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The Influence of Seasonal Climatic Parameters on the Permafrost Thermal Regime West Siberia, Russia

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Objectives

- to assess impact of climatic parameters' variability on frozen soil temperature (FST) and maximum seasonal thaw depth (STD) fluctuations for various grounds in different climatic conditions
- to reveal major climatic parameters affecting temperature regime of the FST and STD
- to detect recent climate changes essential for the permafrost regime

Methods

Time series of FST and maximum STD were de-trended and correlated to the climatic parameters: seasonal mean SAT, positive/negative temperature sums, and winter mean snow depth.

Cross-correlation functions were examined to reveal the factors of permafrost regime changes.

Relative effect of climate parameters on FST and maximum STD variations was evaluated using forward stepwise multiple regression. Statistical significance was estimated at 5% level.

Data

- Time series of **summer ground temperature** at 10 m depth from different experimental sites with various types of ground: mire (1979-2000); sand field (1979-2002); dry tundra (1979-2000) at 10 m depth in Marre-Sale

- Time series of maximum **active layer depth** from different experimental sites with various types of ground: mire, peat and tundra (1972-2005) in Nadym; dry tundra (1979-2005) in Marre-Sale. Both sites are located in West Siberia; the data courteously provided by Dr. A.Vasiliev.

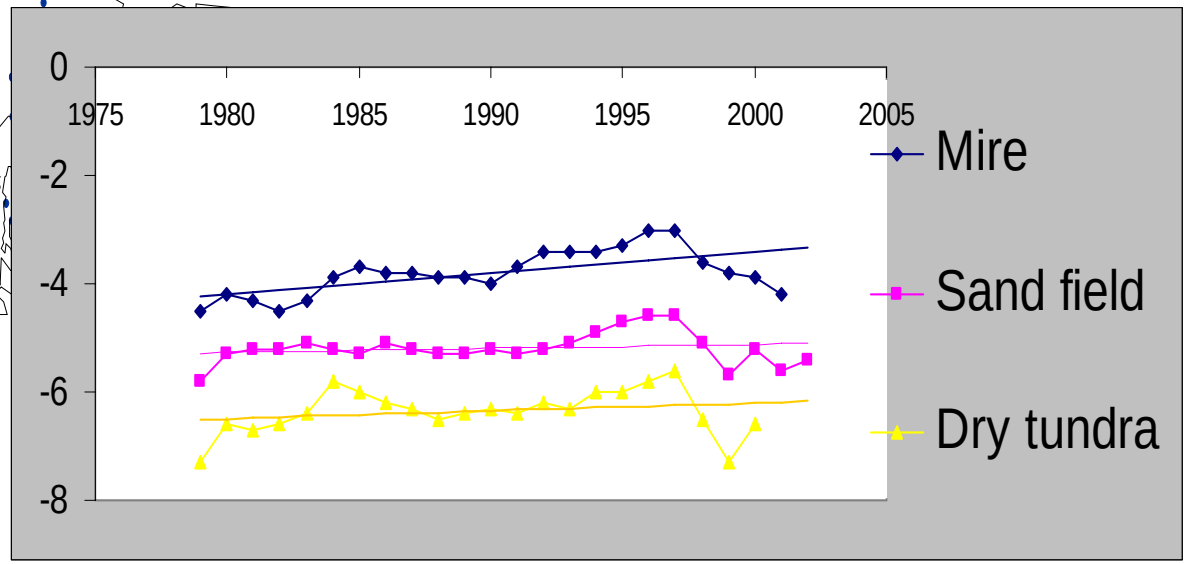
- Climate Parameters:

  Monthly mean air temperature time series and winter (December-March) mean snow depth data from meteorological stations Marre-Sale (1972-2005), Nadym (2000-2005), Hoseda-Hard (1972-1999), Berezovo (1972-2001), Surgut (1970-2005), Salekhard (1970-2005), Tarko-Sale (1970-2005)

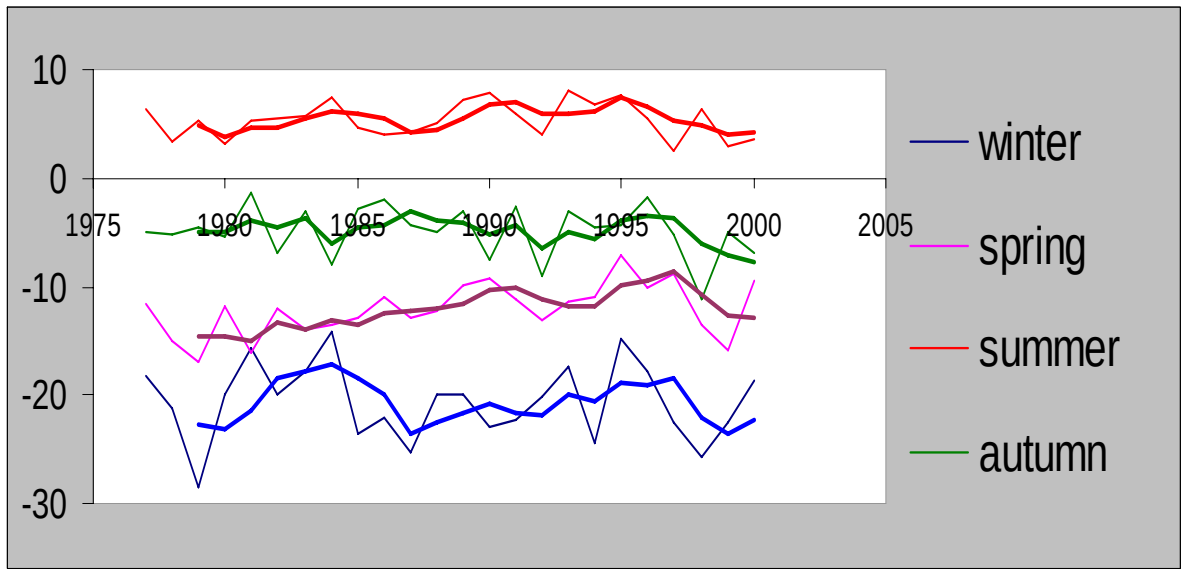
  Average winter snow depth, derived from the daily data collected by first-order meteorological stations in 1936-2001 (Russia Institute of Hydrometeorological Information –RIHMI).

Marre-Sale

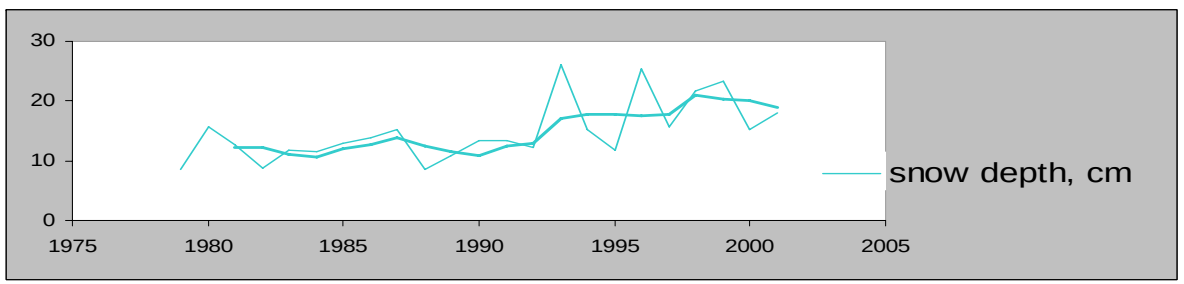
Interannual variations of summer ground temperature at 10m depth for different types of landscape (annual and linear trends)



Interannual variations of seasonal mean air temperature (annual and 3-year running mean)



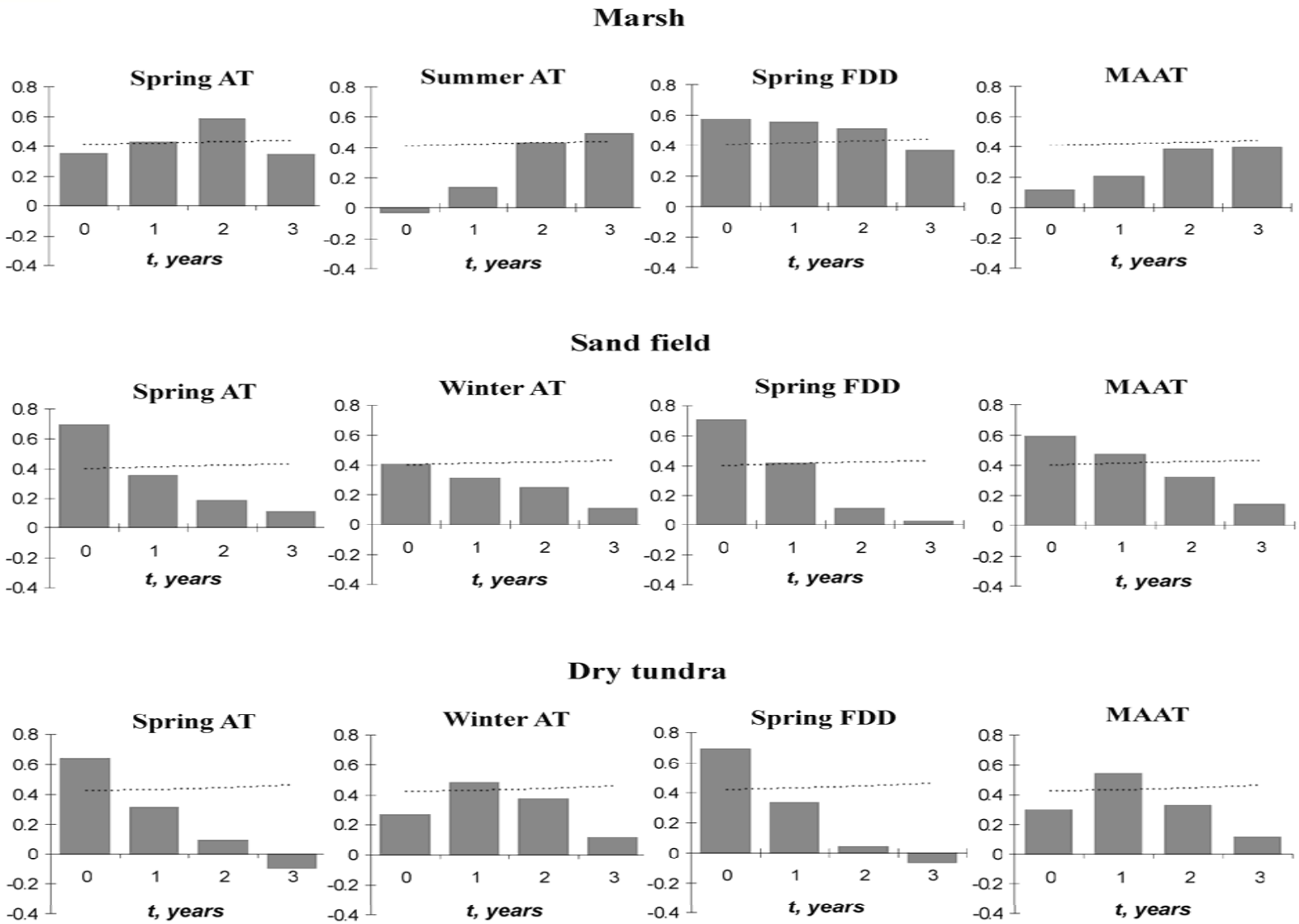
Interannual variations of December-March snow depth

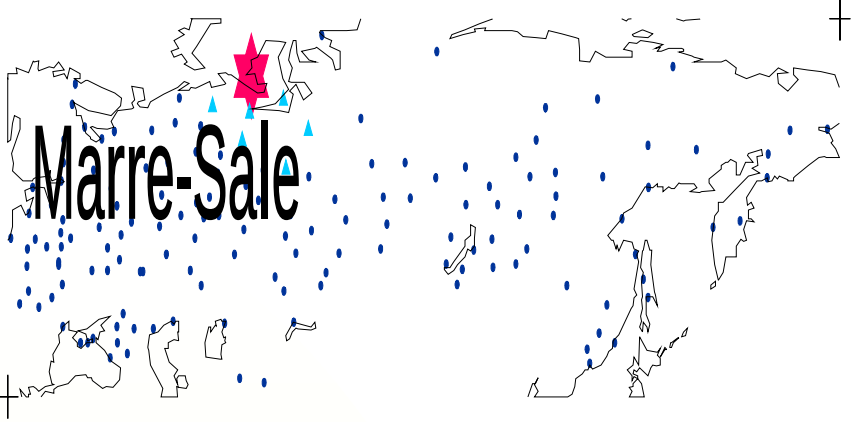


Marre-Sale

Cross-correlation functions summer ground temperature at 10m - climate parameters for different types of landscape.

Purple line indicates 95% confidence level



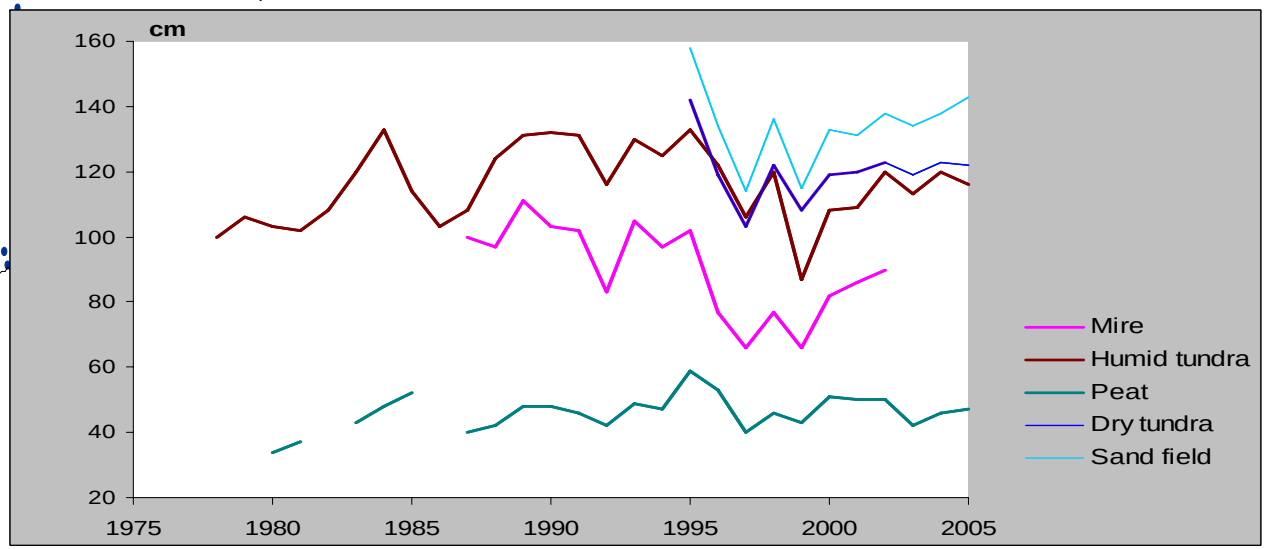


Summary of Stepwise Regression:

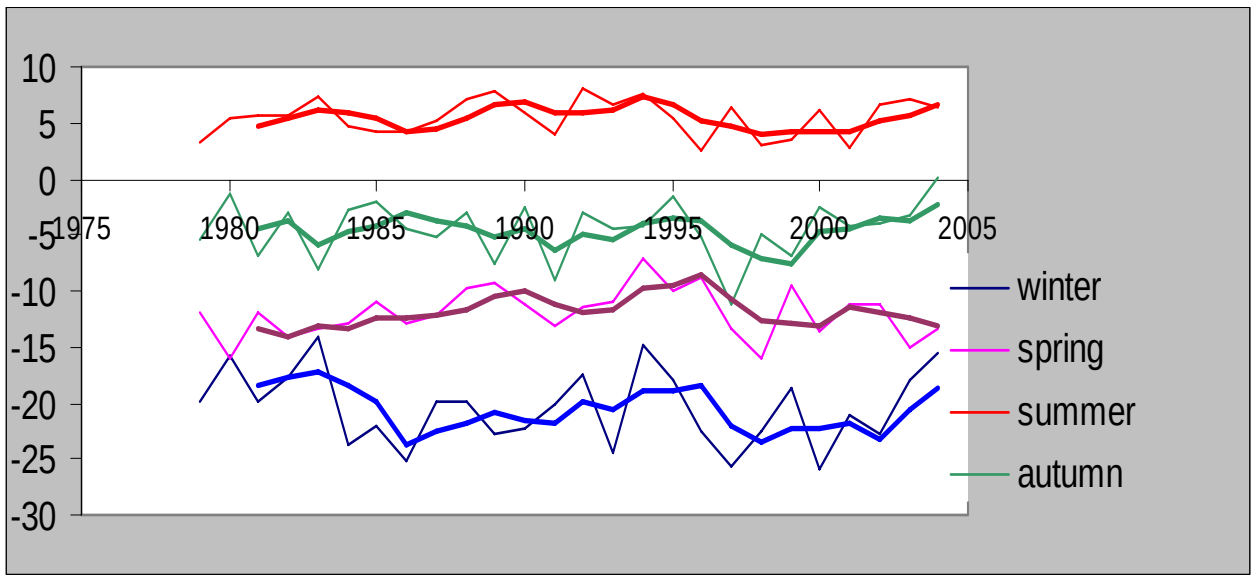
summer ground temperature (at 10m) - climate parameters for different types of landscape

Terrain	Parameters	B	Multiple R	Multiple R-square%	R-square Change%	p-level
Dry tundra	FDD_{spring}	0.12	0.64	41	41	0.00
	$T_{win\ (-1)}$	0.05	0.77	60	19	0.01
Marsh	$T_{spring\ (-1)}$	0.06	0.66	44	44	0.02
	$T_{spring\ (-2)}$	0.08	0.78	61	18	0.00
	FDD_{spring}	0.07	0.85	72	10	0.02
Sand field	FDD_{spring}	0.07	0.71	50	50	0.00
	$T_{spring\ (-1)}$	0.05	0.81	66	16	0.01

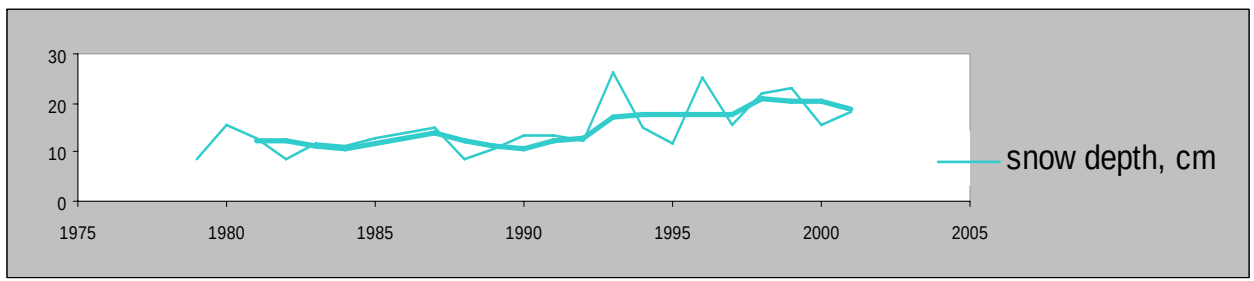
Interannual variations of maximum active layer depth for different types of ground



Interannual variations of seasonal mean temperature (annual and 3-year running means)



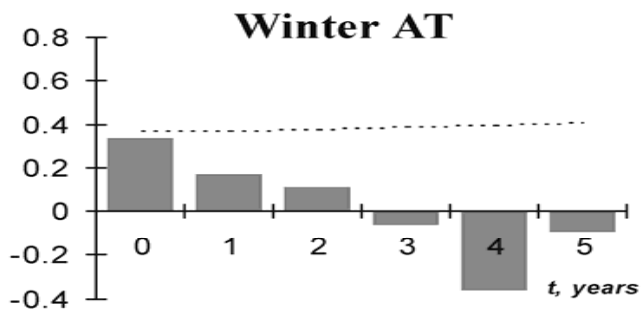
Interannual variations of December-March snow depth

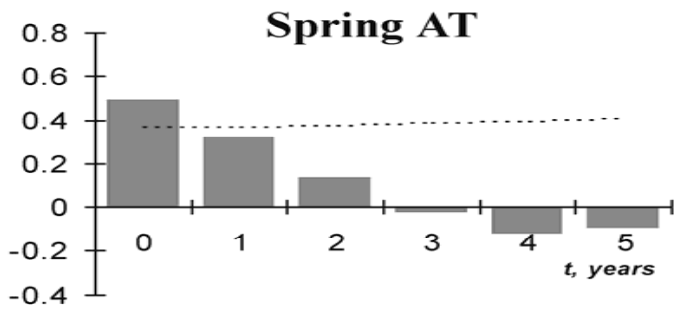


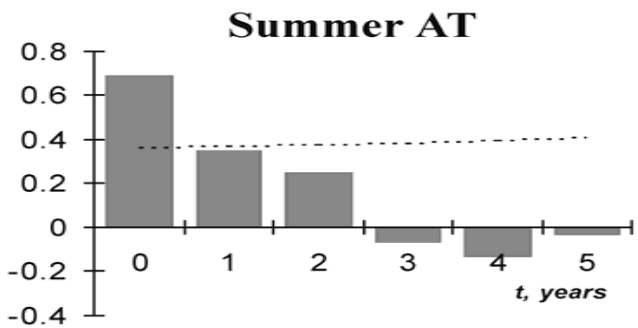
Marre-Sale

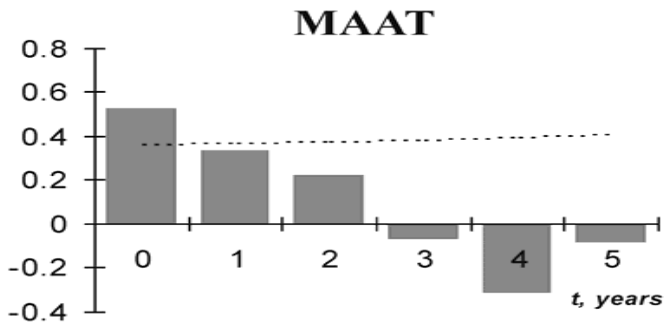
Cross-correlation functions summer ground temperature at 10m - climate parameters for different types of landscape.

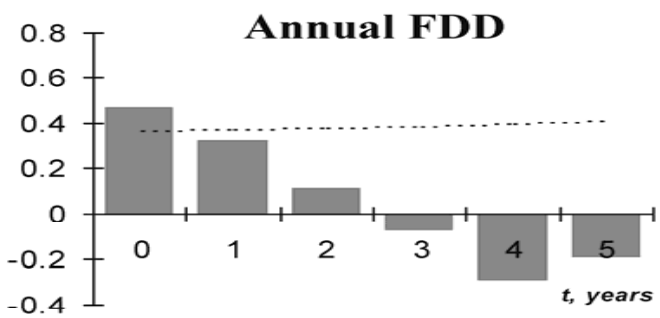
Purple line indicates 95% confidence level

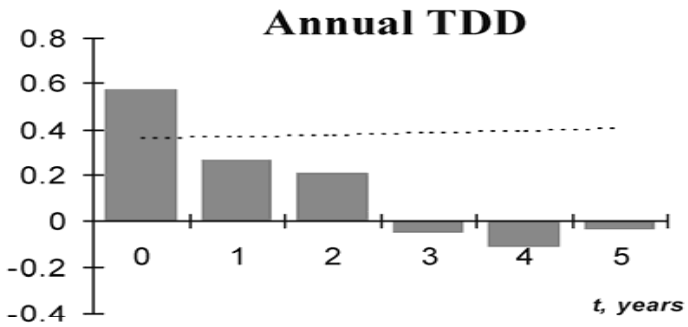


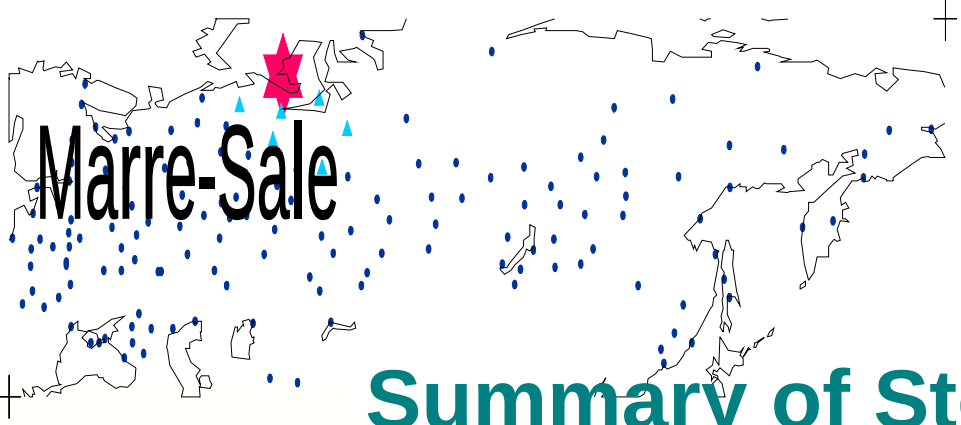








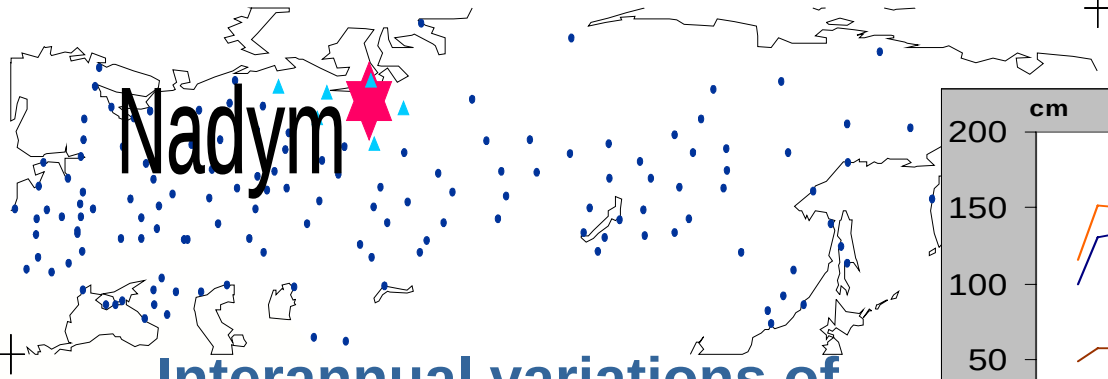




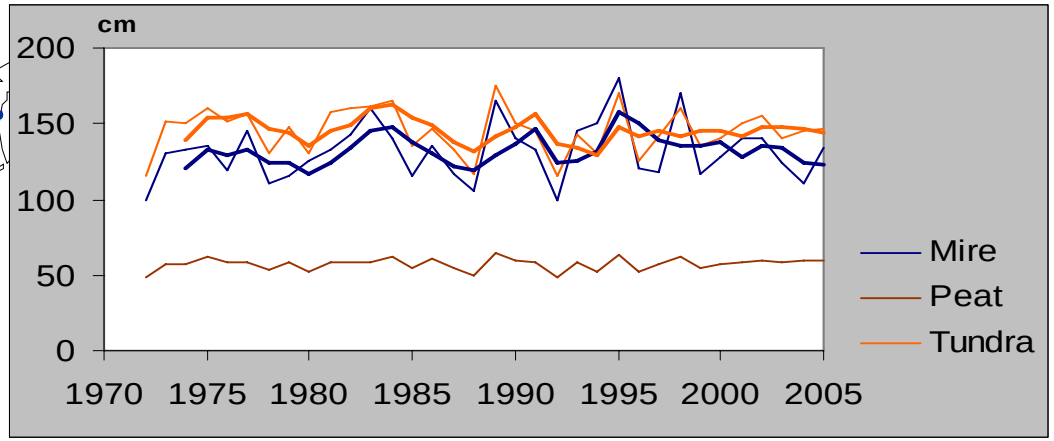
Summary of Stepwise Regression:

active layer depth - climate parameters for different types of landscape

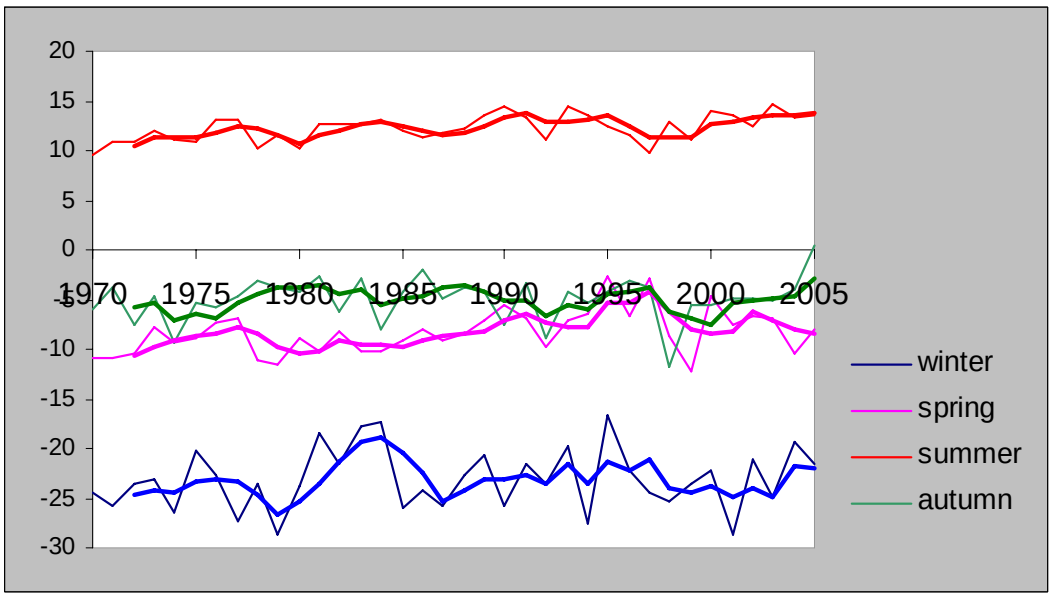
Terrain	Parameters	B	Multiple R	Multiple R-square%	R-square Change%	p-level
Humid tundra	T_{sum}	4.86	0.65	42	42	0.00
	$T_{sum\ (-1)}$	2.18	0.71	51	10	0.03
	$T_{sum\ (-2)}$	2.19	0.78	60	9	0.03
Marsh	T_{sum}	3.64	0.62	38	38	0.00
Peat	T_{sum}	1.81	0.53	28	28	0.00
	$T_{sum\ (-1)}$	1.43	0.68	47	19	0.01
	$T_{sum\ (-2)}$	1.17	0.77	59	12	0.03



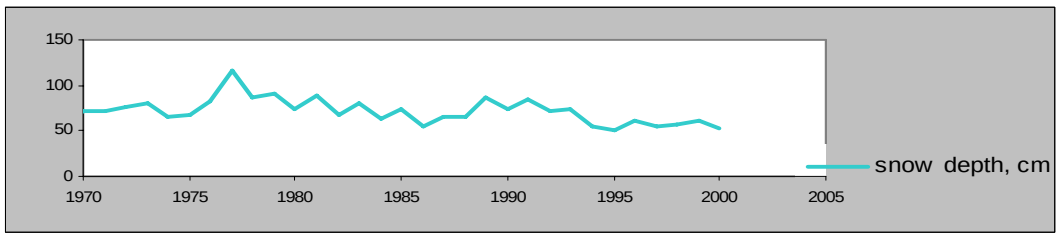
Interannual variations of maximum STD for different types of ground (annual and 3-year running means)

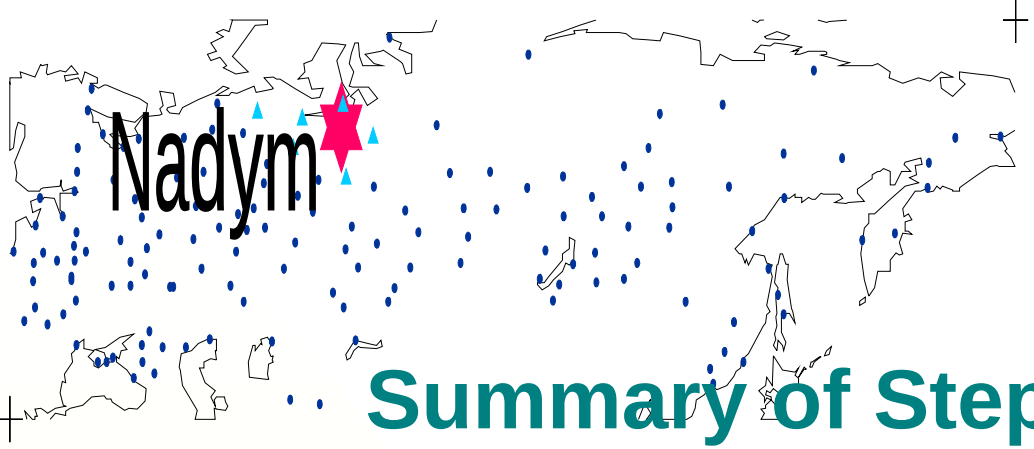


Interannual variations of seasonal SAT temperature (annual and 3-year running means)



Interannual variations of December-March snow depth





Summary of Stepwise Regression:

active layer depth - climate parameters for different types of landscape

Terrain	Parameters	B	Multiple R	Multiple R-square%	R-square Change%	p-level
Tundra	T_{win}	1.60	0.53	28	28	0.04
	T_{sum}	3.93	0.68	47	19	0.04
Marsh	T_{sum}	4.72	0.48	23	23	0.00
	T_{spr}	2.98	0.58	33	10	0.04
Peat	T_{sum}	1.02	0.39	15	15	0.04
	T_{win}	0.38	0.51	27	12	0.03

Conclusions

- Interannual variations of the active layer depth in the tundra zone of Western Siberia (Marre-Salle) are mostly related to air temperature of current summer and, at peatland and humid tundra, summer(s) of 1-2 preceding year(s). In the northern taiga zone of Western Siberia (Nadym), the active layer depth is also dependent on summer air temperature and, to less extent, spring and/or winter air temperature.

- Variations of ground temperature in summer at 10 meters depth are influenced, first of all, by the spring air temperature regime. Indirectly this might be also connected to snow accumulation and melting, as the melt water can increase the soil thermal conductivity and force the heating. Other important factors are characteristics of the spring thermal regime of previous 1-2 years(s). This implies that permafrost thermal anomalies of the current summer can be reinforced or weakened by the preceding years, depending on the sign of anomalies.

- Seasonal air temperature (in particular, summer and spring AT characteristics) explain more of the ALD and ground temperature variability than mean annual air temperature and annual TDD/FDD. In total, the most important factors for changes in the permafrost regime are spring and summer air temperature. These dependencies of the permafrost regime on meteorological parameters differ by regions and landscape type within a region and suggest that analyses of the impact of future climate change must take into account both seasonal tendencies and terrain type.