

Climate change impact on water exchange processes in the cryolithozone of the North-East of Russia

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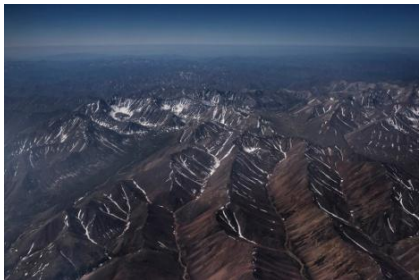
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Relevance

- The flow of rivers in the Arctic zone is most sensitive to global warming.
- The mechanisms leading to observed changes of hydrological regime **have not been identified.**



Where's the truth?

Main hypotheses

Main hypotheses in the context of increasing river discharge in the Arctic regions:

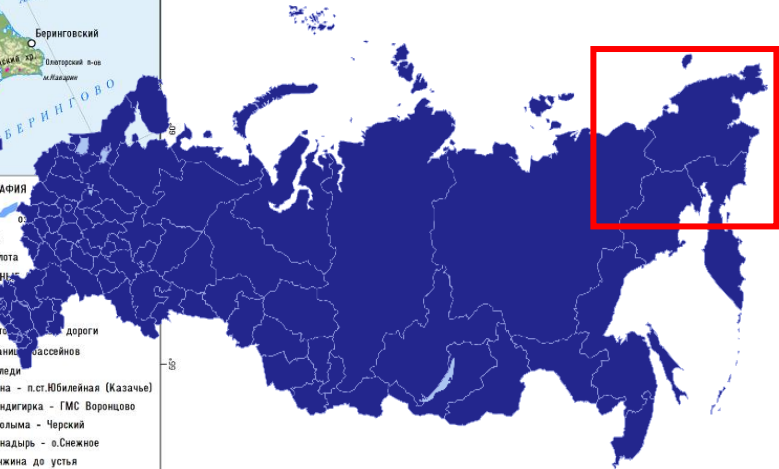
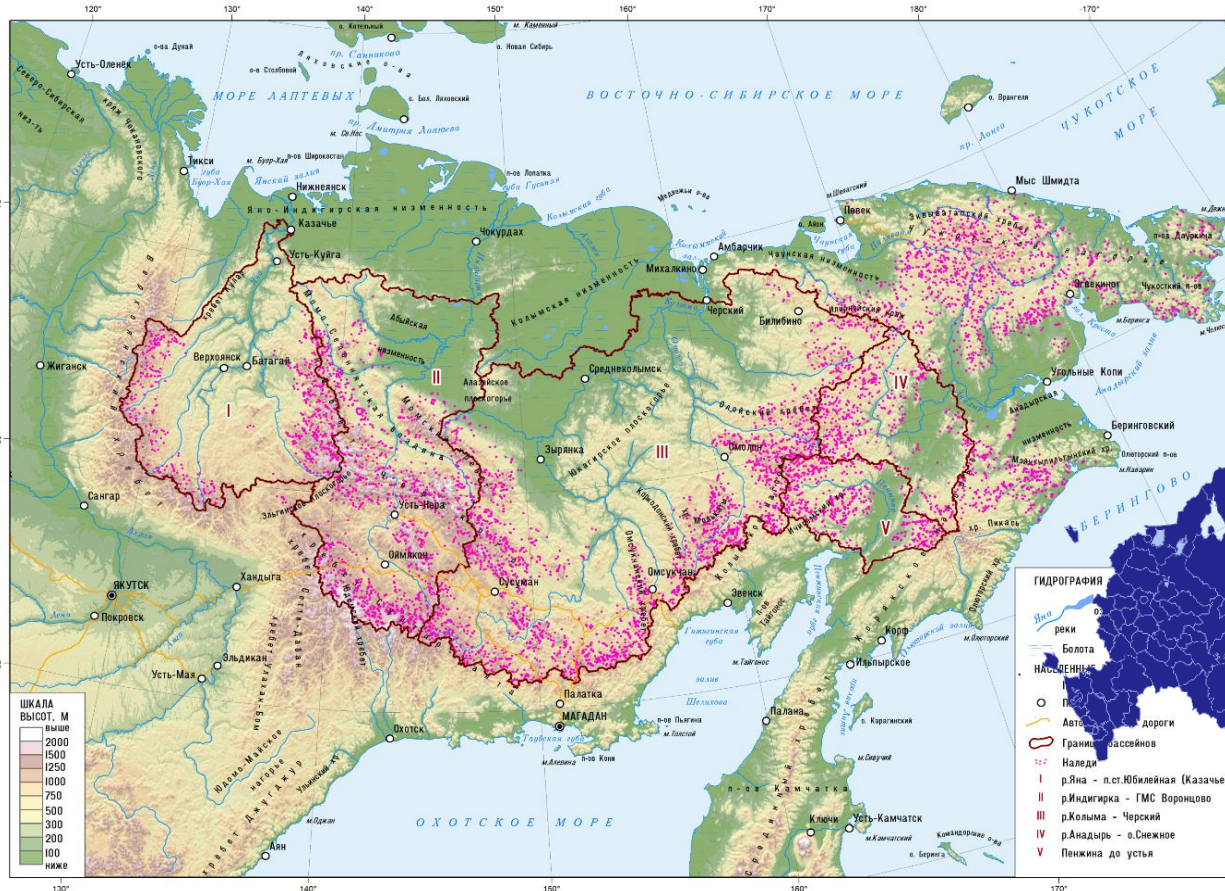
- 1) **permafrost degradation** (Romanovsky et al., 2010; Walwoord et al., 2012)
- 2) melting of **glaciers** (Liljedahl et al., 2017)
- 3) **increase** in precipitation (Dyurgerov, Carter, 2004).

The aim of this research is to study the climate change impact on water exchange processes in the cryolithozone of the North-East of Russia.

Study area

The North-East of Russia

high-altitude parts of the Yana, Indigirka, Kolyma Kiver basins, and the Chukchi Peninsula





Data

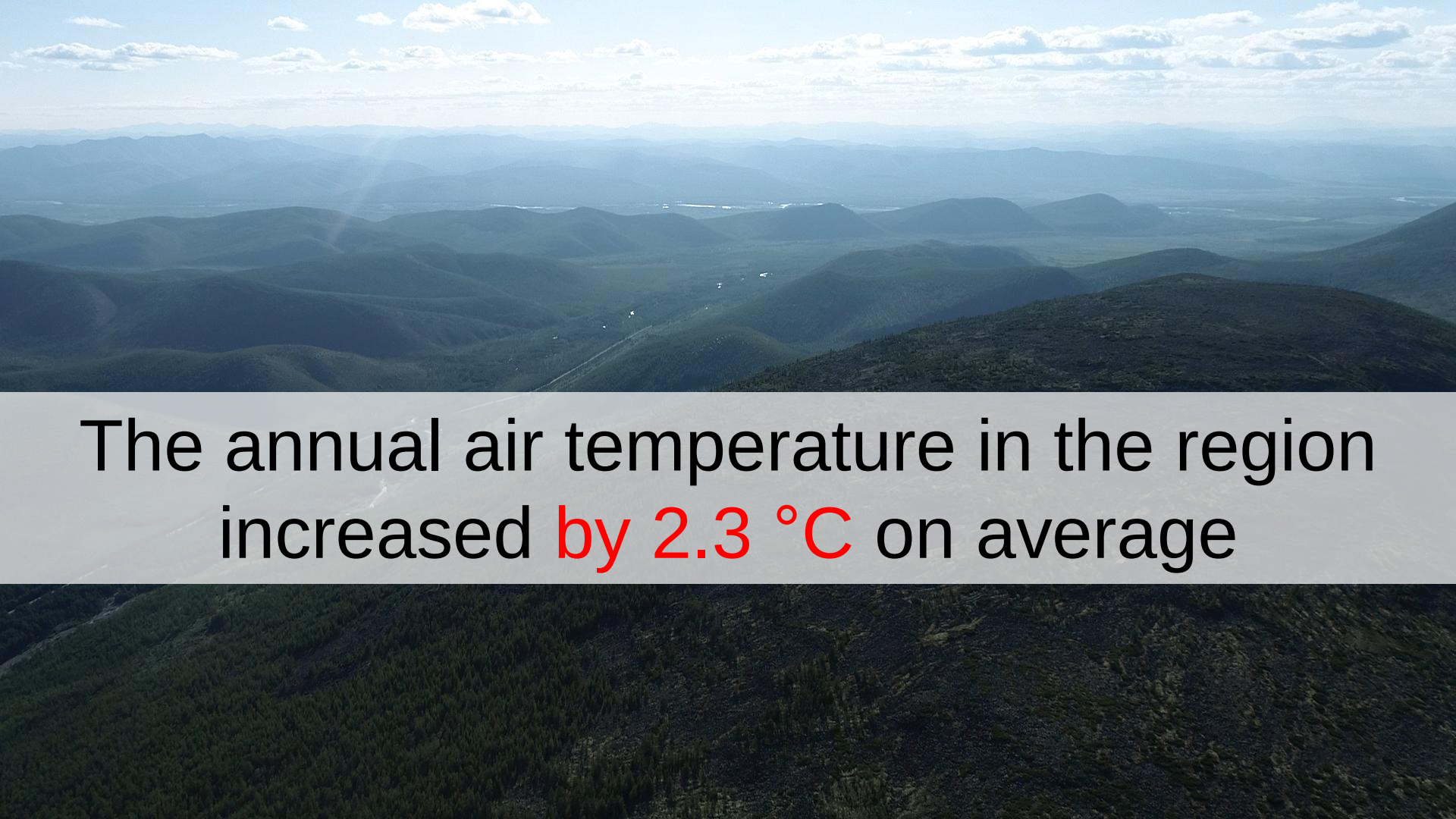
The analysis of changes in the characteristics

- the climate (air temperature, precipitation),
- water discharge,
- soil temperature at the 80 cm depth
- river-ice cover for a period of 50 years (1966-2018)
- historical and modern data of aufeis area.

Method

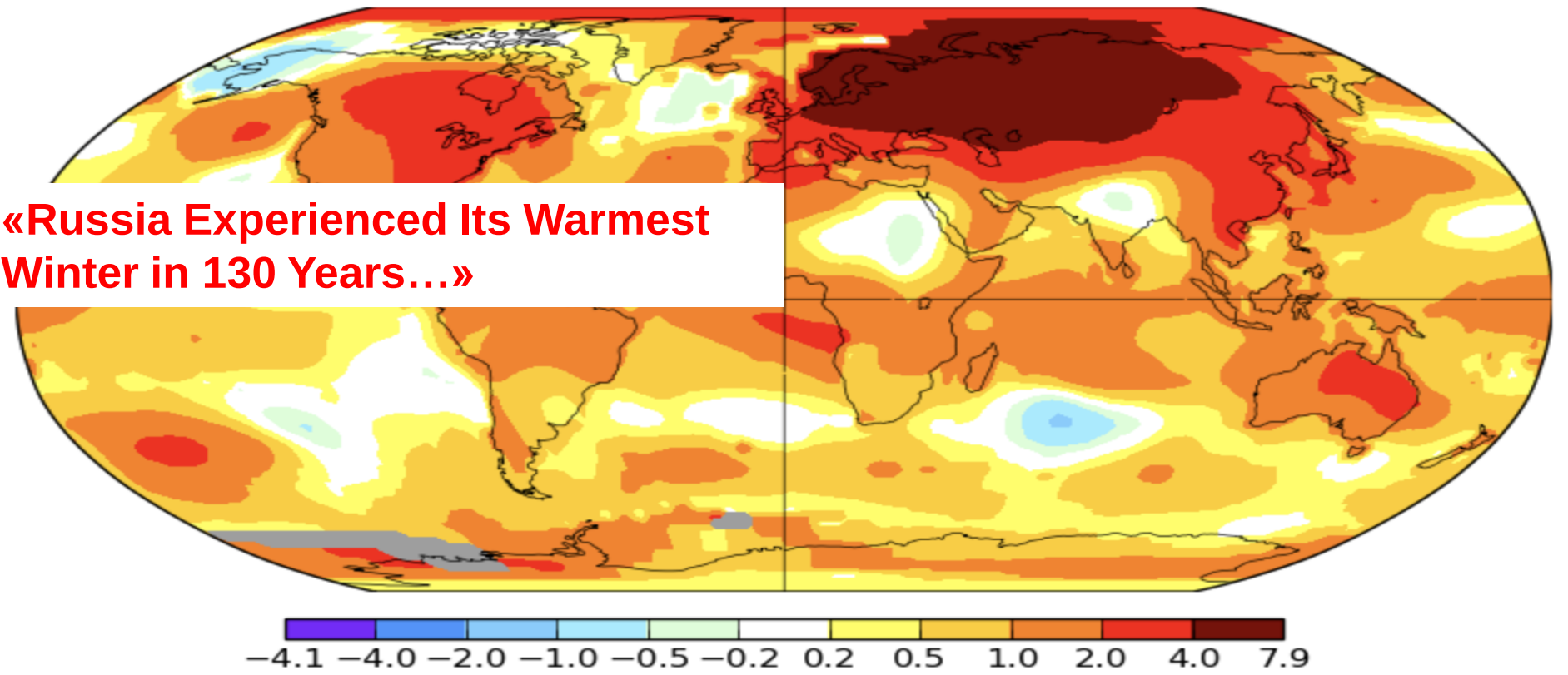
Mann-Kendall and Spearman rank-correlation tests, at the significance level of $p < 0.05$ (Mann, 1945; Kendall, 1975).

The Pettitt's test (Pettitt, 1979) was applied to look for the presence of a change point in the time series at $p \leq 0.05$.



The annual air temperature in the region
increased **by 2.3 °C** on average

«Russia Experienced Its Warmest Winter in 130 Years...»

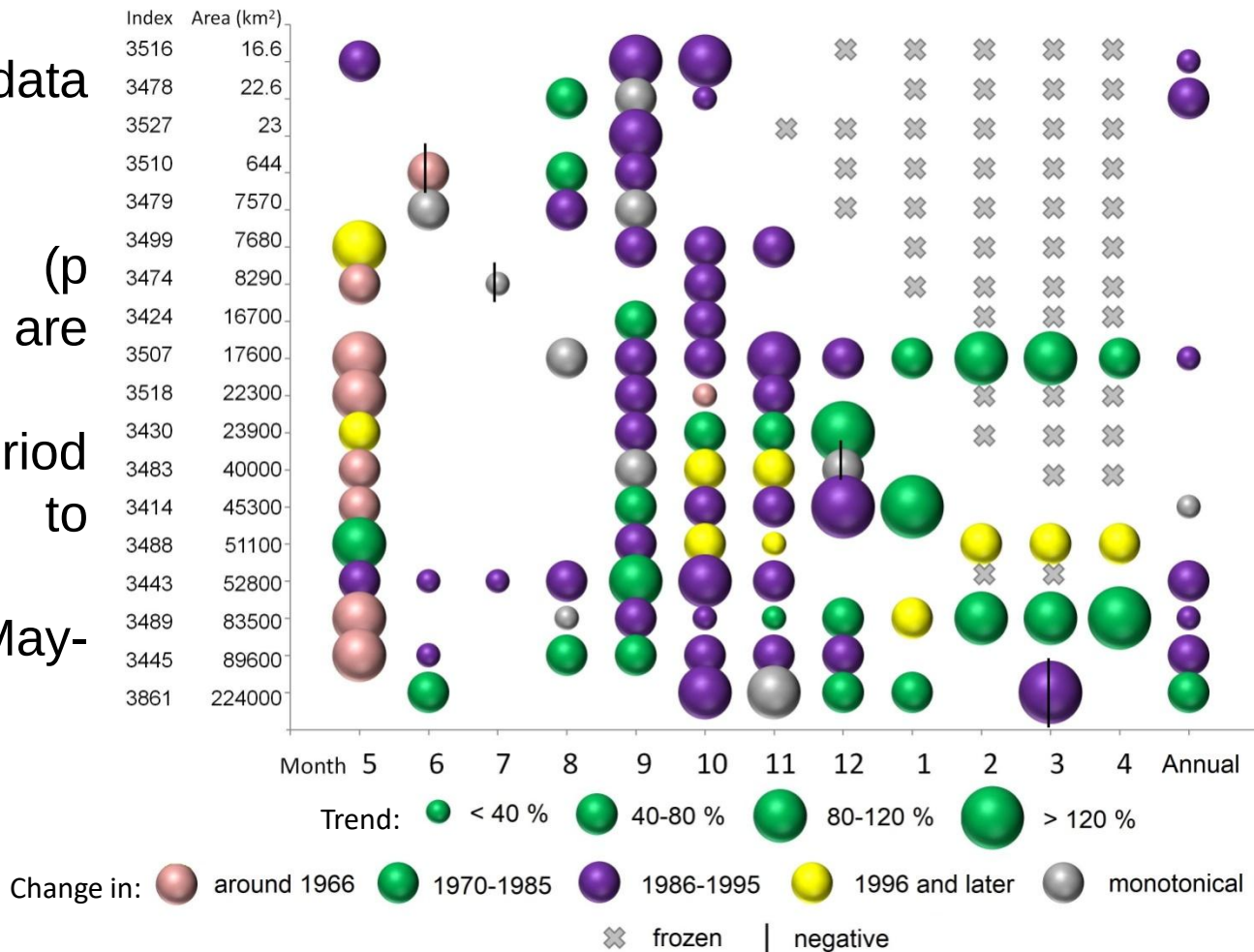


The Yana and Indigirka River basins

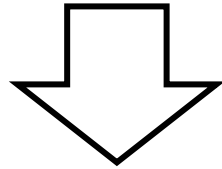
Analysis of the runoff data (1936-2015):

statistically significant ($p < 0.05$) positive trends are observed during:

- the autumn-winter period (from September to December) and
- the spring flood (May-June).



**Changes in the hydrological cycle and water exchange
processes in the cryolithozone**

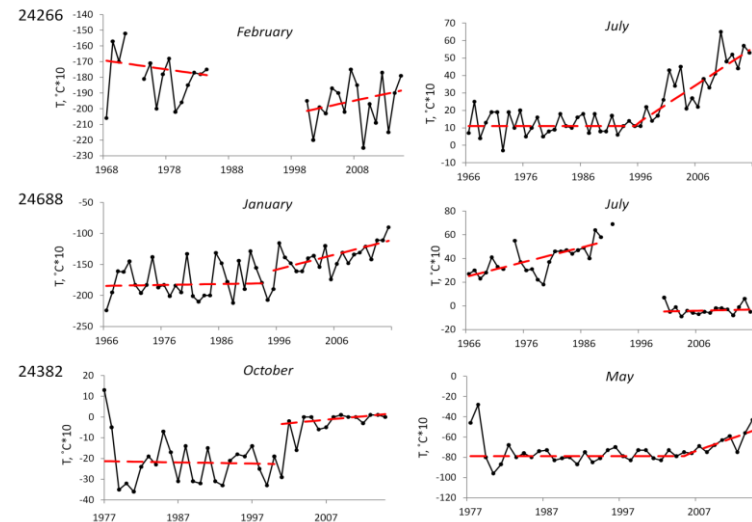


Only permafrost?

Soil temperature (80 cm), active layer thickness

- On average, the annual soil temperature increased by 1.7 C for the region
- Not enough observations
- Errors of observation
- There are no general trends

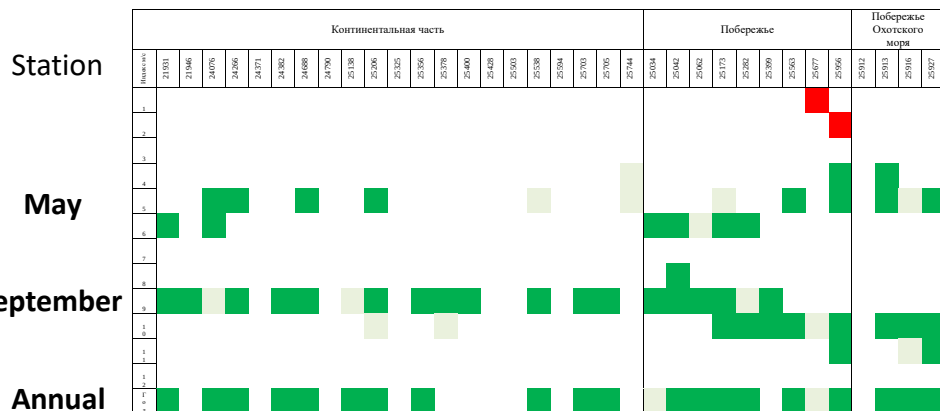
	1	2	3	4	5	6	7	8	9	10	11	12	ALT	D
24266 Verhovansk, 1966-2015														
N	31	31	33	33	48	50	49	49	50	49	49	34		
M	-16.8	-18.9	-18.6	-14.3	-6.6	-1.4	2.1	2.9	1.3	-0.5	-5.8	-12.4		
T	-1.8	-2.3	-2.4	1.2	3.3	2.5	3.8	3.7	1.7	0.2	0.6	-1.2	45	18
Y					2003	1999	1996	1996	1998					
24688 Oymyakon, 1966-2015														
N	47	45	44	46	35	38	40	41	43	48	46	47		
M	-16.1	-17.5	-17.4	-13.8	-5.3	-1.0	2.3	3.1	1.5	-0.2	-4.9	-11.7		
T	7.6	6.3	5.0	2.5	-1.8	-2.3	-4.2	-3.5	-1.0	0.7	4.5	7.3	-77	32
Y	1995	1995	1990	1983						1977	1983	1994		
24382 Ust-Moma, 1977-2015														
N					34	38	38	38	38	39	38			
M					-7.3	-2.5	0.3	1.0	0.3	-1.5	-6.7			
T					1.7	1.1	1.1	1.0	1.0	3.0	5.9		6	40
Y					2006	2006	2006	2001	2001	2001	2002			



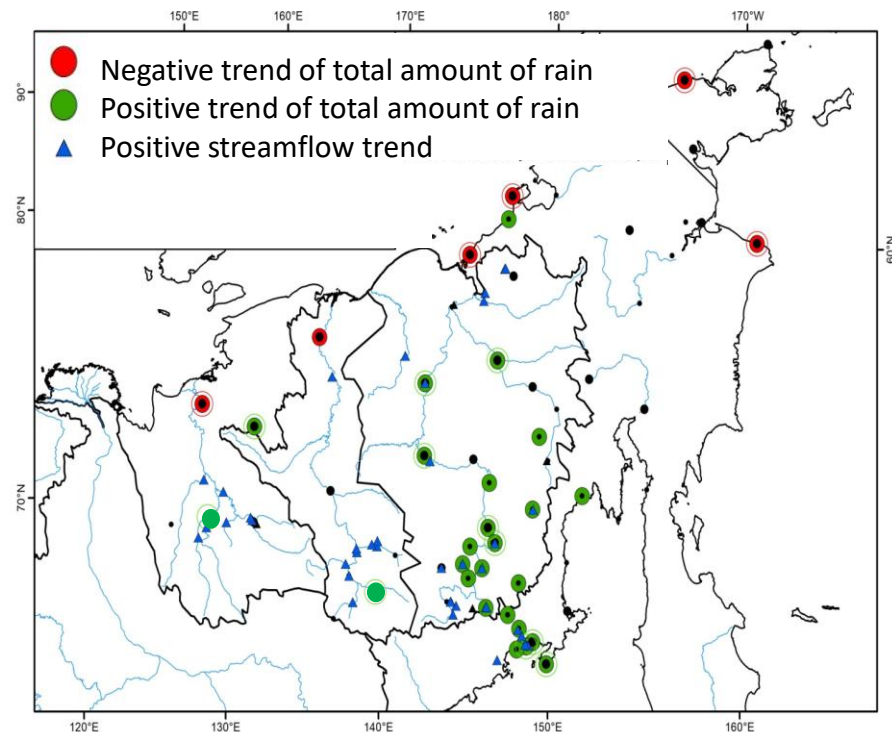
Increase in the proportion of liquid precipitation in the transition months

The increase in air temperature led to a change in the ratio of "rain-snow"

Share of **rain** is increasing in September and annually



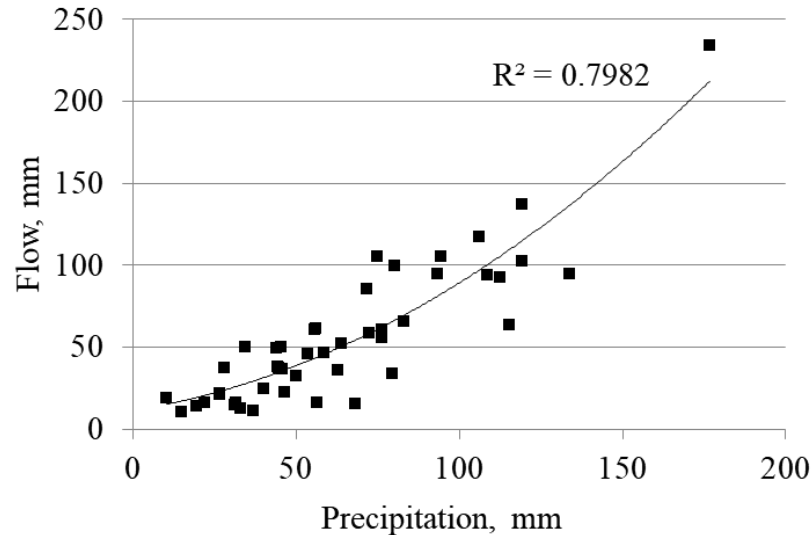
Total amount of rain is increasing in August and September



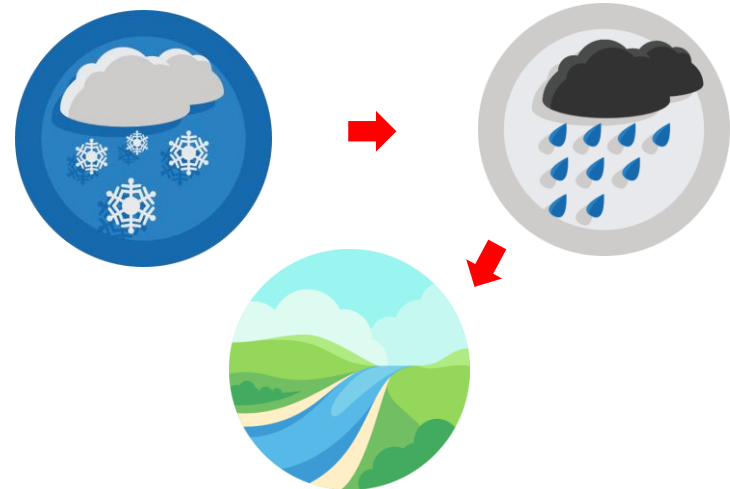
The amount of solid precipitation has decreased by about 20-25 mm, half of which falls as rain, and the other half is the result of a decrease in precipitation at the end of winter.

The increase in low-water runoff is due to the transition of the precipitation type from solid to liquid and the corresponding increase in runoff in September, which continues in the following months.

The calculated correlation coefficients between the precipitation and the runoff in August and September for small and medium-sized catchments located near meteorological stations vary from 0.45 to 0.80.



**Dependence of streamflow in
September on rain at small catchments**



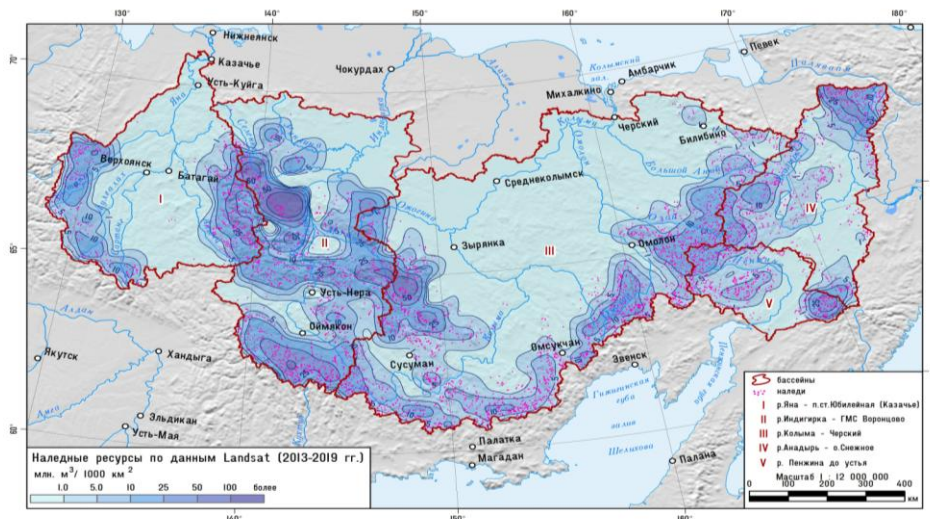
The high water is observed at an earlier time in the spring.

Interestingly, both the "loss" of snow and the earlier timing of the spring flood in May do not lead to a decrease in runoff in June.



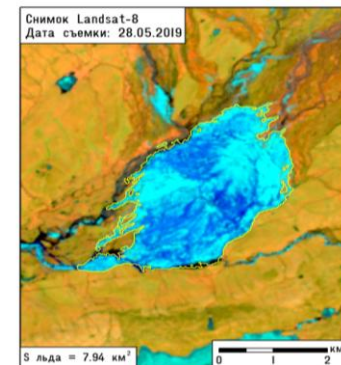
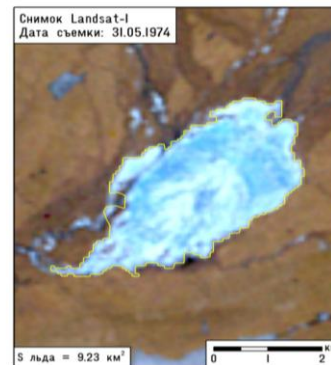
This may indicate the increase contribution of the melting of cryosphere objects such as glaciers and aufeis.

Increase in the amount of aufeis and decrease in the area when comparing historical Cadastre data (1958) and Landsat data (2013-2019)



The ratio of the amount and area of aufeis according to the Cadastre and satellite observations

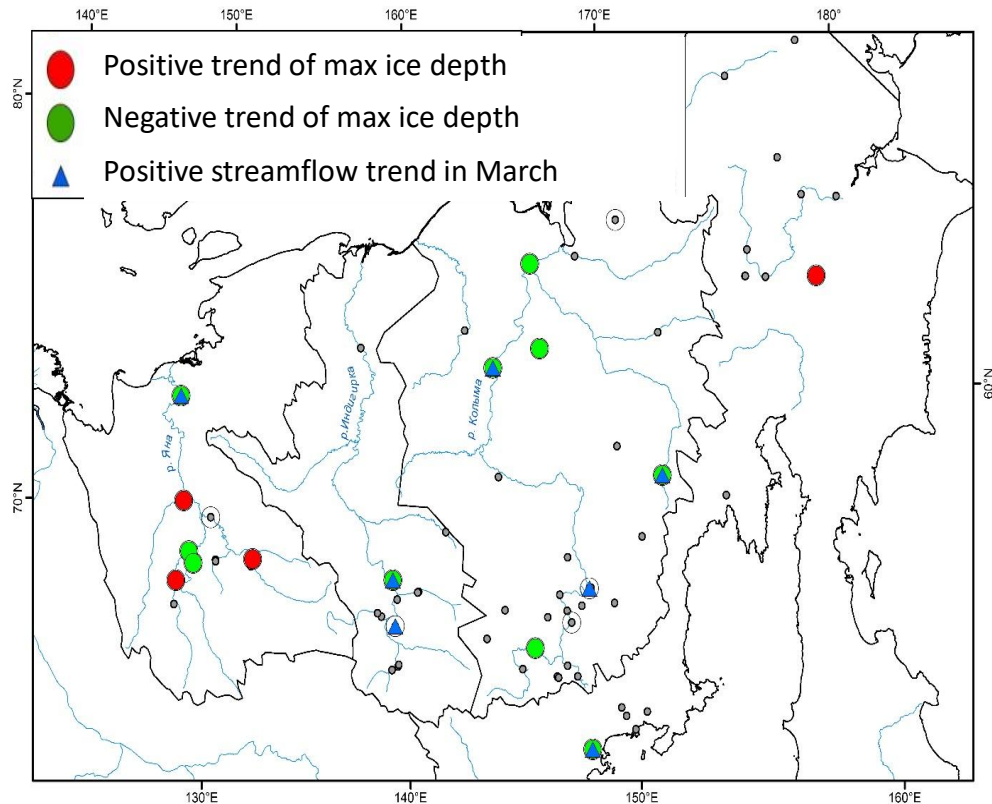
IN TOTAL		
Cadastre (1958)	4642 (7181)	↑1.3 (↓2.0)
Landsat (2013-2019)	6217 (3579)	



There are significant changes in the characteristics of the river ice cover and the time of the river ice formation



On average, the decrease of river ice cover maximum depth was **39 cm (27%)** and the period of formation of river ice with a thickness of 60 cm (necessary for using winter roads for passenger cars) has shifted to later period **by 7-40 days**.

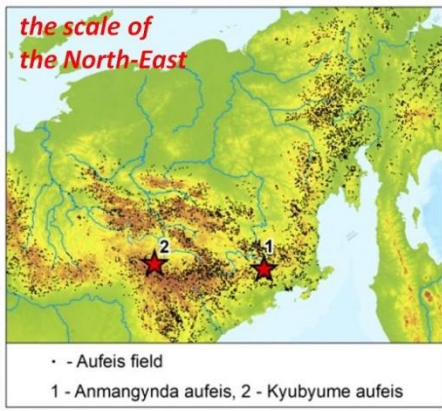
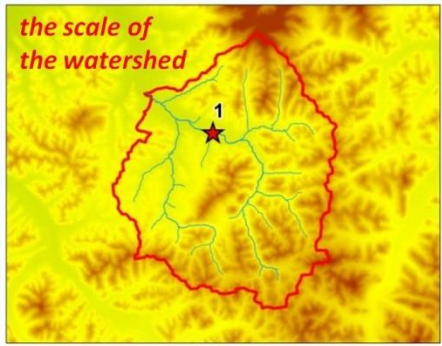
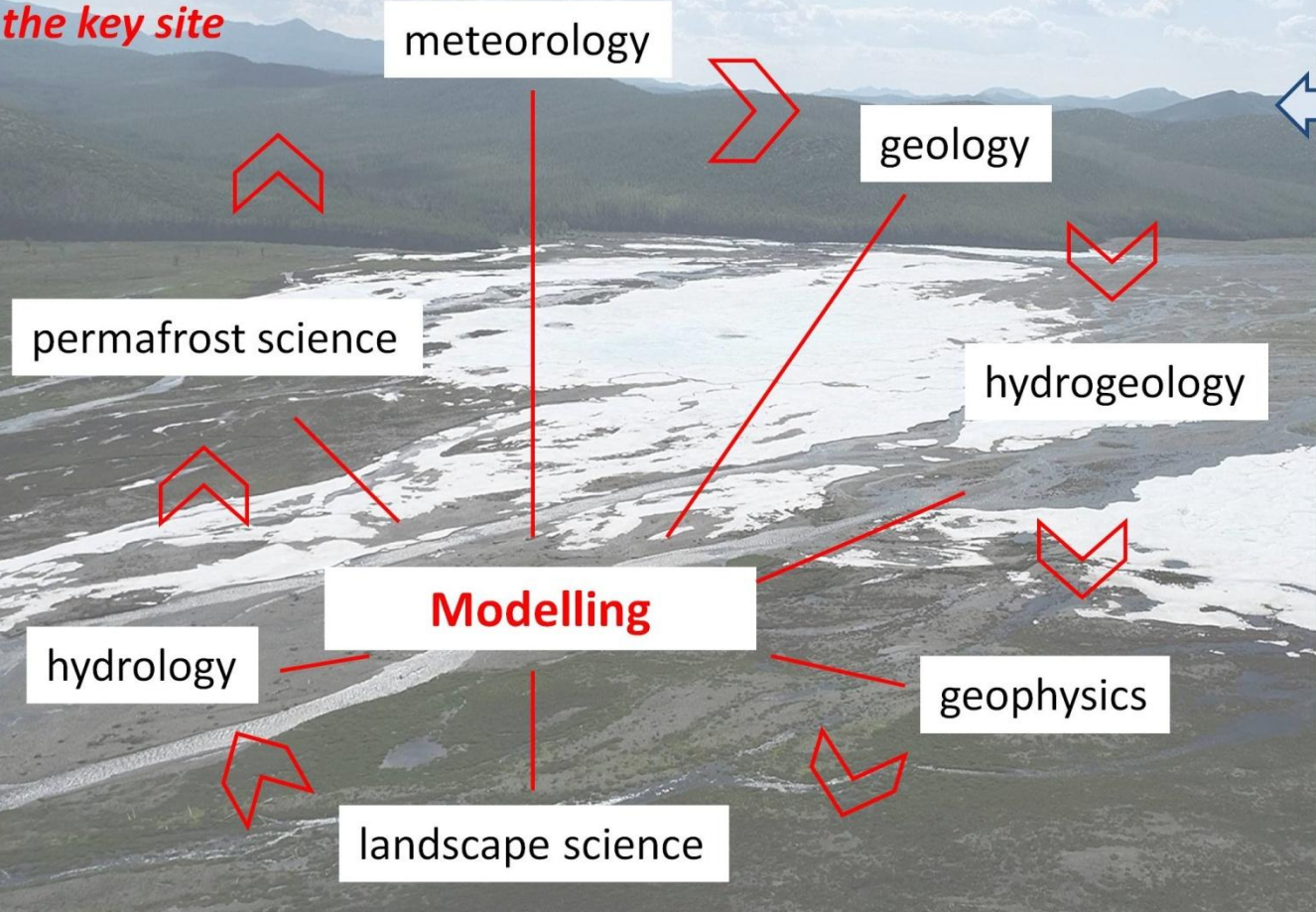


HOW TO STUDY?

The strategic goal is to complex study the permafrost-hydrogeological and hydrological conditions, the water-ice regime of rivers, permafrost conditions and the specifics of the development of cryogenic landscapes in a changing climate, transport, energy and industrial development of the North-East of Russia.

The main task is to create and develop new objects of observation and to conduct complex studies using modern methods, equipment and methods of data processing.

*the scale of
the key site*



**Dynamics,
climate change,
projections**

The authors of the report conduct field research at:

Renewal observation at the
**Kolyma Water-Balance
station** (Upper Kolyma)

*Continuation of historical observations
(1948-1997) of water balance elements at
the small representative catchment*

The Anmyngynda aufeis (Kolyma
River) to study the aufeis impact
on river flow

*Studying the interaction of surface and
underground waters in the context of
climate change*



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<https://www.youtube.com/watch?v=mehBEb2JFcA&t=2s>

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