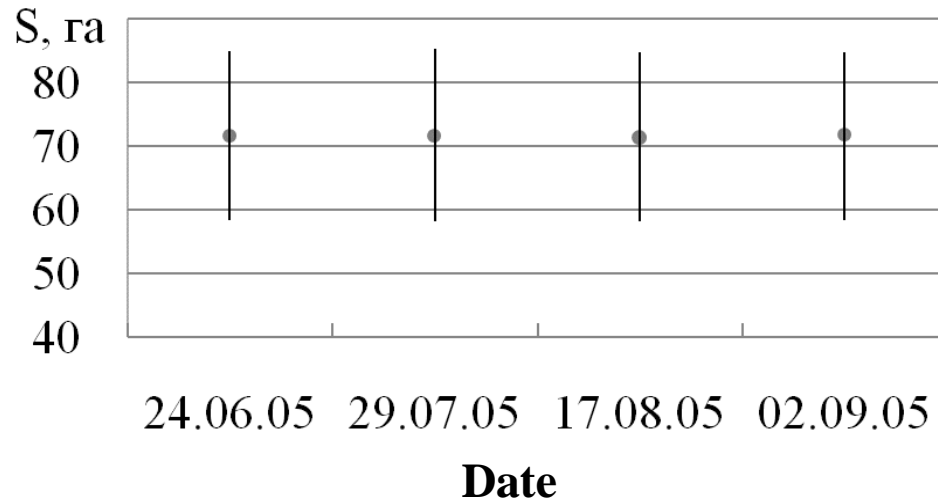
Intraseasonal changes of thermokarst lakes areas using radar images, discontinuous permafrost

Pilot territories	Year	Month				
		May	June	July	August	September
PT-1	2004	68,5	71,0	69,2		
	2005			68,7	69,4	70,6

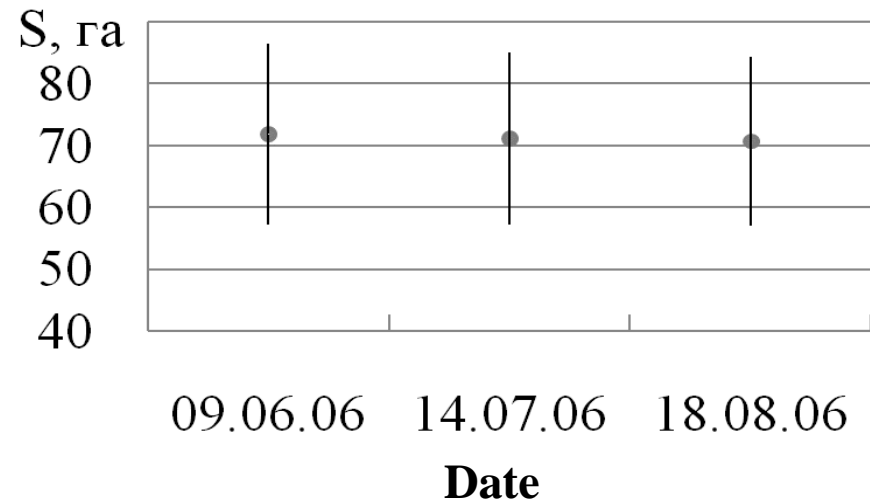
**PT-1
2004 -2005**



Intraseasonal changes of thermokarst lakes areas using radar images ERS-2, continuous permafrost



PT-8
2005 -2006





**Спасибо
за внимание!**