

Changes of snow cover in North Eurasia: tendencies and consequences

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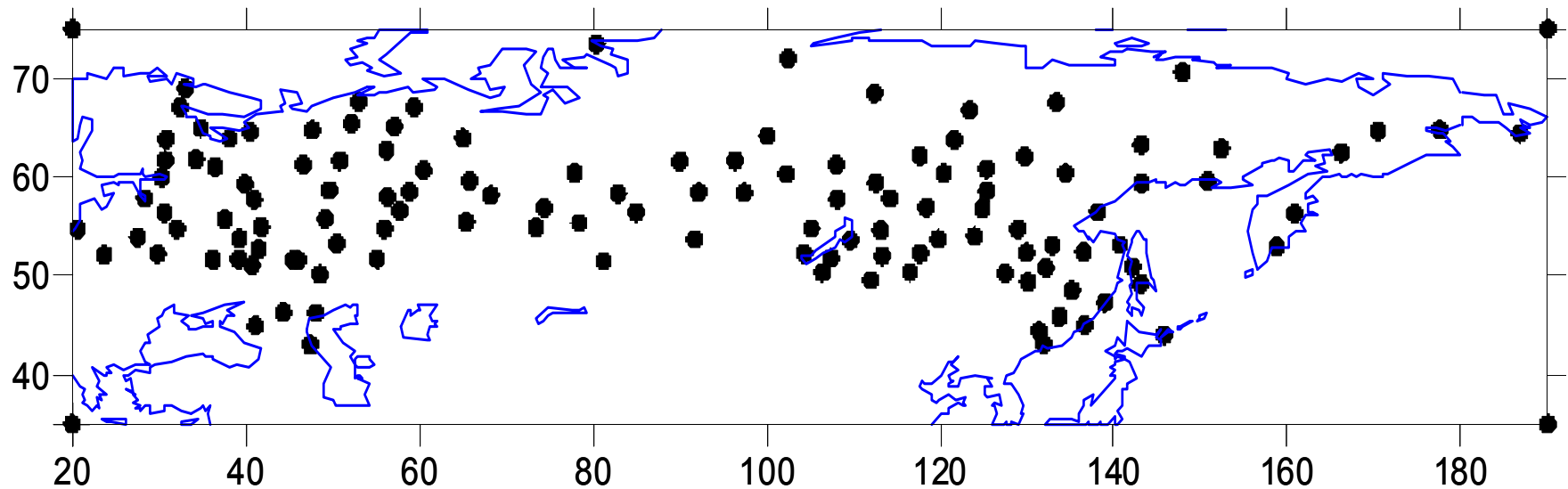
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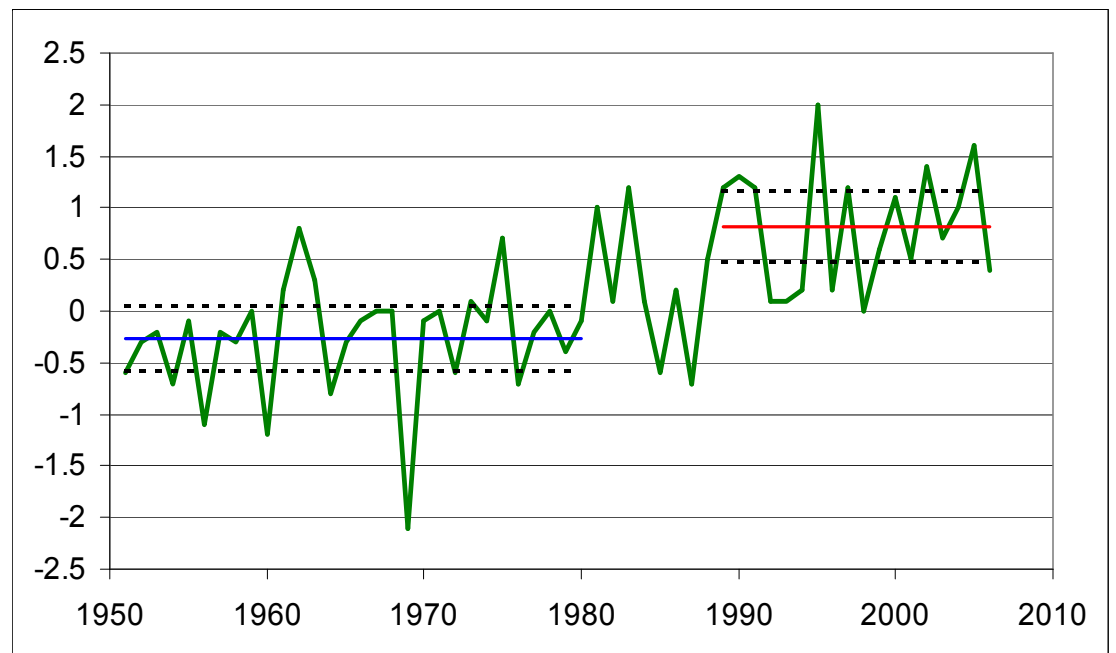
Institute of Geography RAS

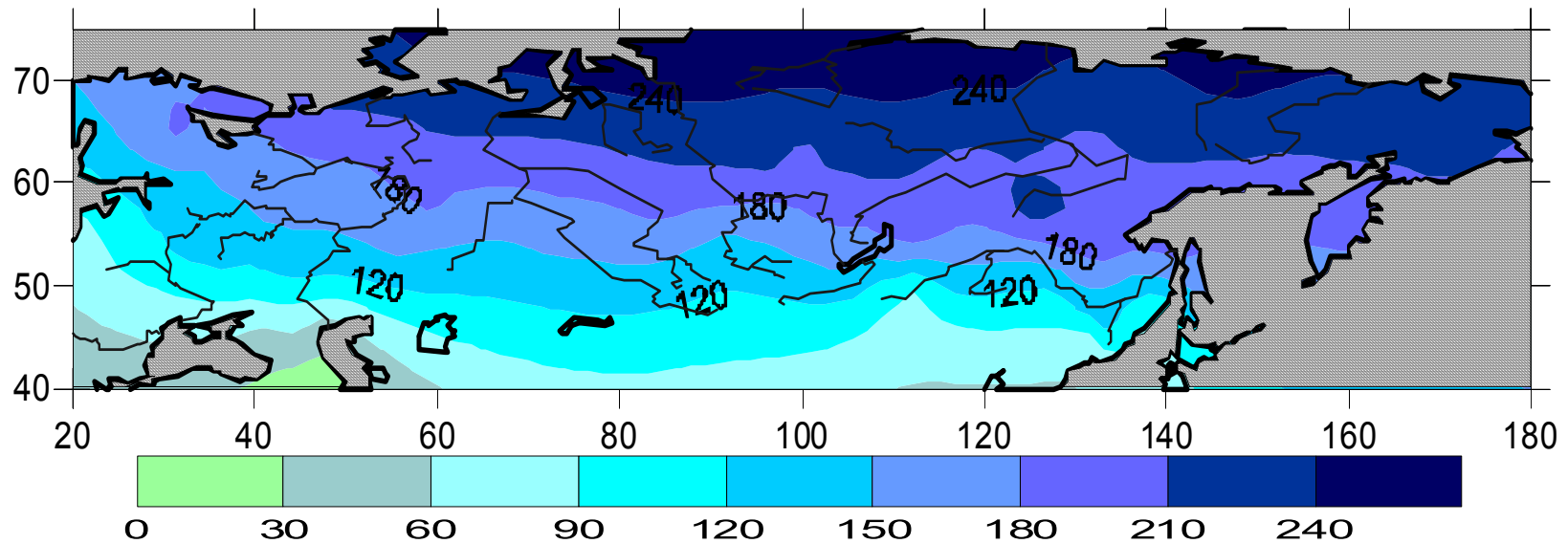
Moscow



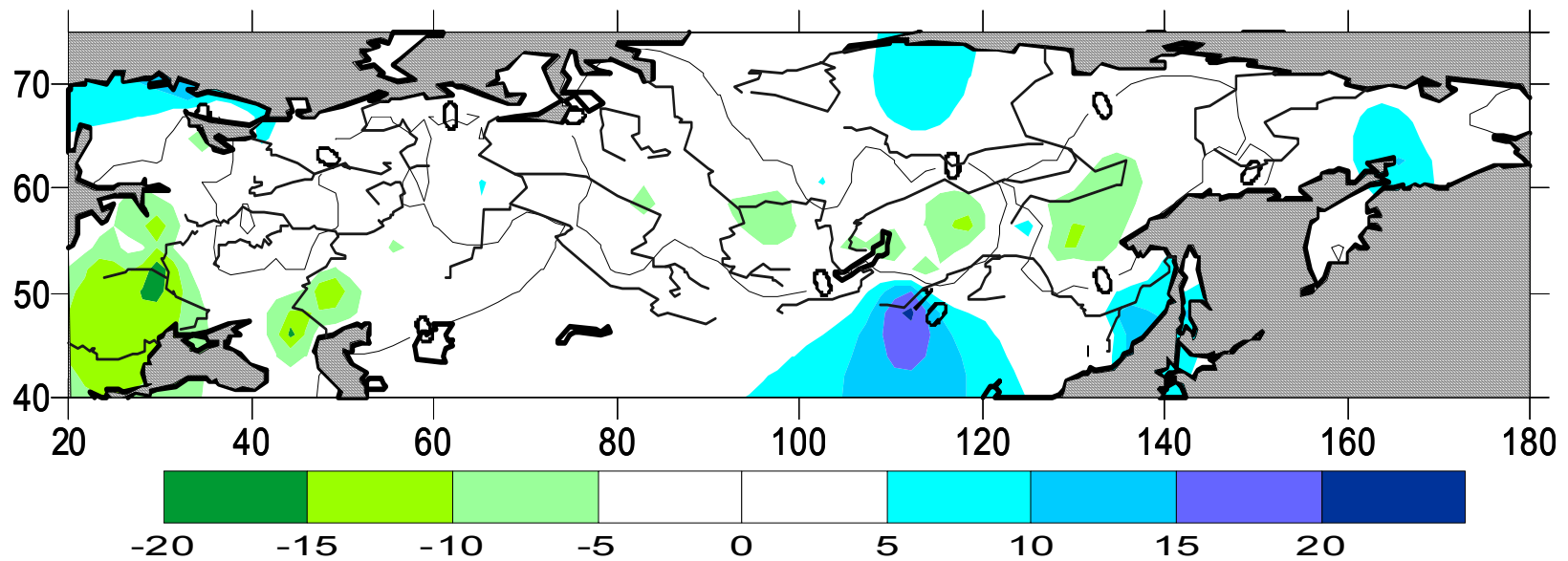
Distribution of meteorological stations used for the analysis

Each parameter has been determined for each year (depending on availability of the data), and then averaged by two periods (1951-1980 and 1989-2006), significantly different from each other by the average annual air temperature.

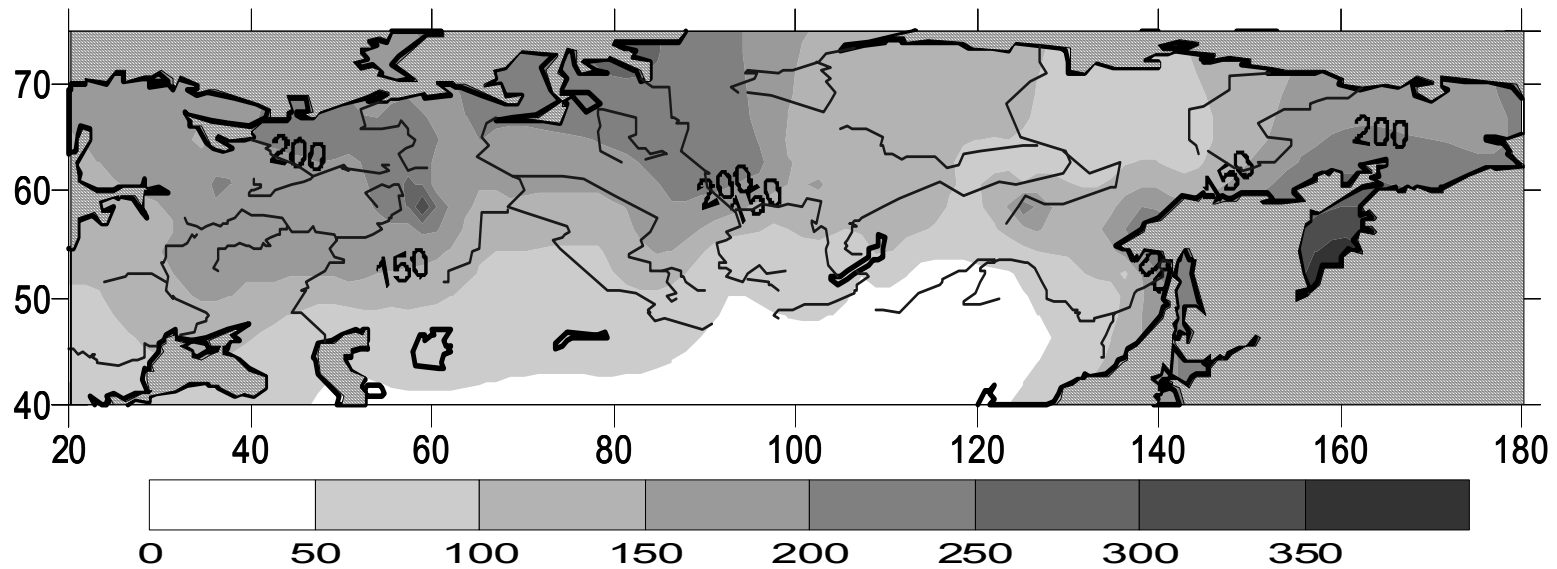




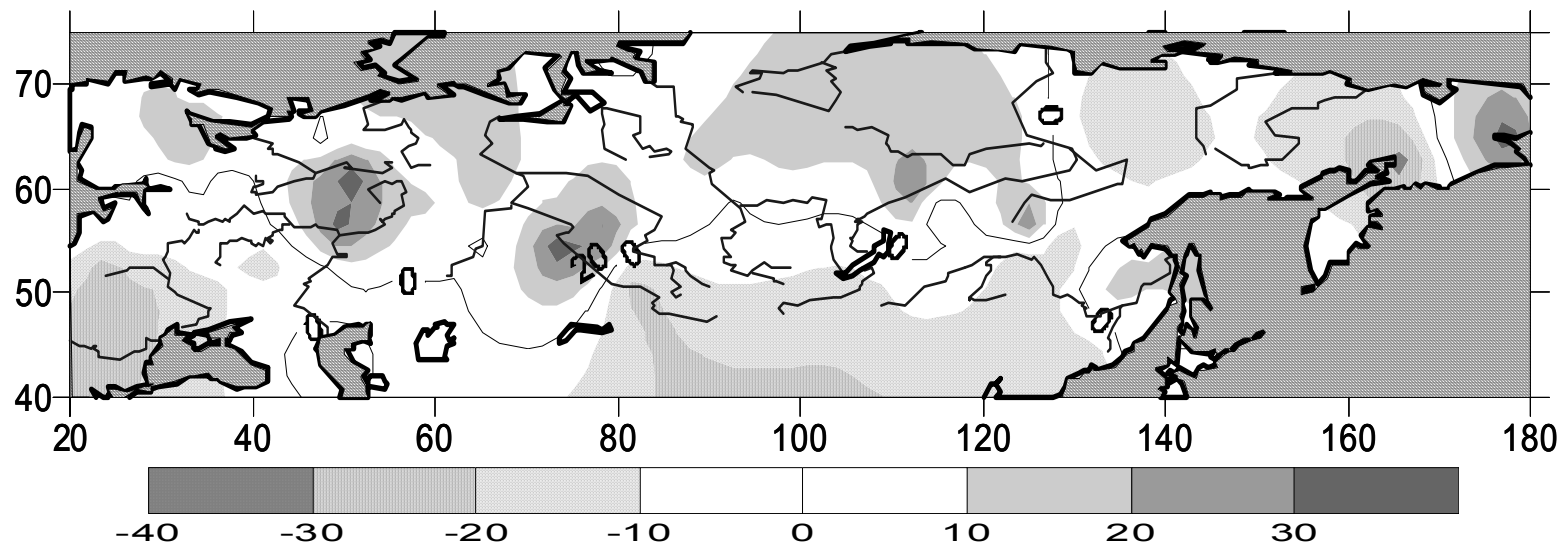
Annual number of snow days in North Eurasia averaged for 1951-1980



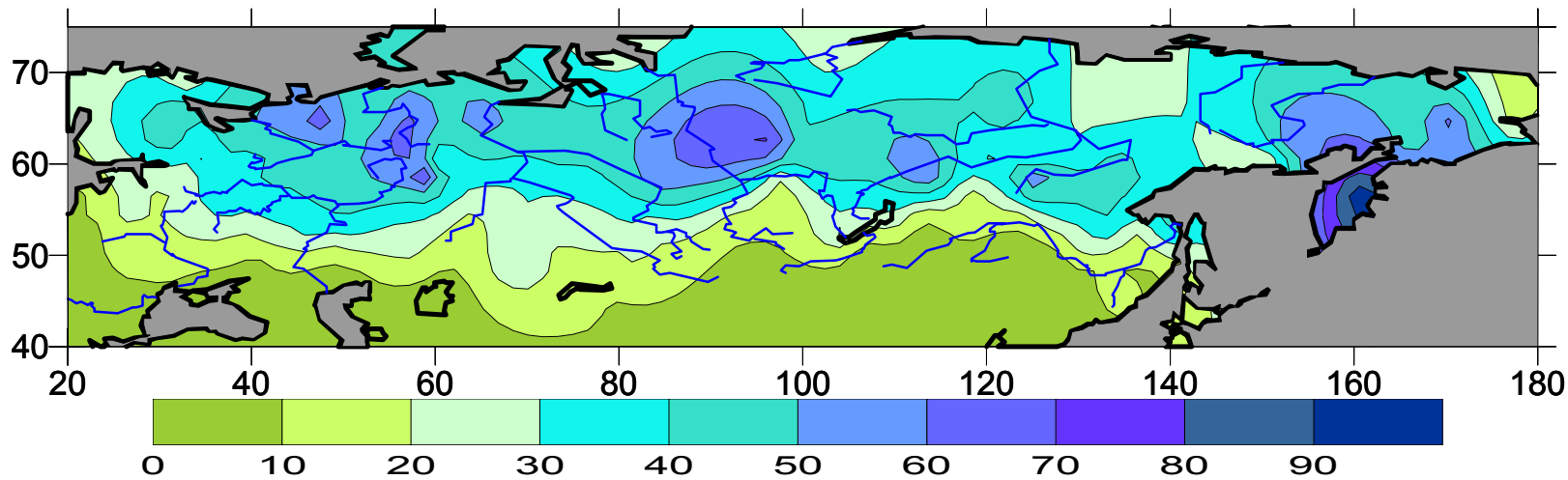
Change of annual number of snow days in 1989-2006 as compared to 1951-1980



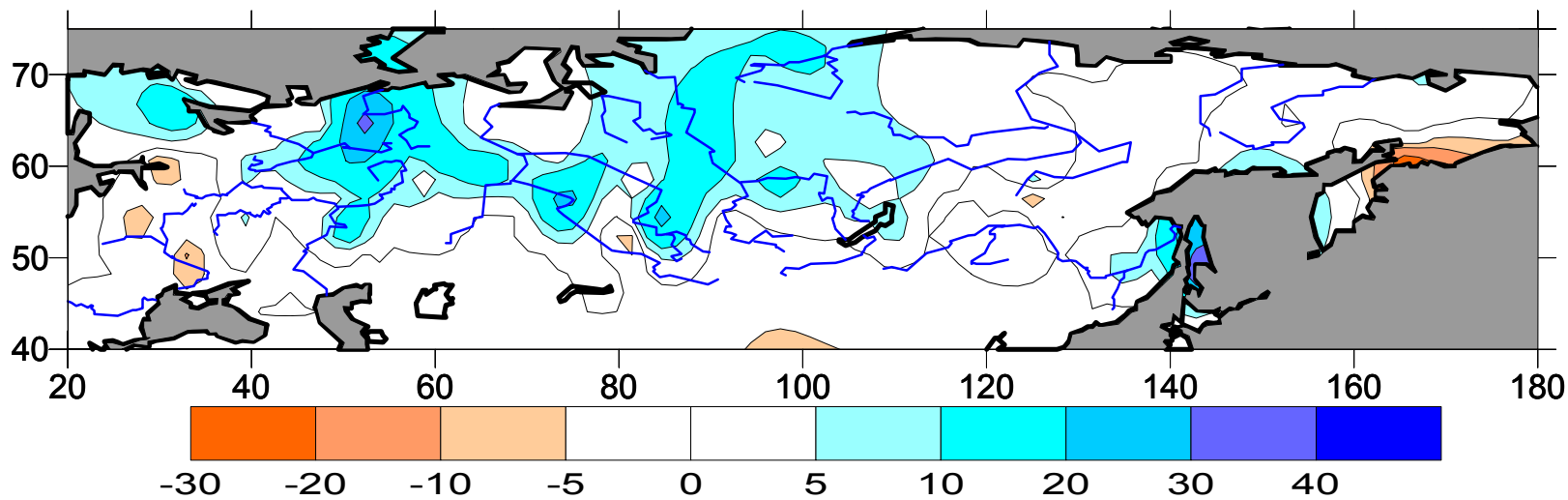
Annual solid precipitation sum (mm) in North Eurasia averaged for 1951-1980



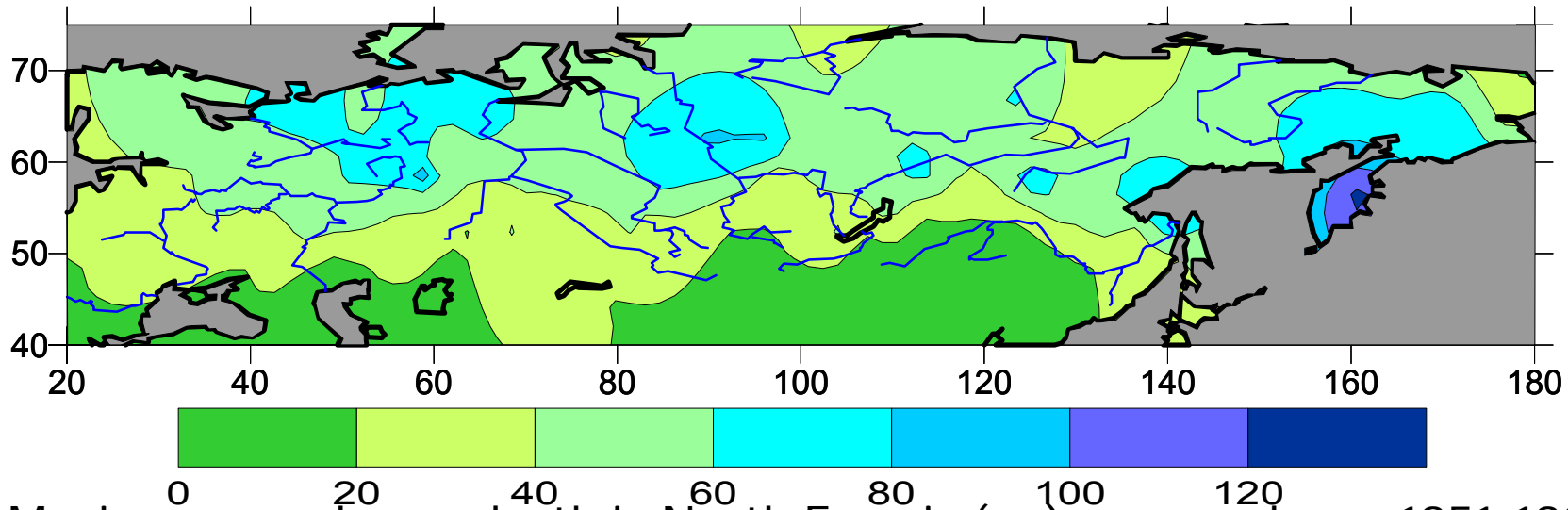
Change of annual solid precipitation (%) in 1989-2006 as compared to 1951-1980



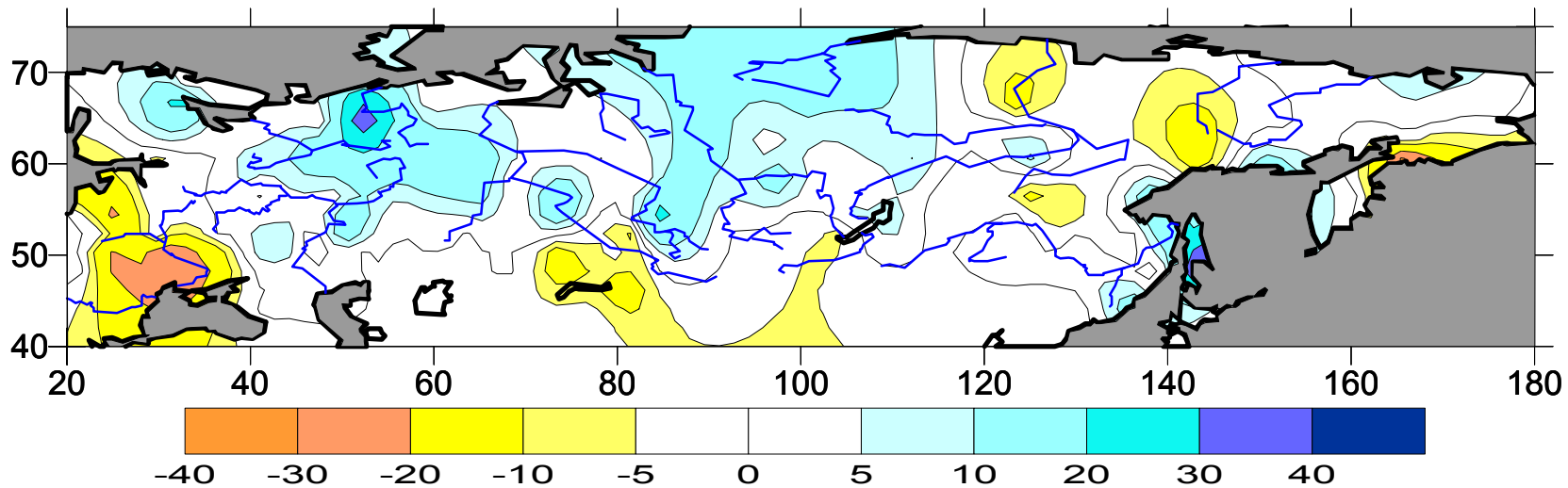
Snow depth in North Eurasia (cm) at the end of February, averaged over 1951-1980. The regions beyond ex-USSR borders are not covered by observed data.



Change of the snow depth (cm) at the end of February in 1989-2006 as compared to 1951-1980. The areas with insignificant change are shown in white.



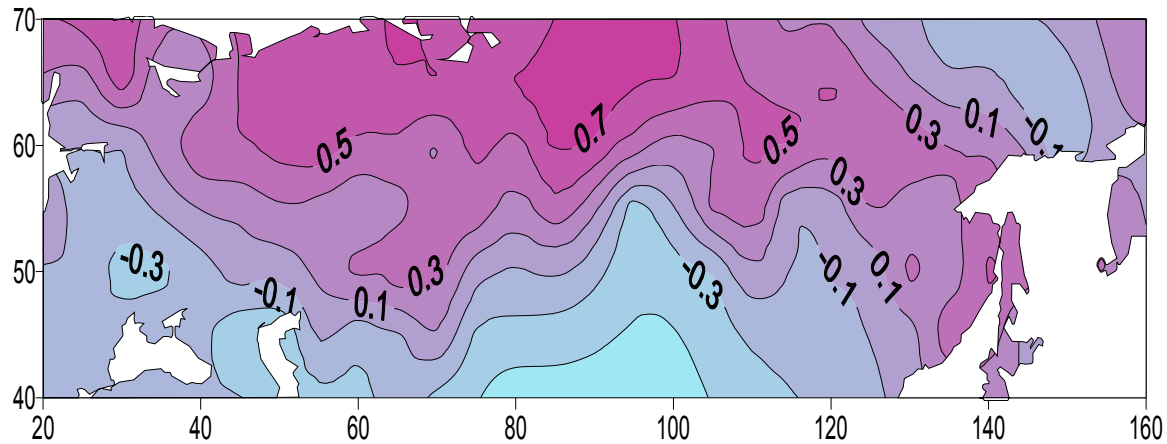
Maximum annual snow depth in North Eurasia (cm), averaged over 1951-1980. The regions beyond ex-USSR borders are not covered by observed data.



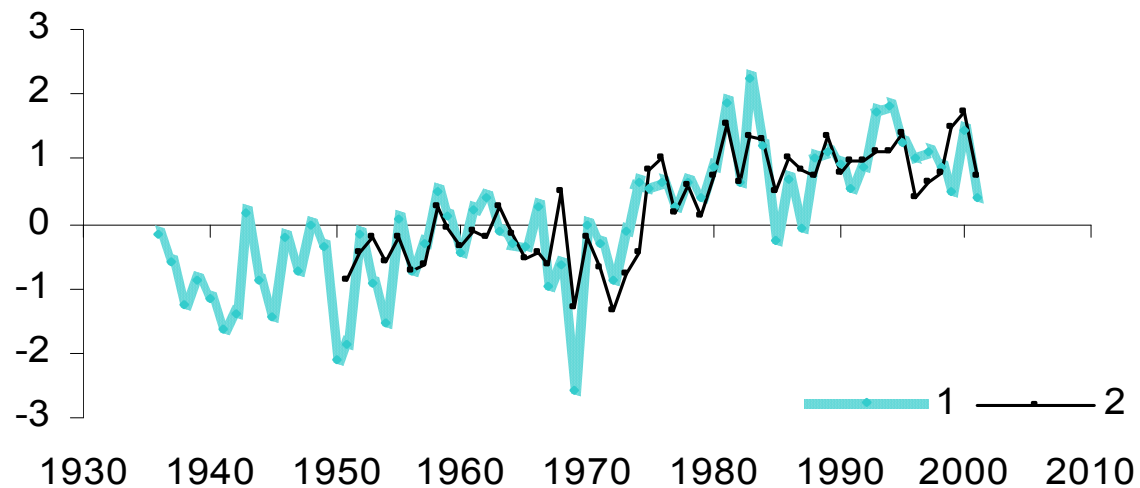
Change of the maximum annual snow depth (cm) in 1989-2006 as compared to 1951-1980. The areas with insignificant change are shown in white.

Role of large-scale atmospheric circulation patterns in the snow depth variability over North Eurasia

Circulation patterns: NAO, PNA, WP, POL, SCAND



Pattern and time series of February snow depth PC1 (17.3%)



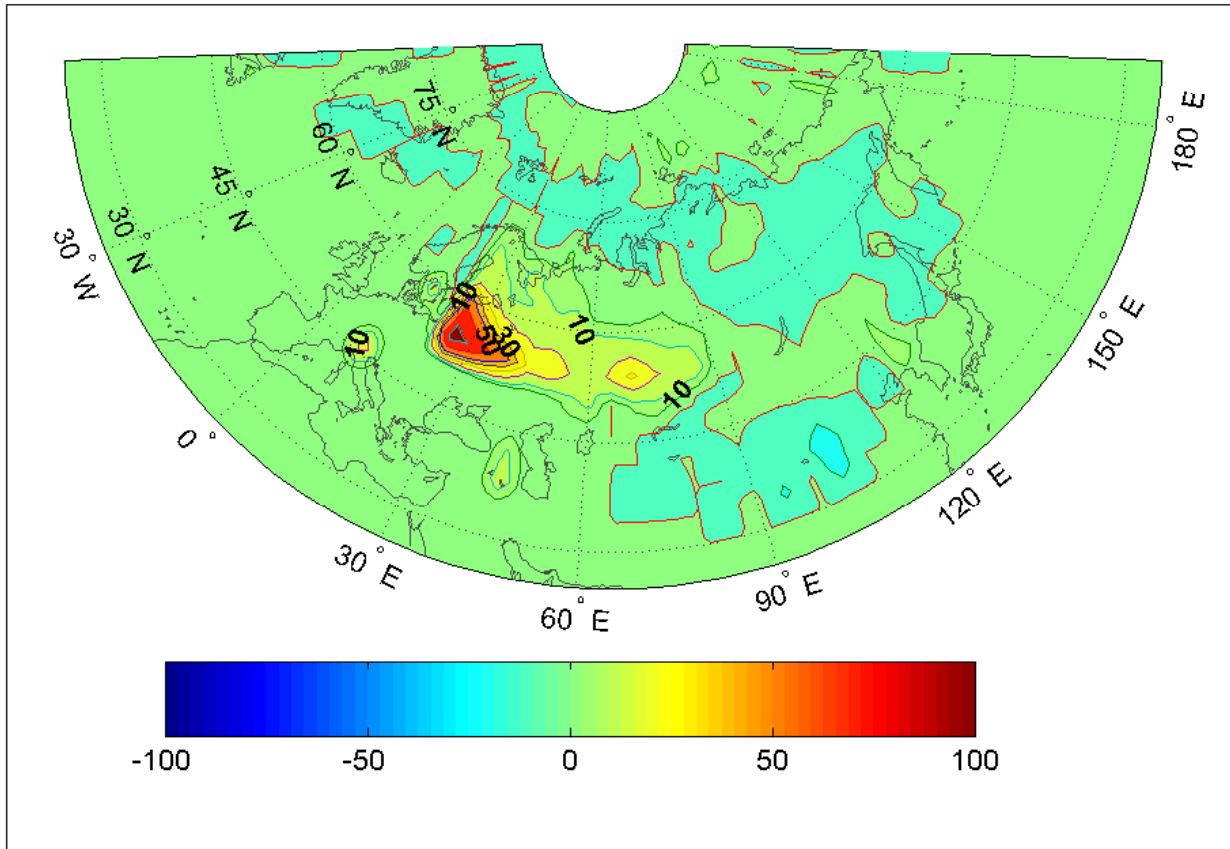
1 – PC1, based on observed data
2 – calculated PC1, based on stepwise multiple regression with indices I_{NAO} , I_{SCAND} , I_{PNA} , I_{POL}

Multiple regression on snow depth PC1 and the fractions of the variance in snow depth (R^2) associated with circulation indices for two periods. Numbers in bold are statistically significant ($p < 0.05$).

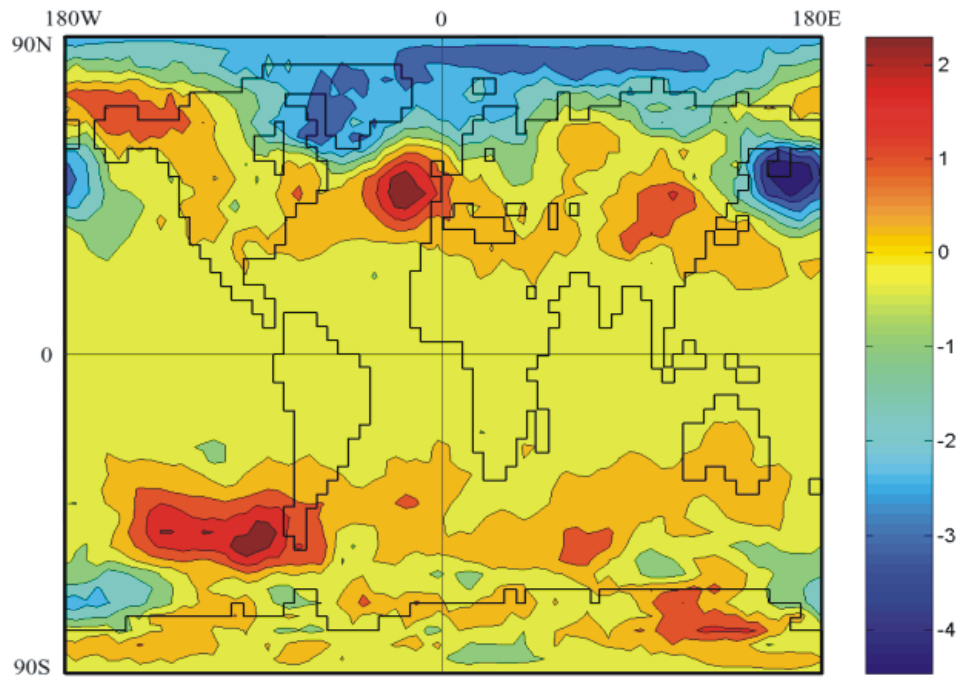
<i>Parameters</i>	<i>Value</i>	<i>Error</i>	<i>t-value</i>	<i>p-level</i>	<i>R</i>	<i>R² % (accumulated and individual)</i>	
1951-1974							
I_{SCND}	-0.51	0.20	-2.50	0.02	0.43	19	19
I_{PNA}	0.46	0.22	2.10	0.05	0.57	33	14
1975-2001							
I'_{NAO}	0.43	0.15	2.84	0.01	0.63	39	39
I_{SCND}	0.31	0.22	-1.41	0.17	0.65	43	4
I_{PNA}	0.22	0.19	1.20	0.24	0.68	46	3

Circulation patterns can change their relative role in variations

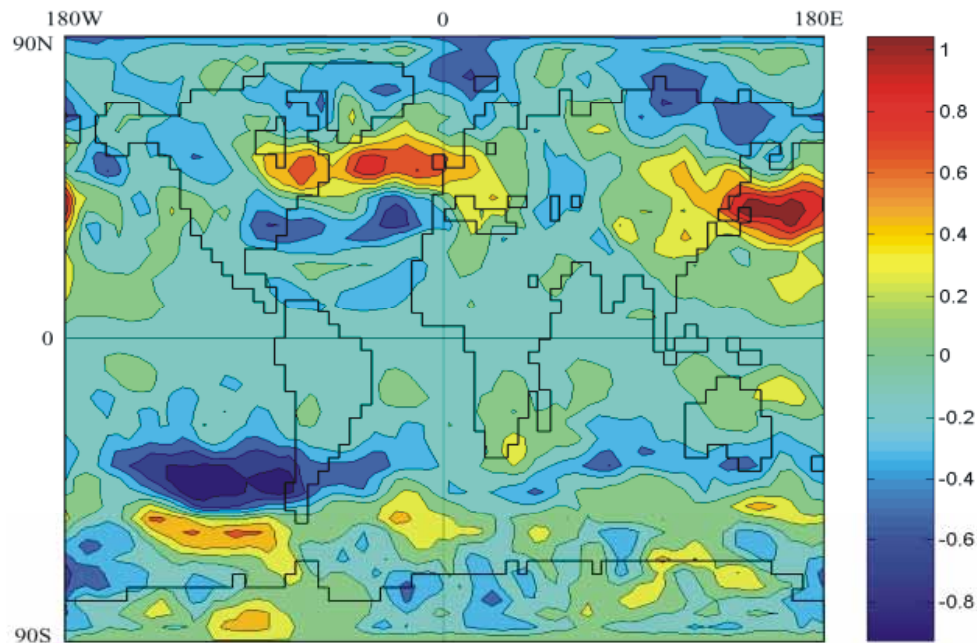
Experiments with atmospheric general circulation model



Change of snow mass in March (%) under scenario of artificially decreased (by 25%) cloudiness over East European Plain as compared to baseline experiment. Due to regional cooling, meridional circulation evolves, which results in positive snow mass anomalies in the south-west of the region.

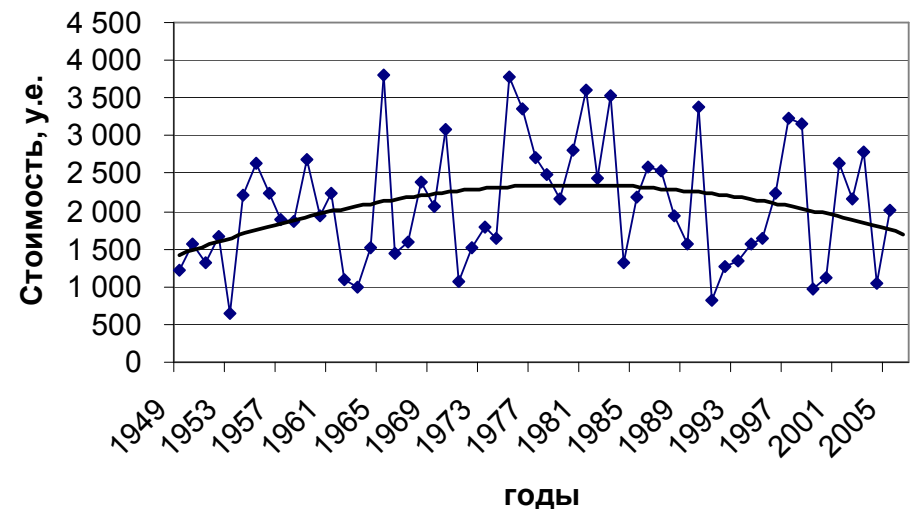
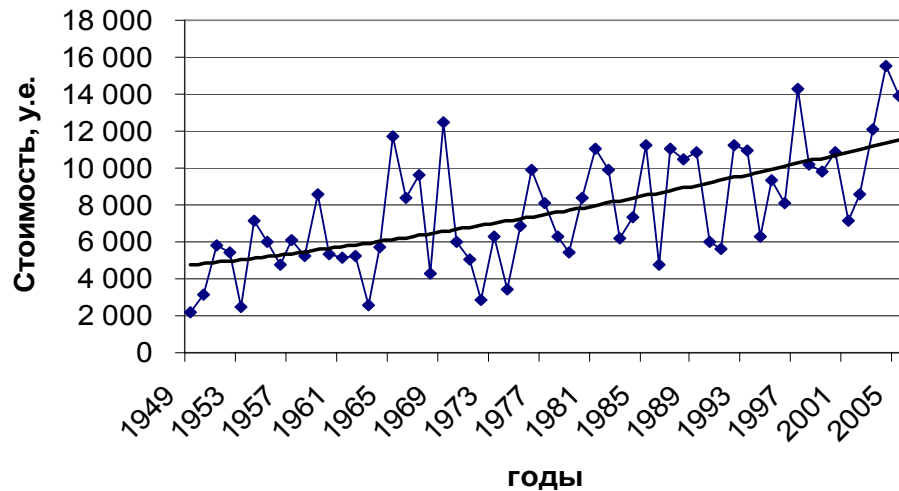
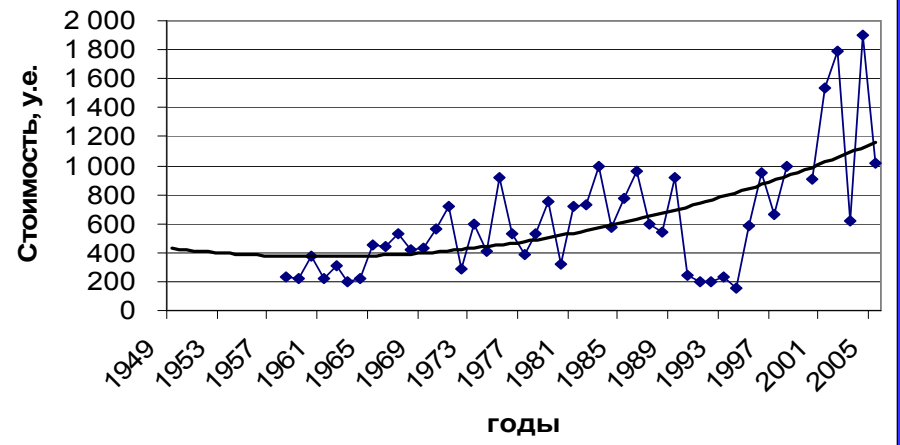


Change of sea level pressure (mB) in May after positive anomaly of the snow mass by 36% in the beginning of March



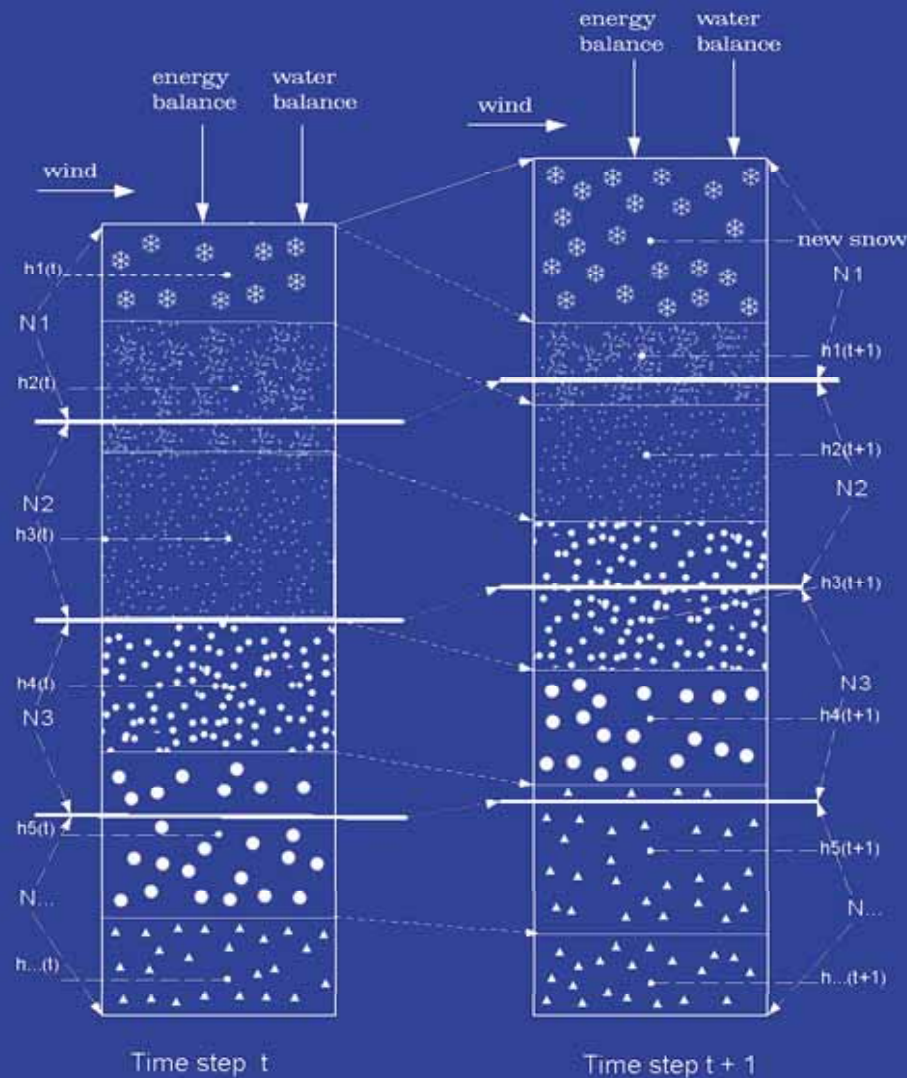
Change of zonal wind velocity (m/s) in May after positive anomaly of the snow mass by 36% in the beginning of March

Change of conventional costs for snow removal from streets in Petropavlovsk-Kamchatsky (top), Moscow (middle) and St.Petersburg (bottom)



Local snow cover model combined with SPONSOR LSM

Density of each snow layer is evaluated, taking into account its seasonal evolution. This, in turn, determines its heat balance (through heat conductivity) and, for the top layer – radiation absorption.



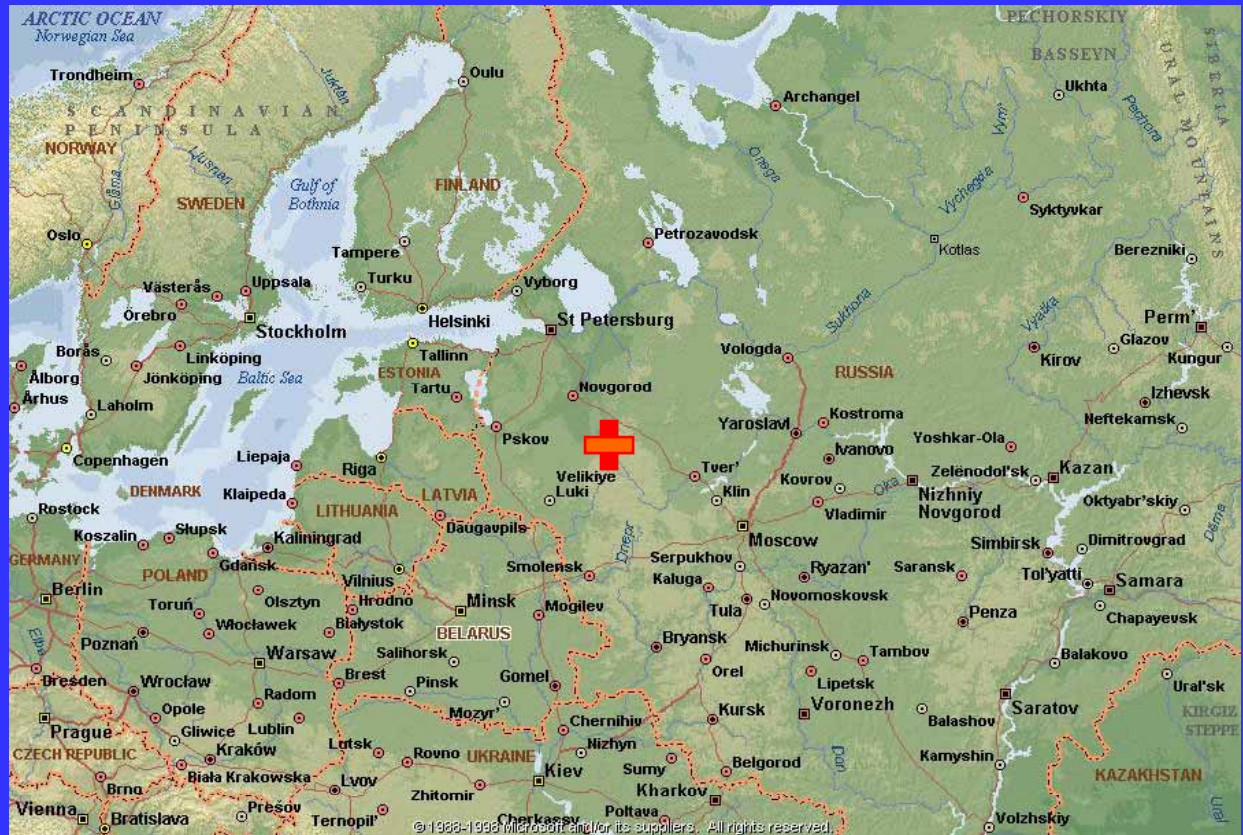
- each snow layer appears after a snowfall;

- snow physical properties change according to meteorological conditions and previous evolution of the snow layers according to certain criteria (Kominami et al., 1998; Pomeroy et al., 1998; Golubev, personal communication; and others).

- snow layers are united once their properties are close enough.

Testing the model against 18-year time series at Valdai, Russia

Location of Valdai site, Usadievski catchment



Usadievsky catchment

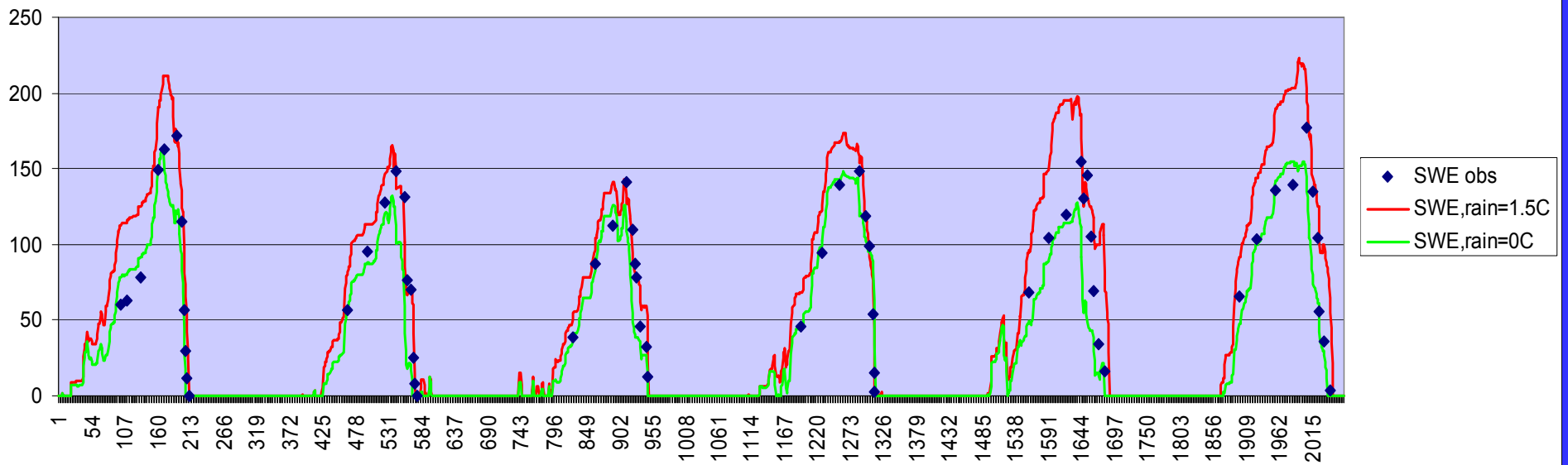
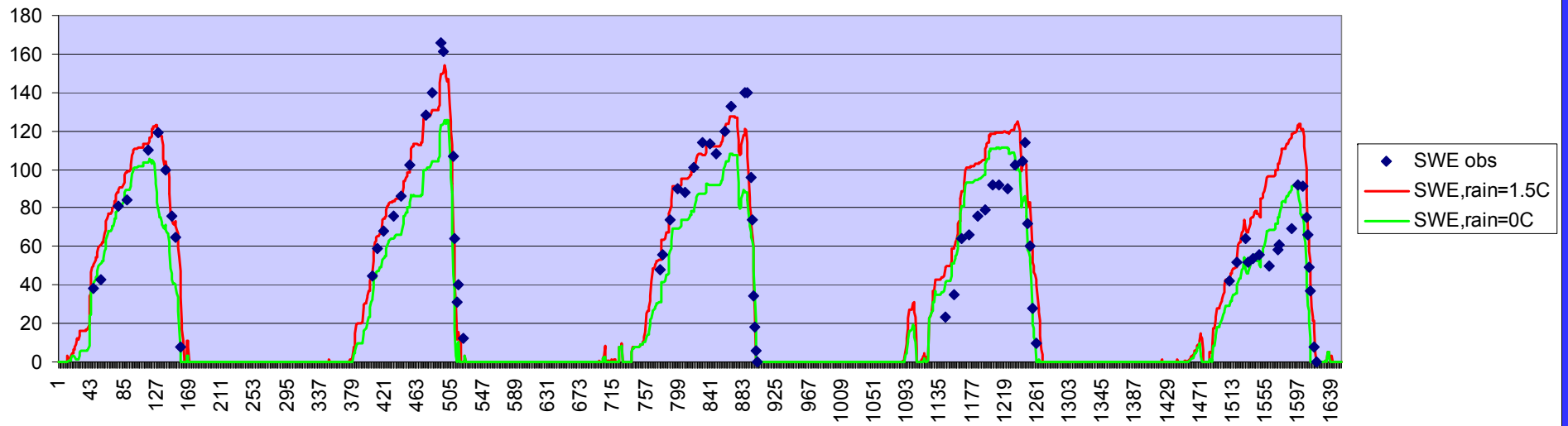
surface area

0.36 km²

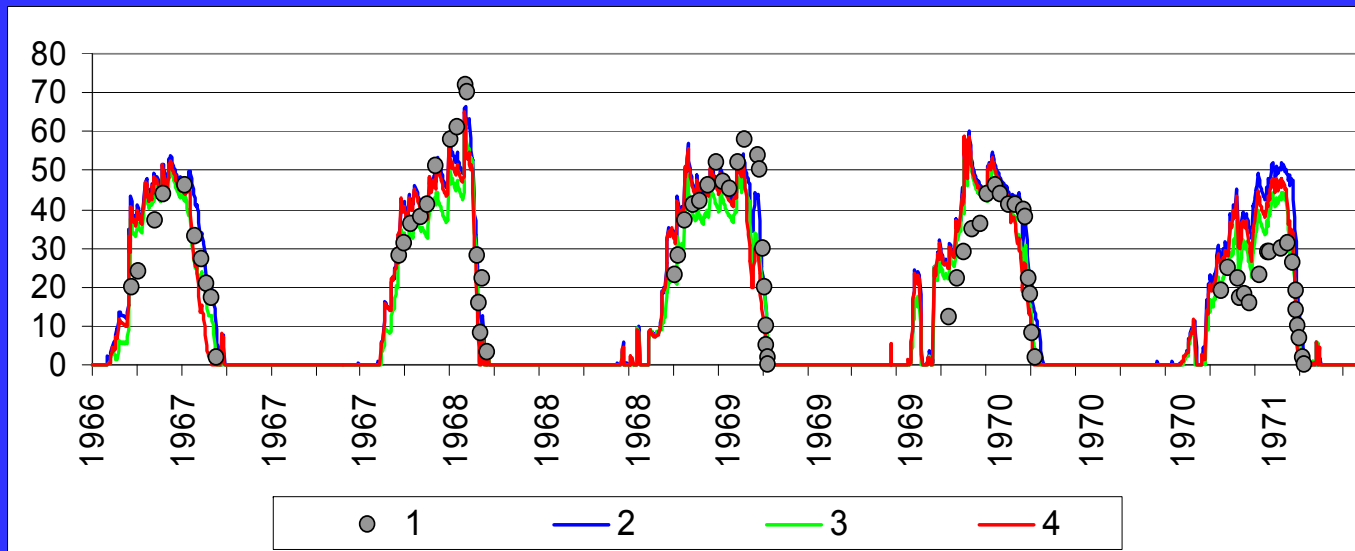
vegetation

grass, sparse bush

Snow at Usadievsky in 1967 – 1972 (top) and 1977 – 1982 (bottom)

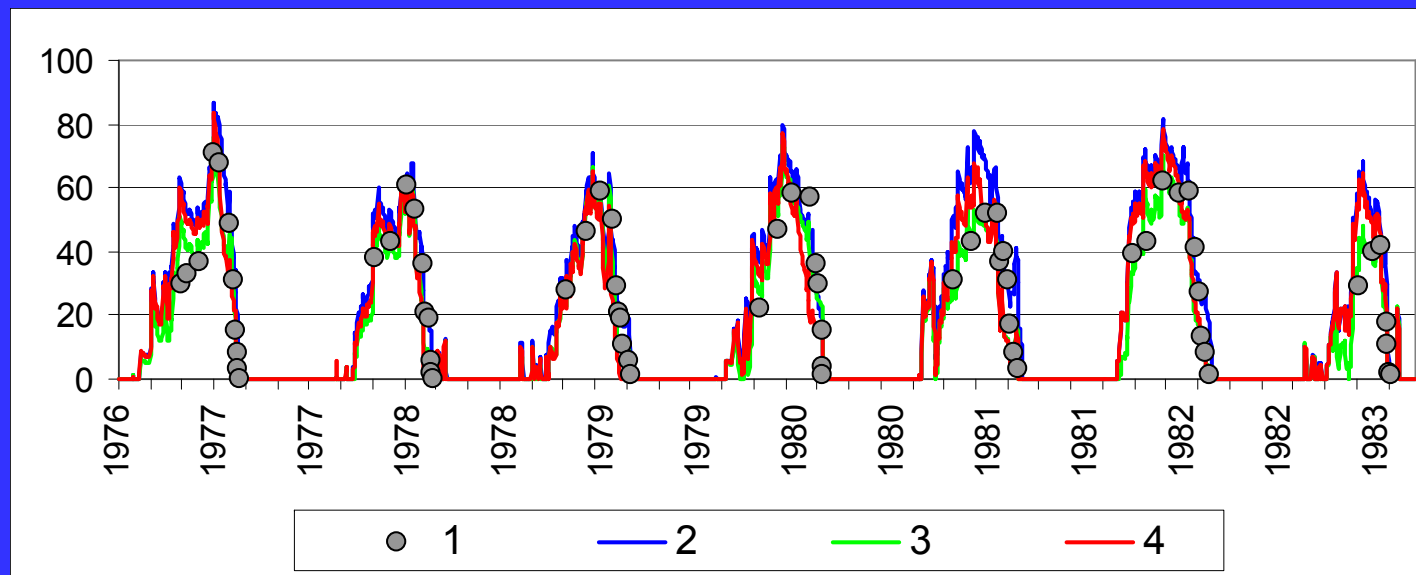


Testing of the model by the snow depth (e.g. by the density evaluation)



1966-1971

observed (1);
rain=1.5°C; $\alpha=$
0.9 and 0.55 (2),
rain=0°C; $\alpha=$ 0.9
and 0.55 (3),
rain=1.0°C; $\alpha=$
0.8 and 0.4 (4)



1976-1983

Conclusions

1. Solid precipitation and snow mass are increasing during last decades over most of North Eurasia; their decrease take place in the south-west of the subcontinent and few other areas. Snow season length does not change significantly, except for its shortening in the west of the East European plain.

2. Spatial and temporal variations of the snow depth on continental scale are well related to key large-scale circulation patterns. Positive phase of NAO (and enhanced westerlies) is a major factor for positive trend of both temperature and snow accumulation since 1970s. Circulation patterns can change their relative role in the influence on climate anomalies.

3. Experiments with atmospheric general circulation model imply existence of various mechanisms of snow dependence on climate and vice versa. Regional snow mass anomalies can result from air temperature anomalies, providing intensive circulation.

4. Costs of snow removal from streets depend on both climatic (number of snowfalls) and socio-economic (length of streets) reasons, thus changing with different trends.

5. On local scale, numerous meteorological and heat/water balance processes influence the snow cover seasonal evolution. Main of them are snowfall intensity, radiation absorption, heat transfer and phase changes.

Thank you!

*Snow in the Sayan mountains,
South Siberia, June 2008*

