

Changes in Snow Cover Characteristics over Northwestern Russia

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In situ observational program in Russia

- First observations in the end of 18th century
- Massive standard observations since 1881
- Standard precipitation observations since 1891
- Change of the major user: mid-1930s
- Reassessments of observational programs:
 - 1936, 1966, 1984
- Increase in volume of digital data:
 - 1936, 1959, 1966, 2000s (peak: end of the 1970s)
- Period of decrease in data volume:
 - mid-1980s, 1990s {now ~1800 stations + posts}

Snow measurements in Russia

- **Snow depth (SD), snow water equivalent (SWE), and snow cover duration are the main characteristics of the seasonal snow cover**
- **SD is measured since 1891, SWE since 1936**
- **Homogeneity issues prior to 1950 (SD) and 1966 (SWE)**
- **In Russia, the snowmelt process can be lengthy with the average duration about 40 days. But, it is decreasing (will discuss this later).**
- **The snow crust and basal ice layer in snowpack arise during snowmelt and/or thaws. In extreme cases, the crust and ice layers may kill some wild species and prevent reindeers' migration and feeding.**
- **In the temperate zone, the basal ice layer can affect the winter crop yield.**

Snow depth homogeneity issues prior to 1950

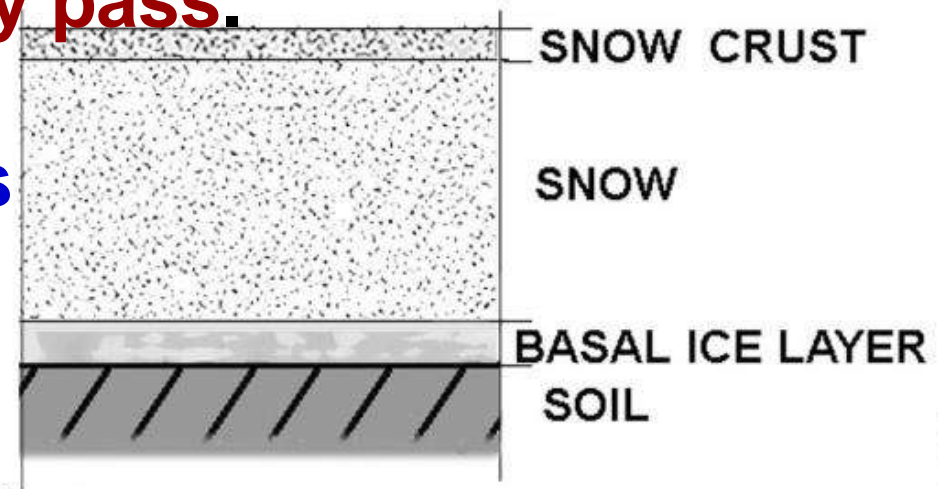
- Since 1936, most of meteorological stations were moved to open locations
- Protected and open locations of snow depth measurements: difference approximately 20% during the cold season
 - Before 1950, the protected sites had a priority
 - After 1950, open sites has a priority
- A lot of snow depth data analyses start in 1936 due to a better data availability

Snow crust and basal ice layer observations:

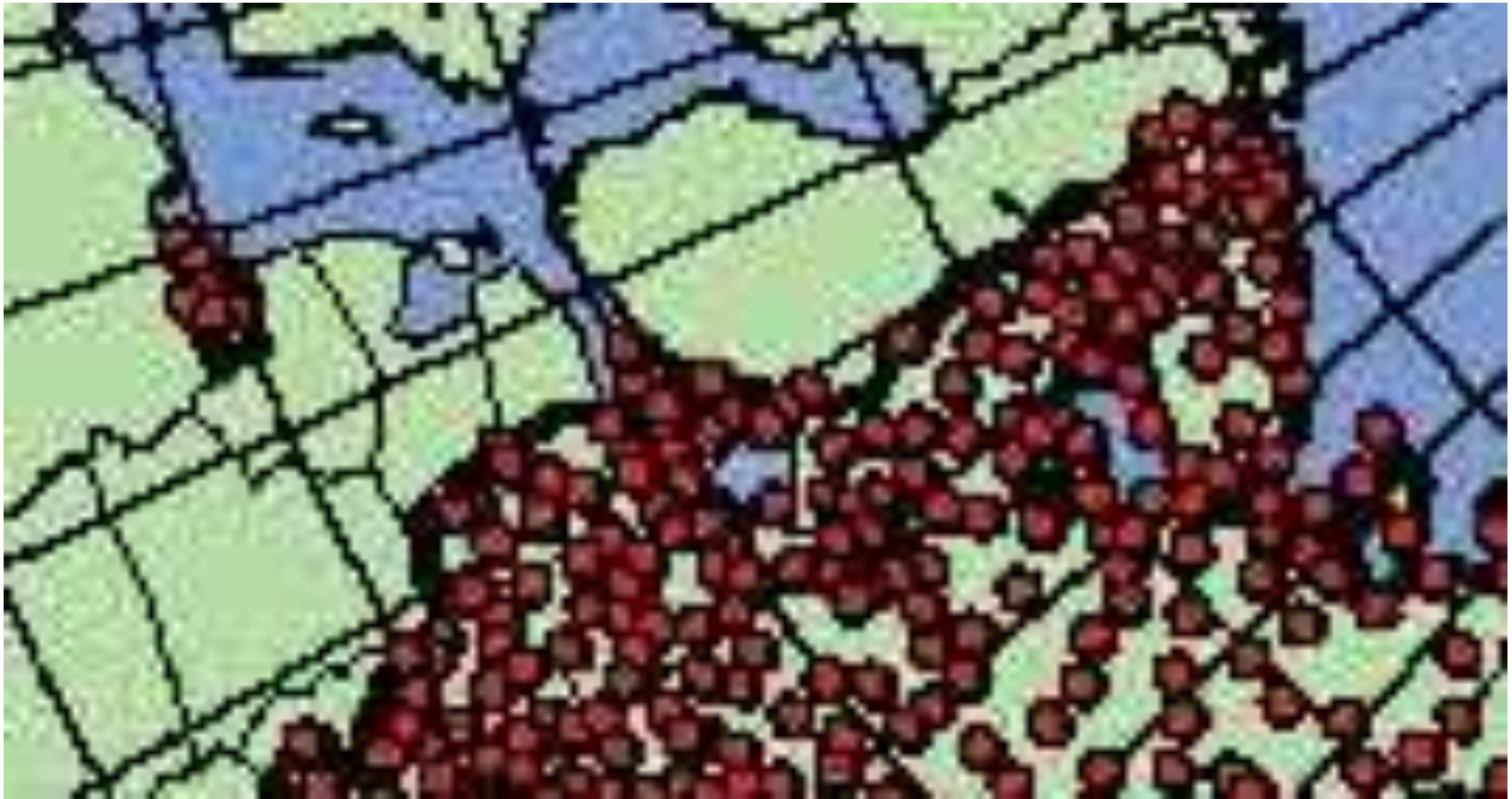
A part of snow survey routine since 1966

- The on-site post-survey data processing delivers for each type of environment: fraction of snow cover, its spatial homogeneity and type (old, wet, etc.), **mean characteristics of snow crust**, maximum and minimum snow depth, mean density, mean depth of wet snow, **snow water equivalent**, depth of the water layer and total water storage above the surface, and **two characteristics of basal ice layer: mean depth and fraction along the survey pass.**

- The basal ice layer and snow crust characteristics and their changes will be discussed further.

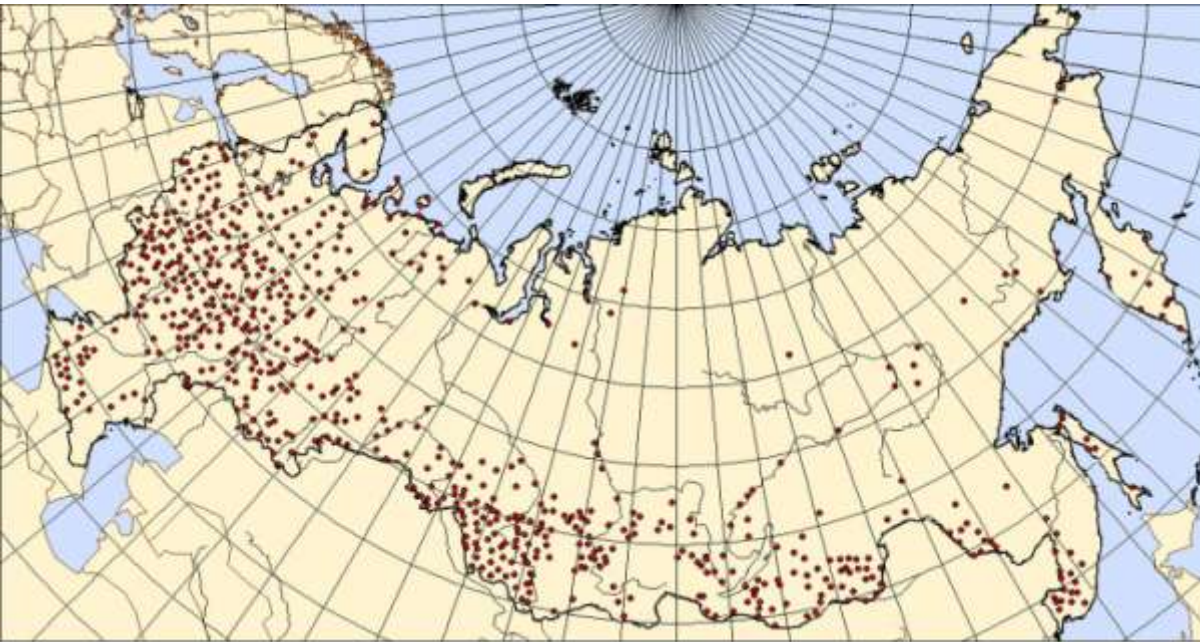


Current meteorological network in the northwestern Russia



Snow Survey Data

Locations of 958 first order meteorological stations with long-term snow survey data for the past 5 decades.

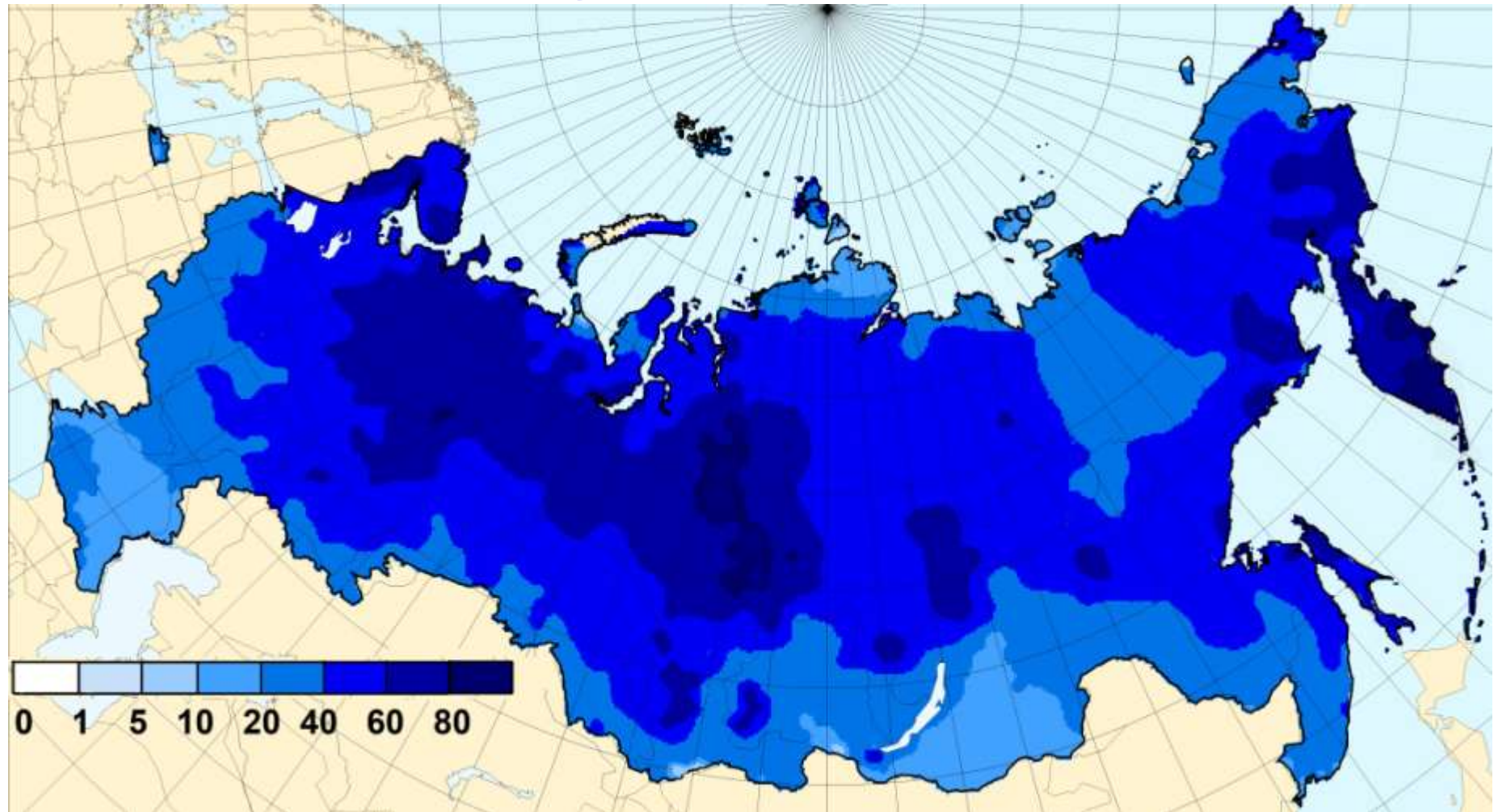


Top: Stations with surveys along the “field” routes (665 stations)

Right: Stations with survey routes in the forest environment (425 stations)

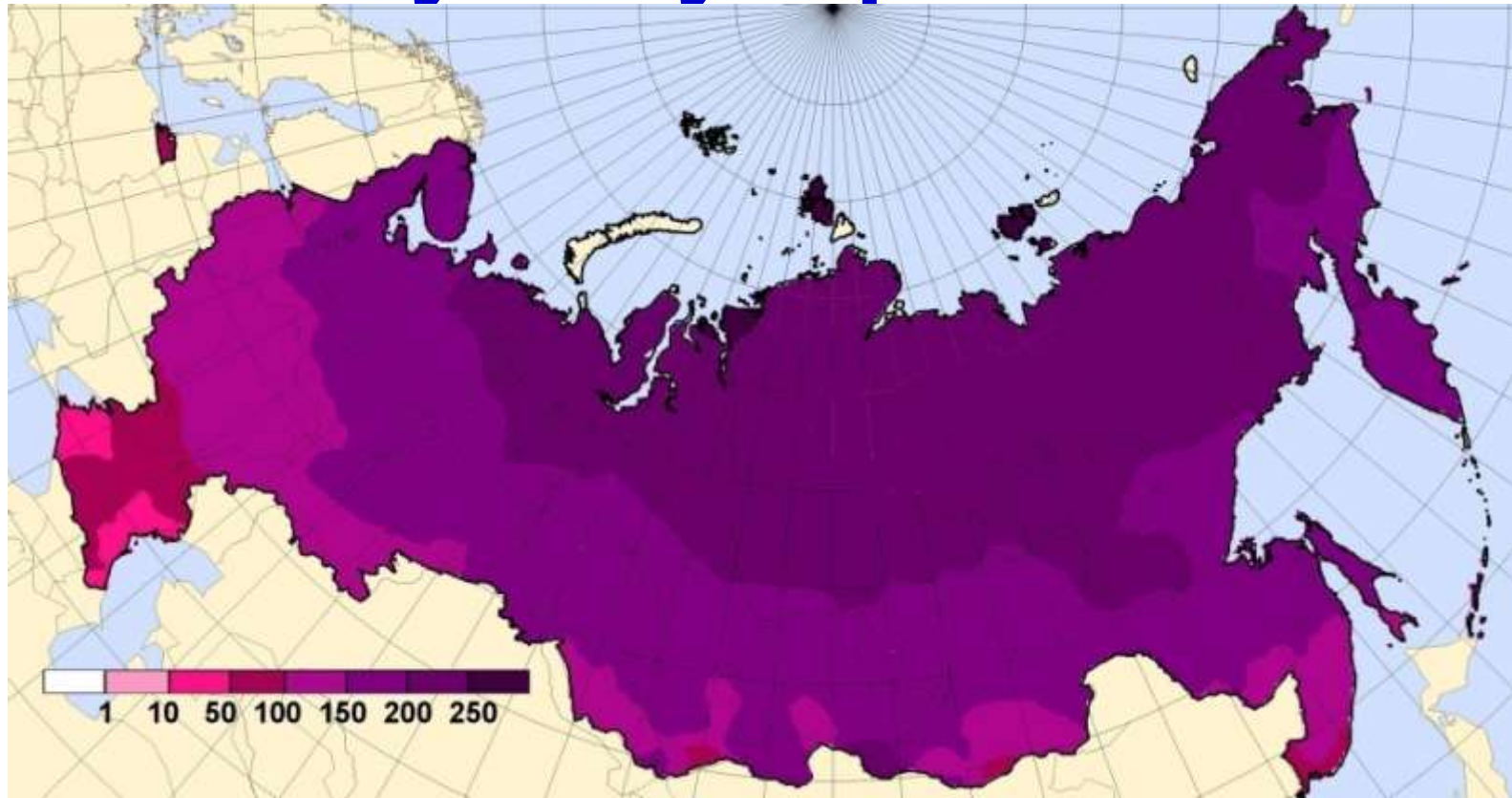
Climatology

Mean maximum snow depth (cm) at synoptic stations



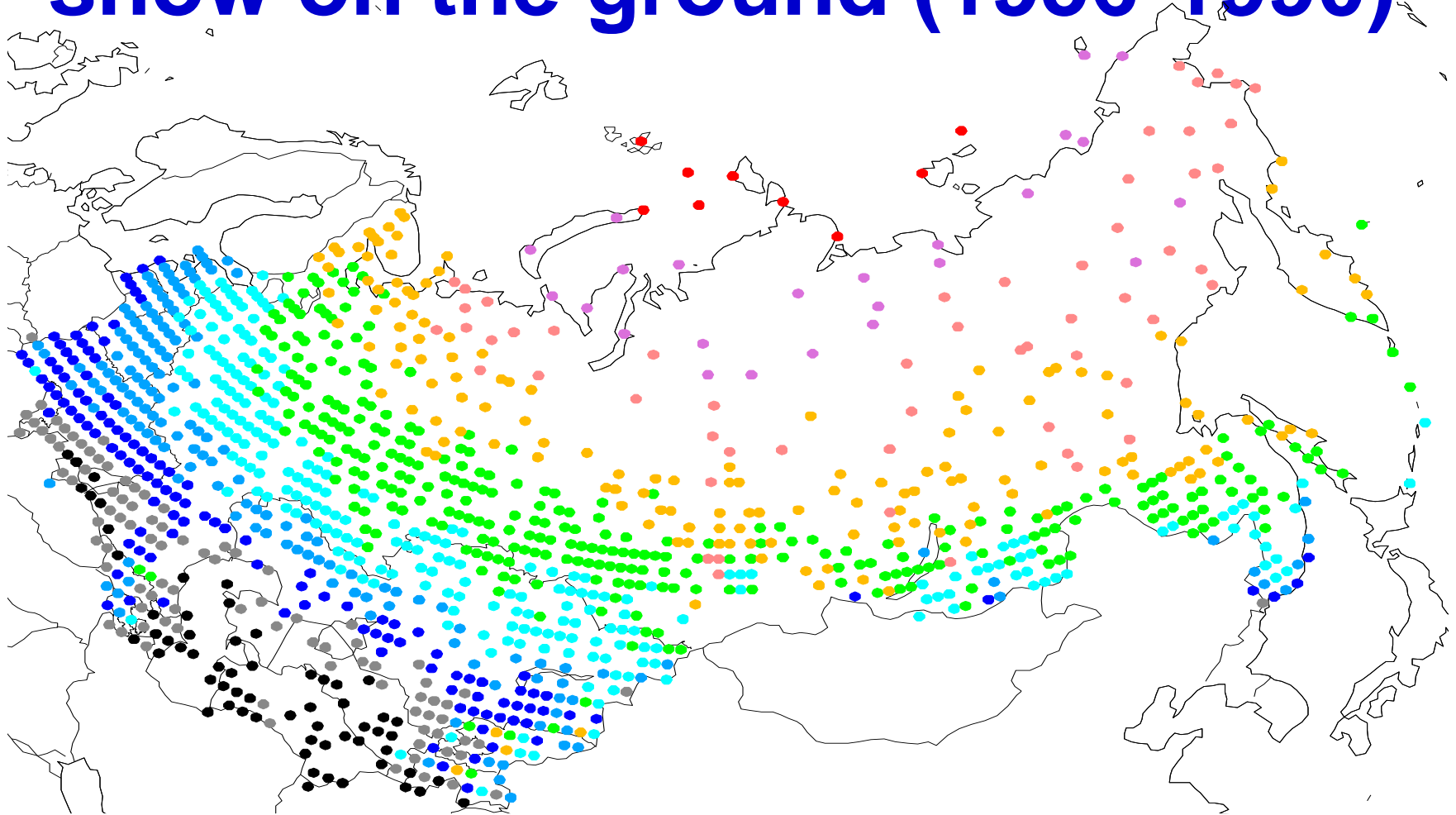
Average mean values over the 1966-2009 period

Mean duration of the presence of snow on the ground (days with >50% of the area coverage) in the vicinity of synoptic stations



Average mean values over the 1966-2009 period

Mean duration of the presence of snow on the ground (1956-1990)



< 30



30 - 60



60 - 90



90 - 120



120 - 150



150 - 180



180 - 210



210 - 240

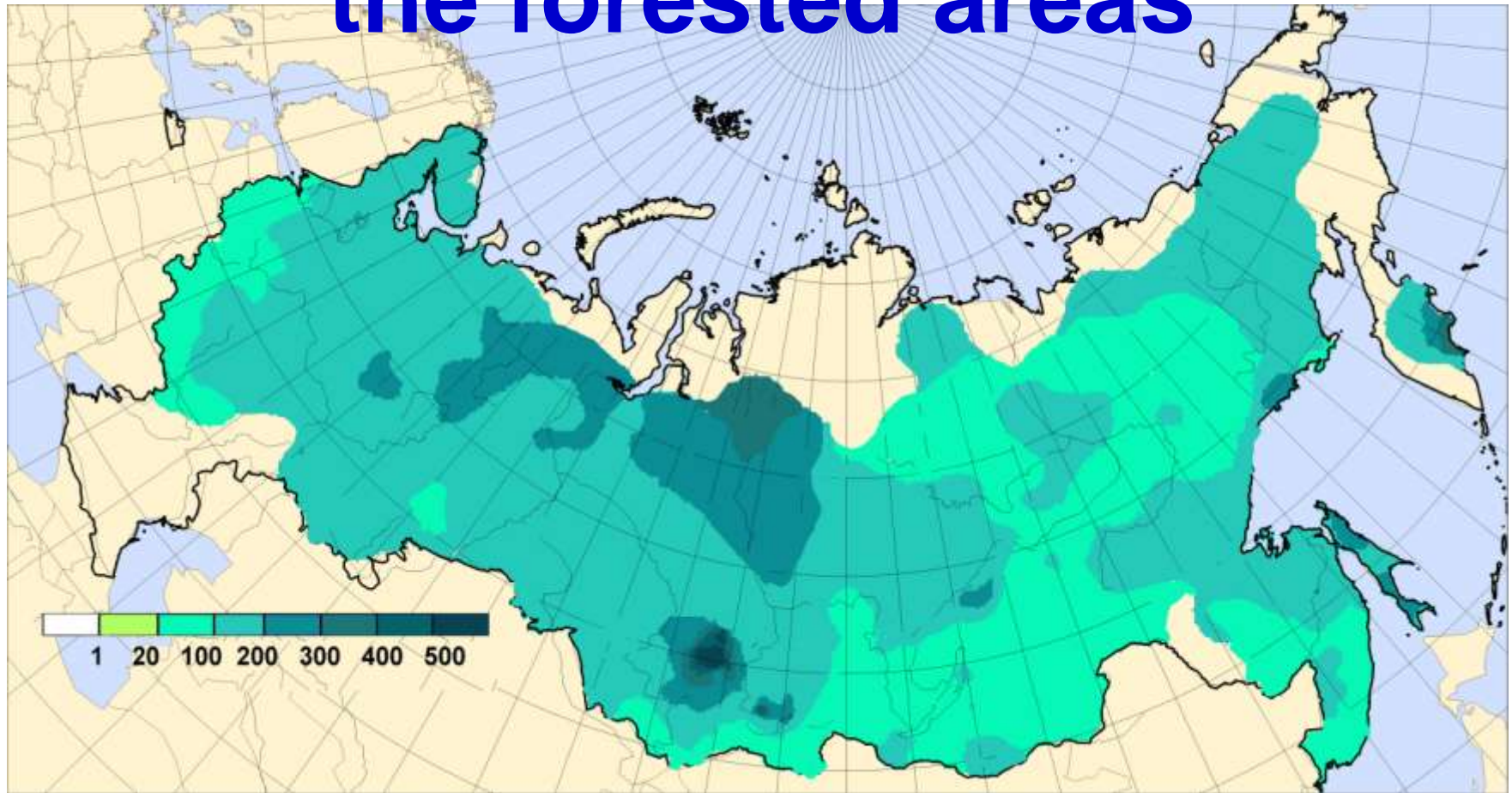


240 - 270



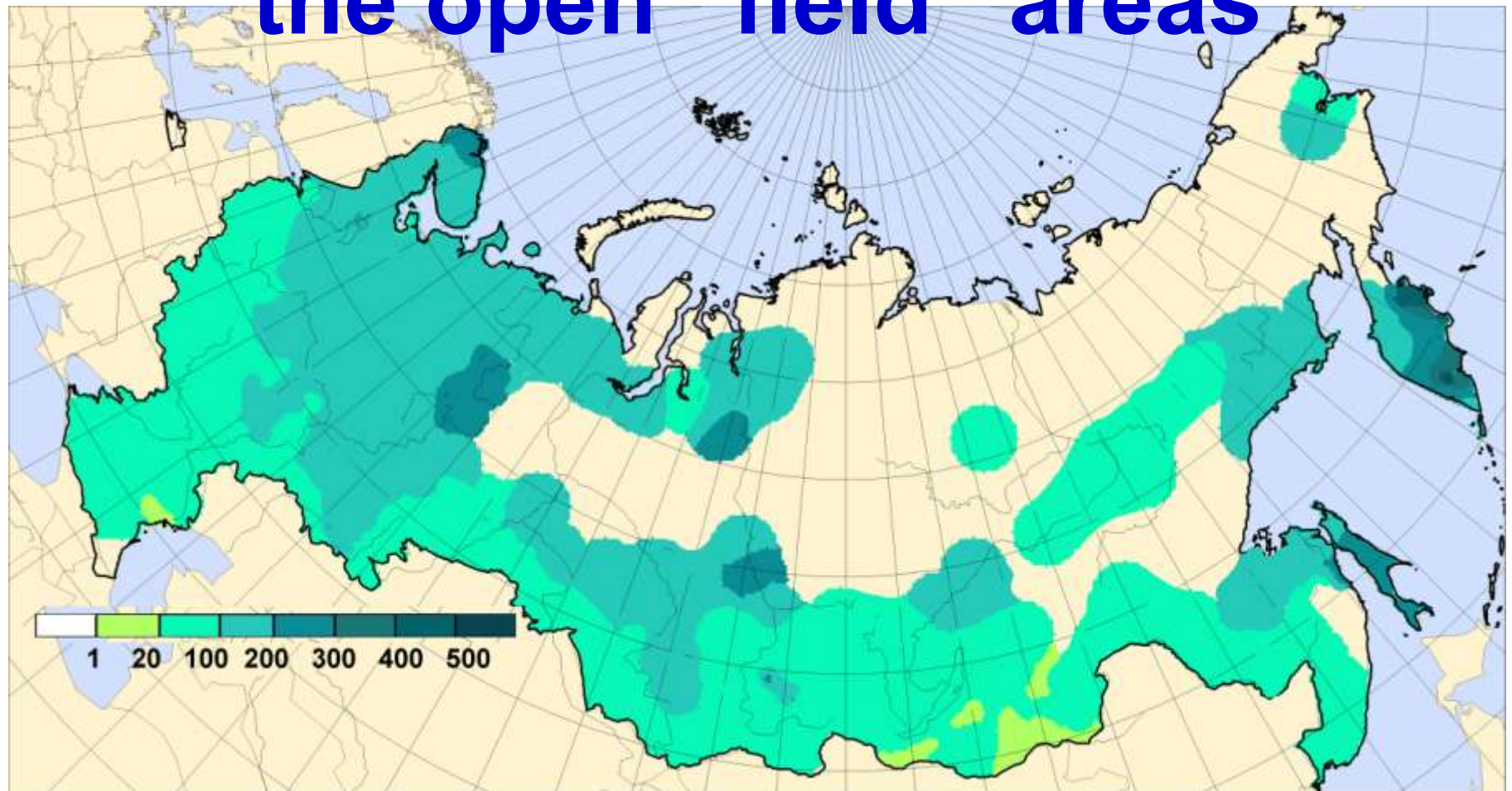
> 270

Maximum snow water equivalent (mm) along the snow surveys in the forested areas



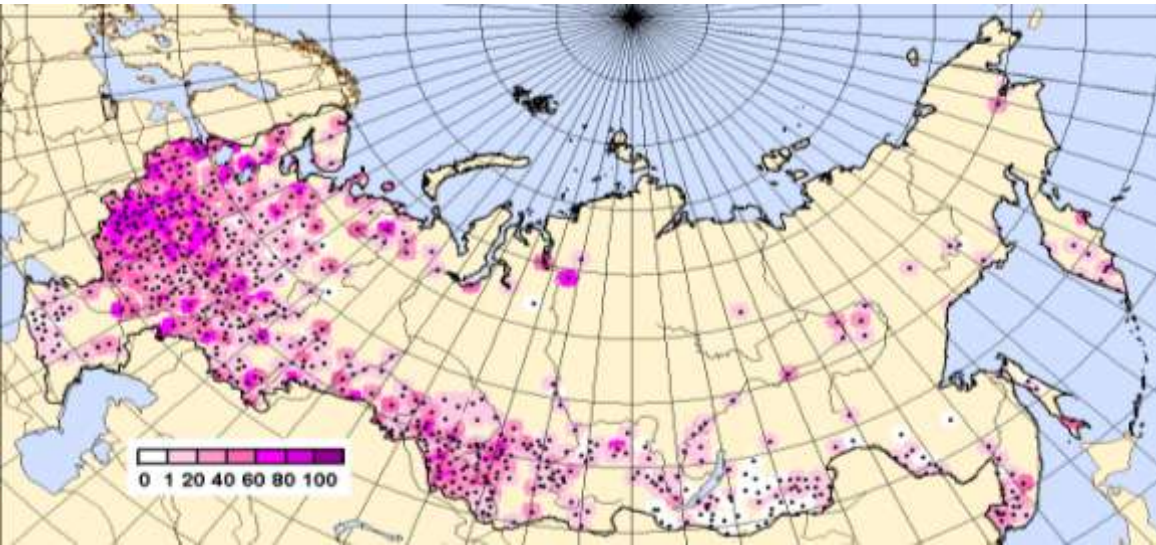
Average mean values over the 1966-2009 period

Maximum snow water equivalent (mm) along the snow surveys in the open “field” areas



Average mean values over the 1966-2009 period

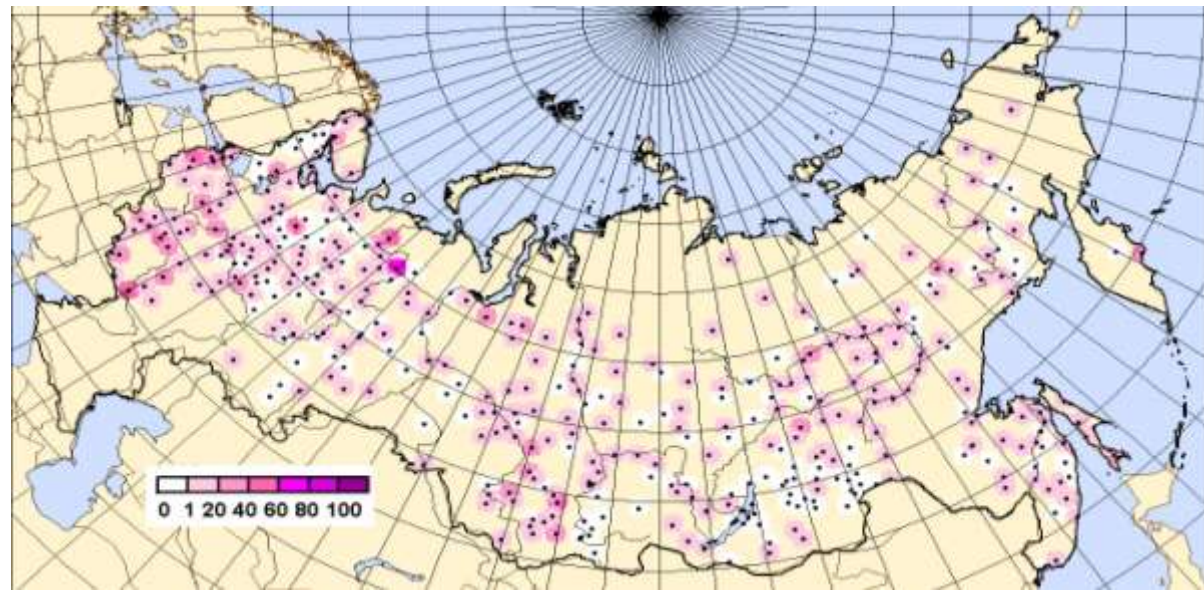
Probability of the non-zero basal ice layer report in given cold season



*Estimates
along the snow
course routes
for the 1967-
2007 period*

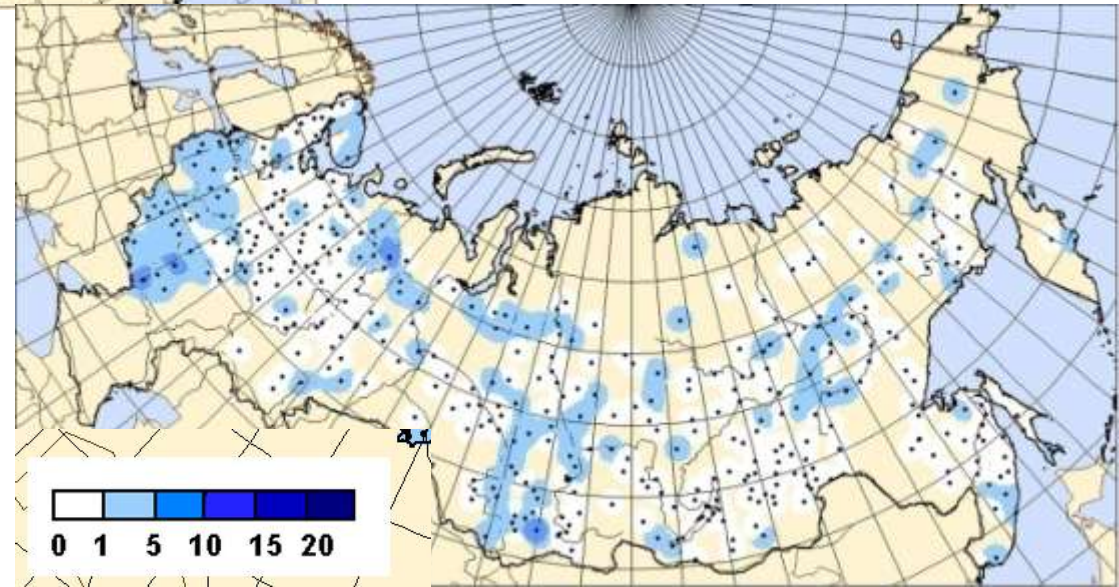
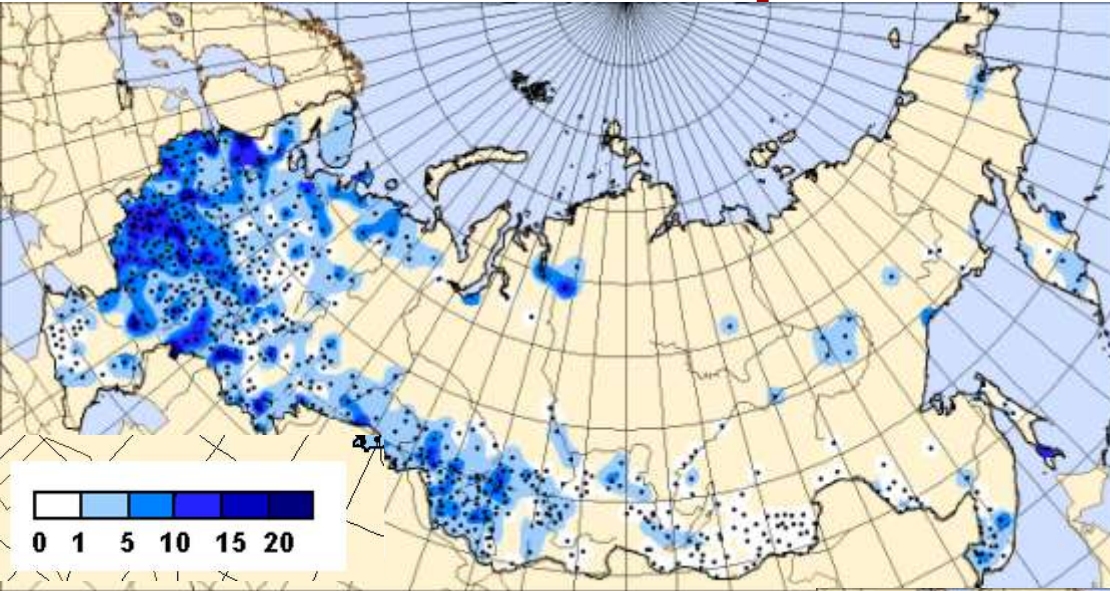
***Top: “field”
courses***

***Right: forest
courses***



Maximum basal ice layer depth during the cold period over Russia

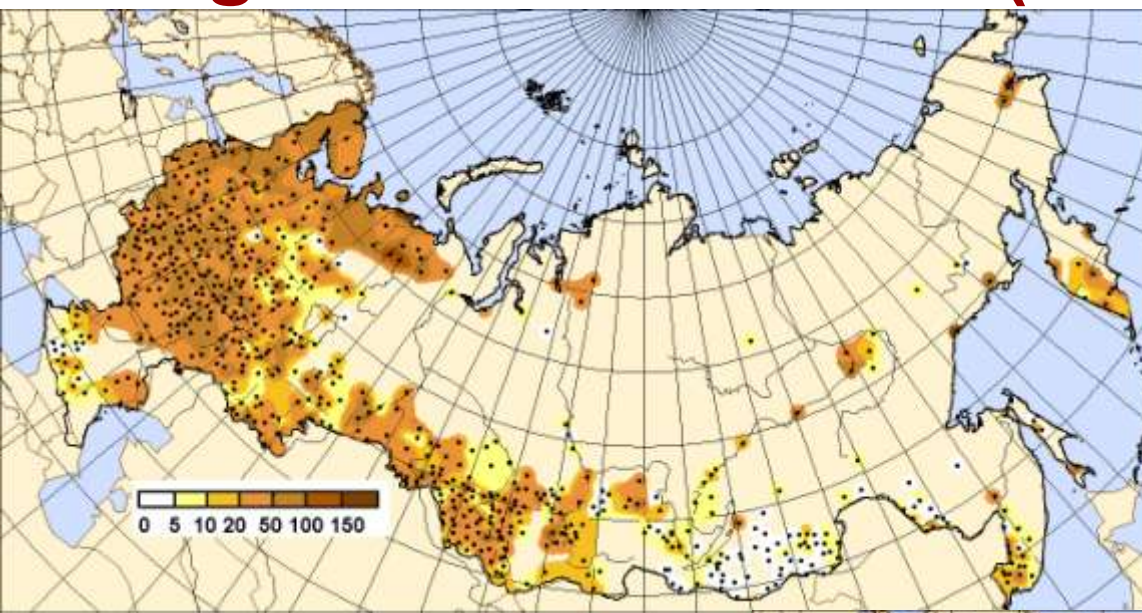
Long-term mean values (mm) along the snow course routes



Top: "field" courses

Right: forest courses

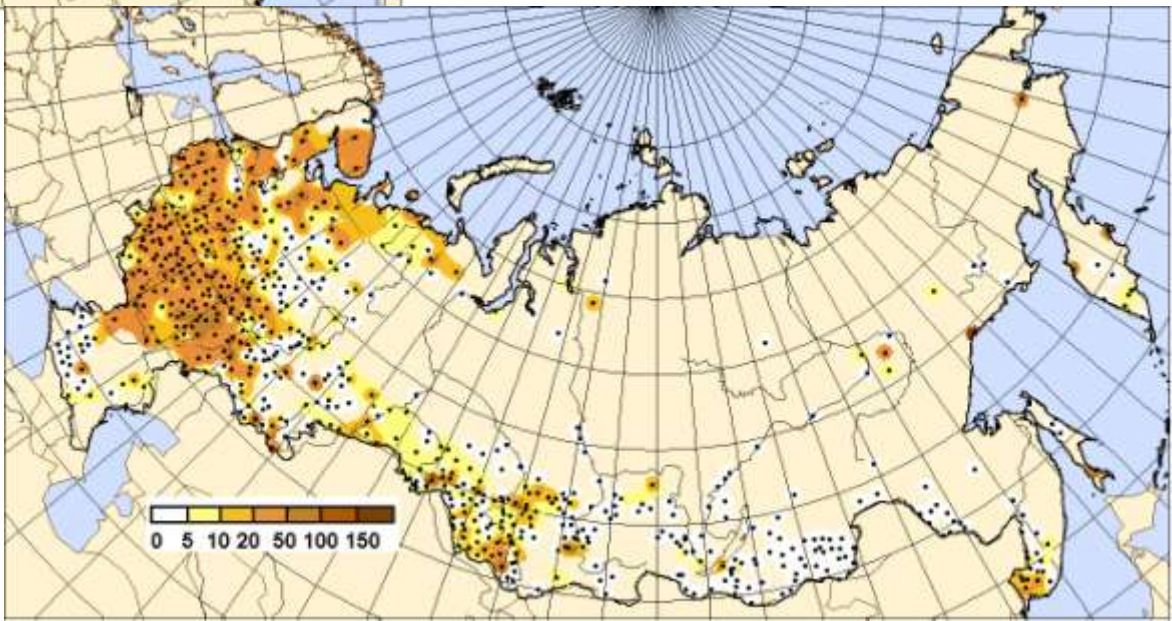
Duration of the basal ice layer presence along the “field” routes (above 0 and 20 mm)



Long-term mean values (days) along the snow course routes

Top: ice layer presence (> 0 mm)

Right: ice layer is above 20 mm

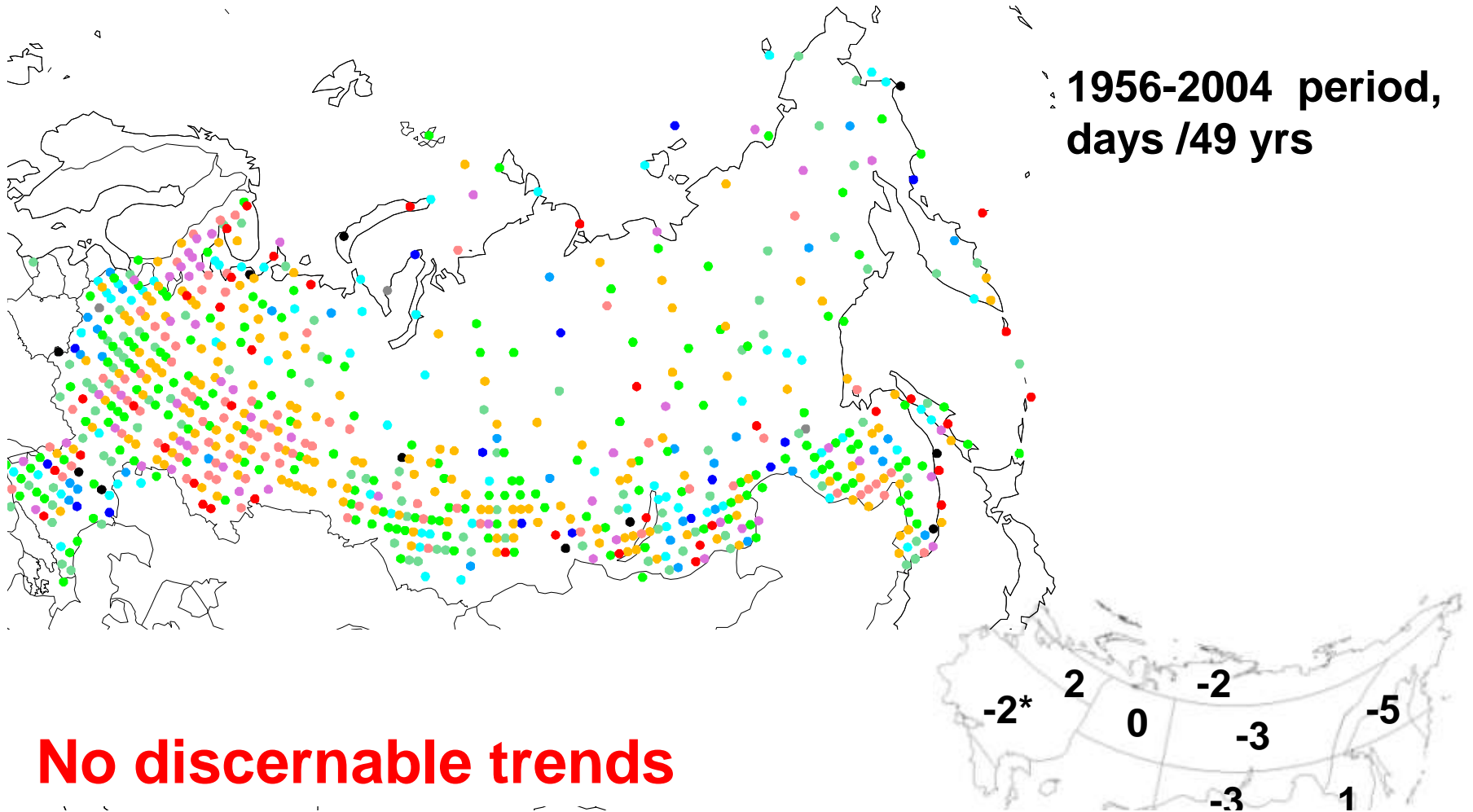


Two characteristics of snow cover during the cold period over northwestern Russia as reported by snow course observations for the 1967-2009 period

	Field snow courses	Forest snow courses
Maximum snow water equivalent, mm	130	150
Crust on the top of snow cover, days	4	2

Trends from in situ data

Linear trends in annual number of days with snow cover



<-30



-30 - -25



-25 - -20



-20 - -15



-15 - -10



-10 - -5



-5 - 0



0 - 5



5 - 10

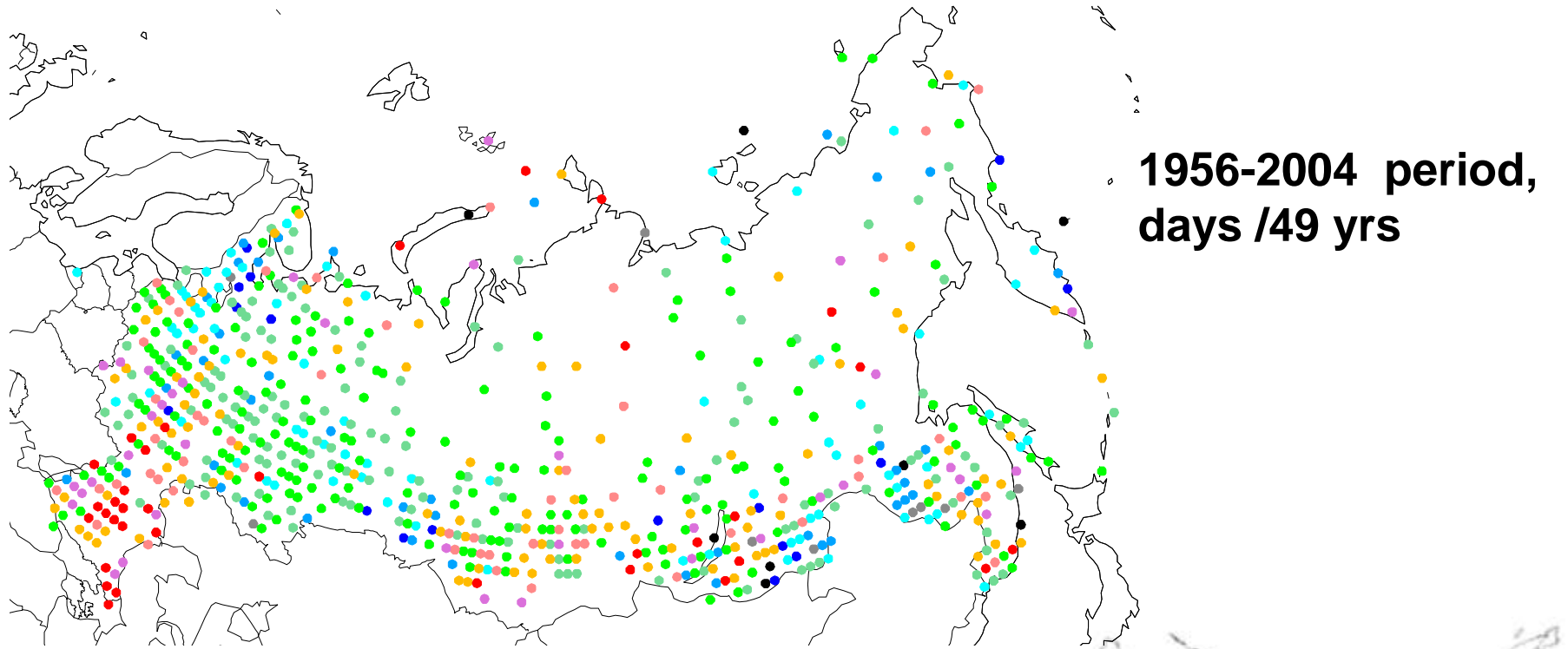


10 - 15

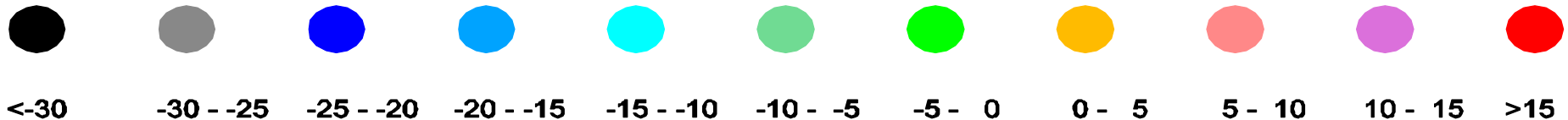
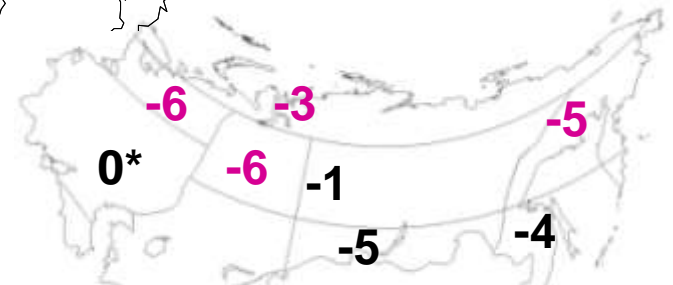


>15

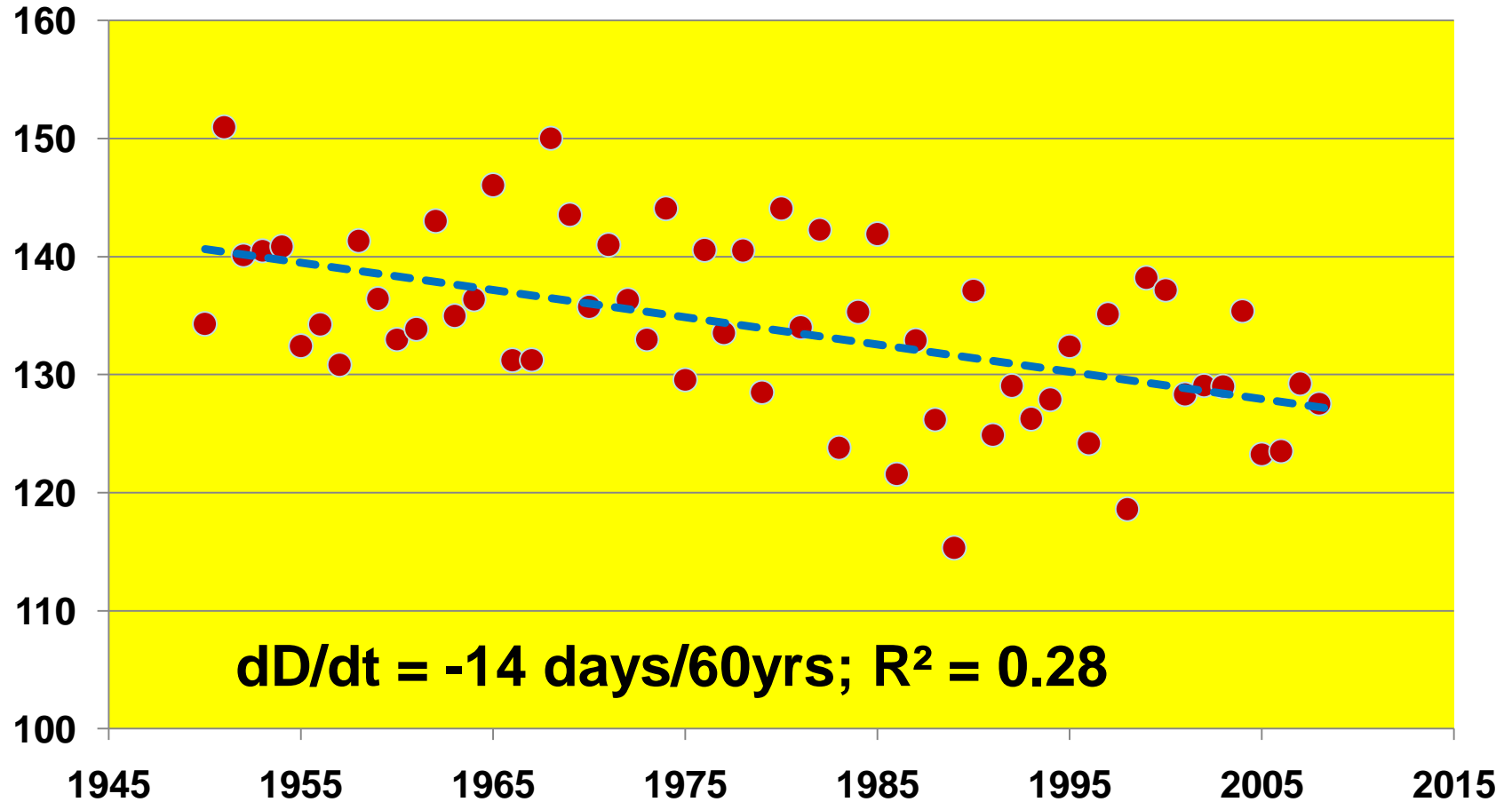
Linear trends in annual number of days with frozen ground, ice, and/or remnants of snow cover



Period of snowmelt is decreasing



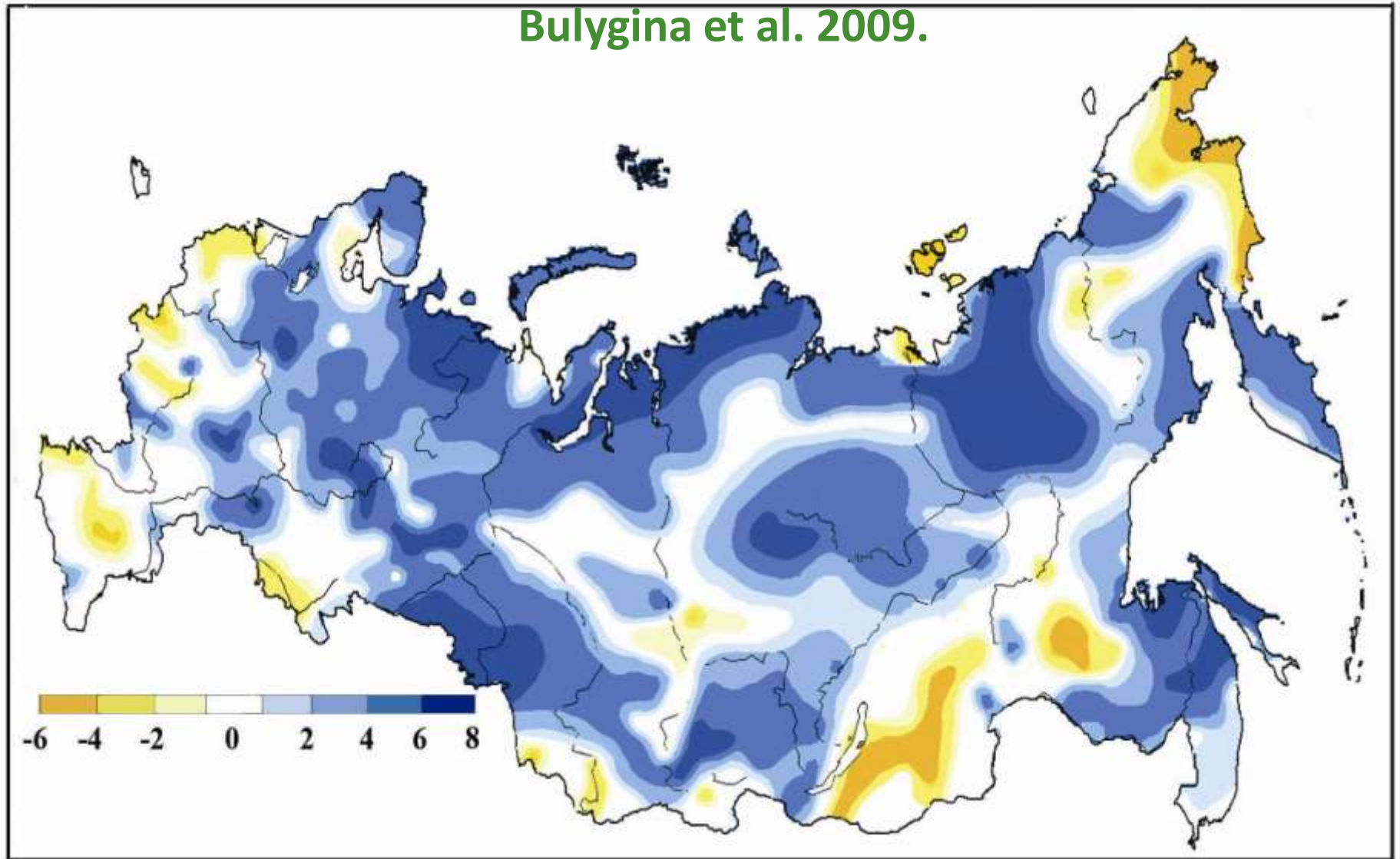
Dates when daily minimum temperature in the Baltic Sea Region of Russia sustainably crosses 0°C in spring and remains above it



Mean date is May 15th. Change is by 2 weeks per 60 years.

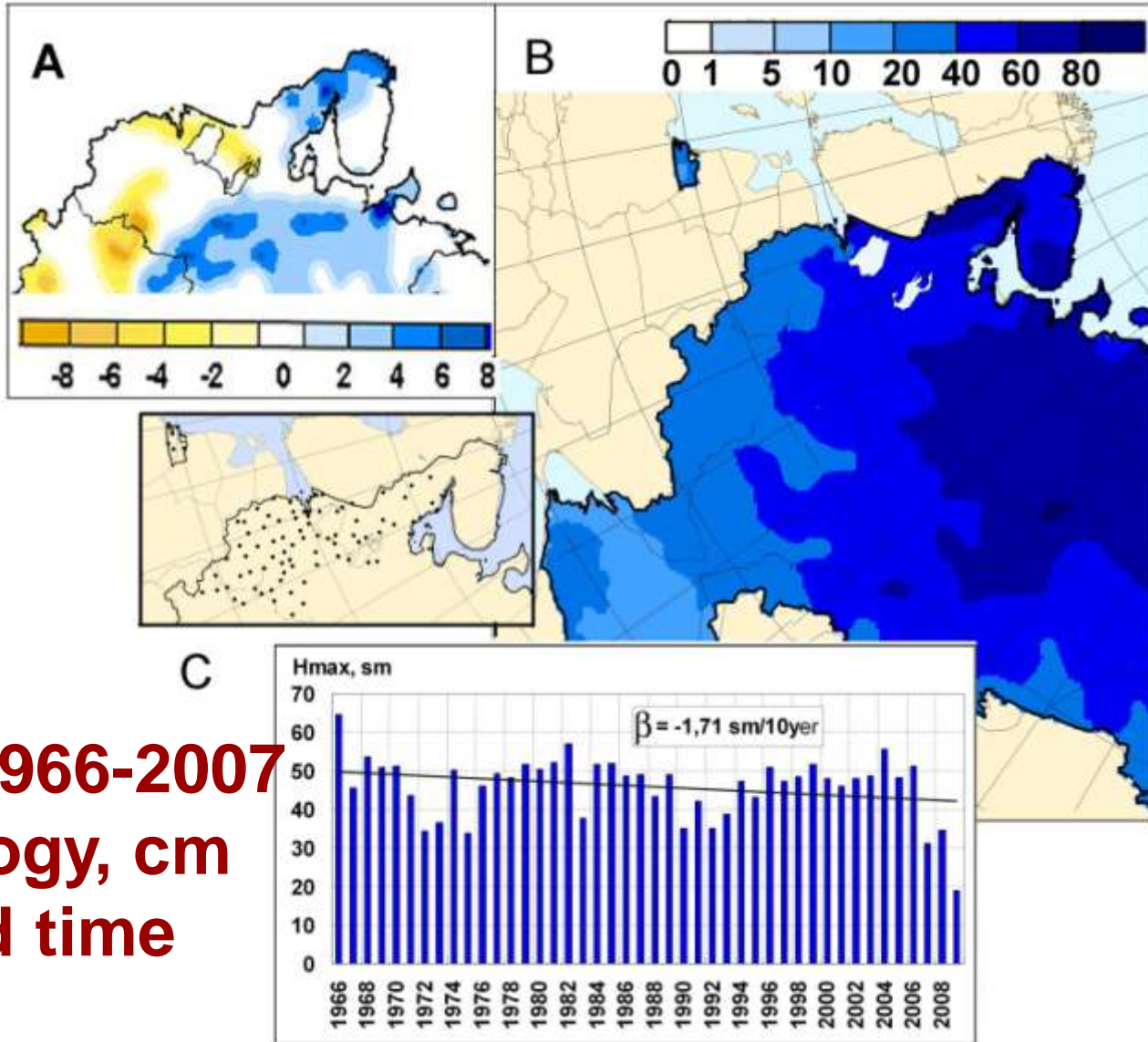
**Number of days with deep snow cover on the ground (> 20 cm).
Linear trends for the 1951-2006 period; [days/10yr].**

Bulygina et al. 2009.



Over Northern Canada and Alaska, negative trends in maximum snow depth were documented (Ross Brown, 2009, Personal Communication)

Maximum snow depth in the winter season over the westernmost Russia (Baltic Sea Basin)



**A. Trends,
days/10yr; 1966-2007**
B. Climatology, cm
**C. Averaged time
series**

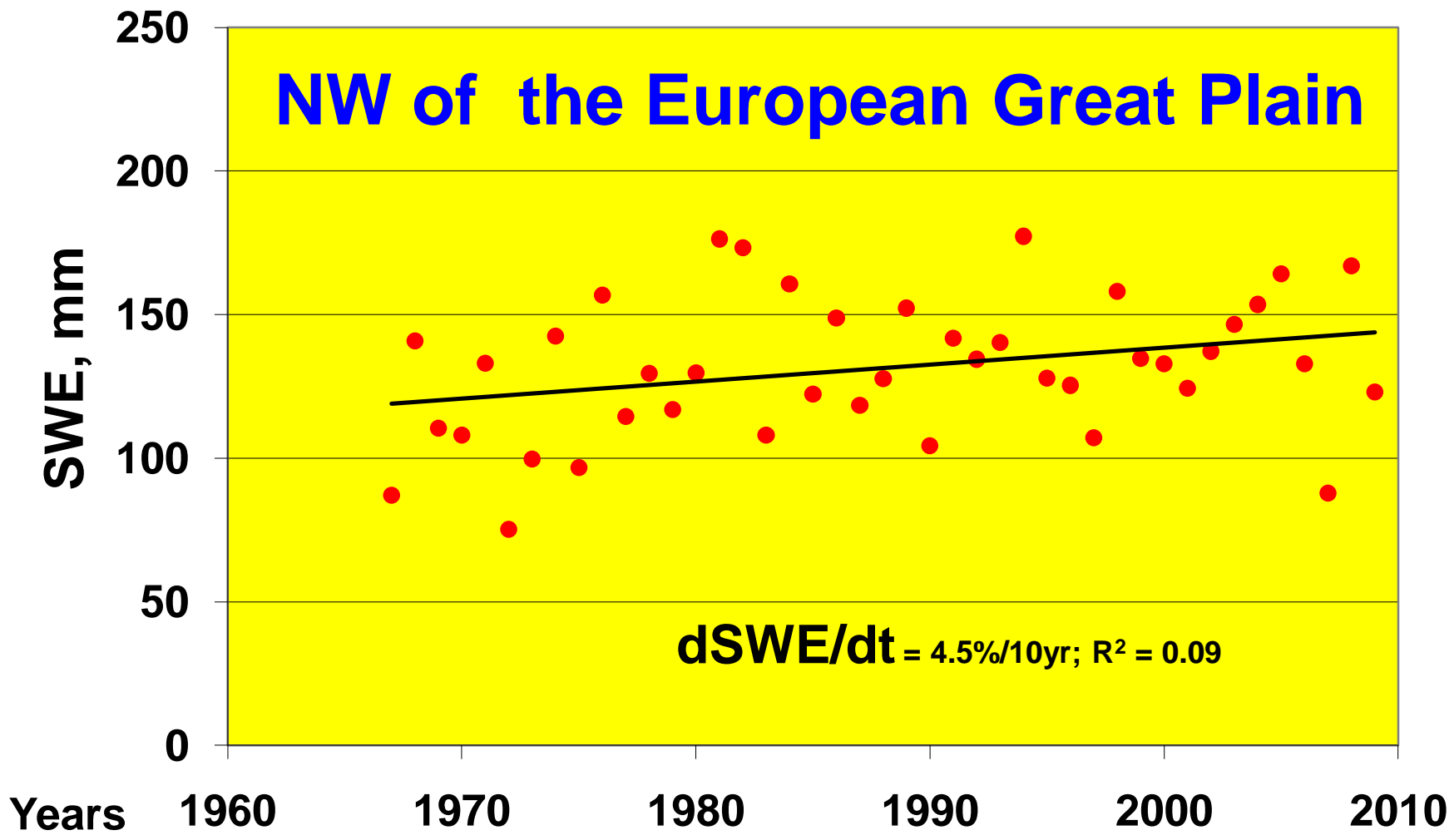
Changes of the maximum snow water equivalent over Russia

Zone, region

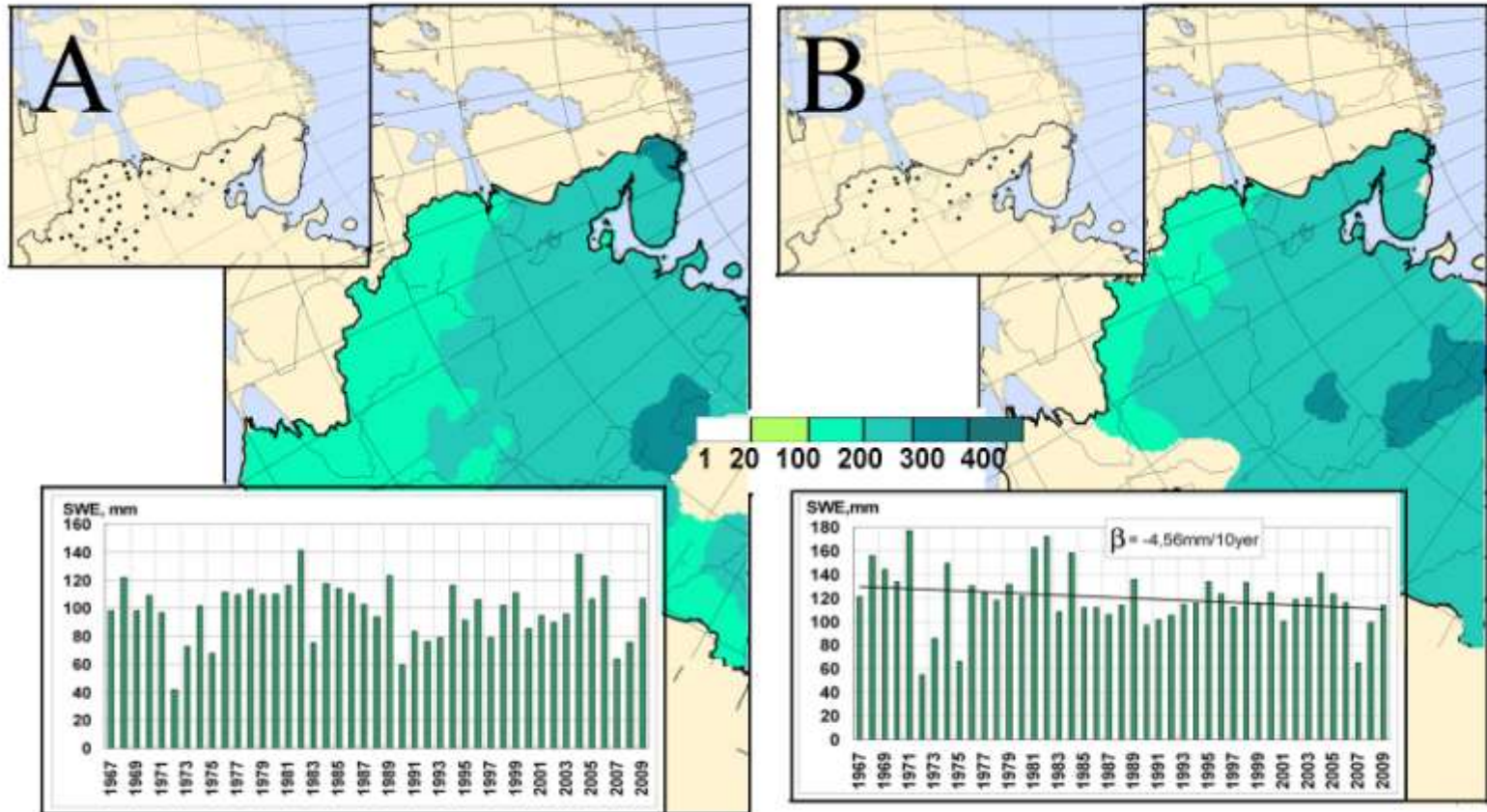
Change in 1967-2009

- Arctic No changes
- Fields of European Russia, north of 55°N Increase by 4 to 6%/10yr
- Southeast of “-”-”-”-”-”-” (ER) Decrease by 4.5%/10yr
- Steppe-forest steppe of ER No changes
- Fields of West Siberia Increase by 6%/10yr
- Central East Siberia Slight increase
- South of East Siberia No changes
- Fields of Russian Far East Increase by 3 to 6%/10yr

Changes in snow water equivalent over the northern Russia along the “field” snow survey routes (approximately, 55°- 65°N lat. belt)



Snow water equivalent over the Baltic Sea Basin within the Russian borders

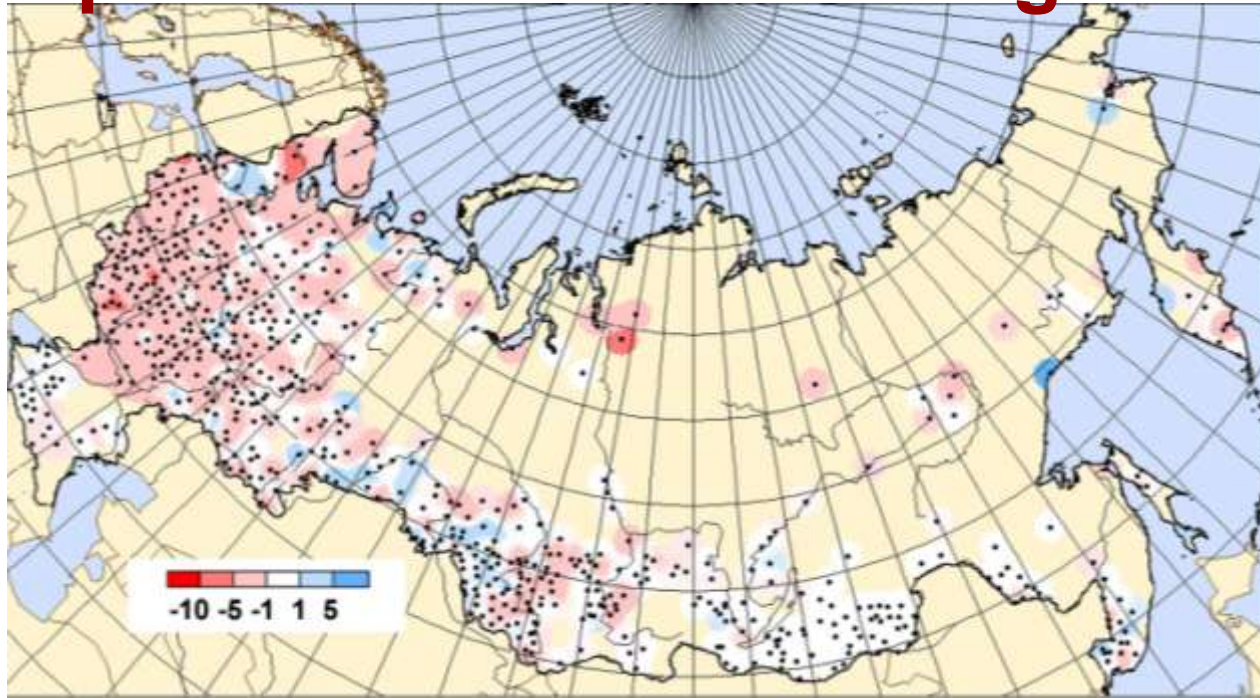


A. Field surveys

Maps: Station distribution and climatology (mm) for the 1971-2000 period

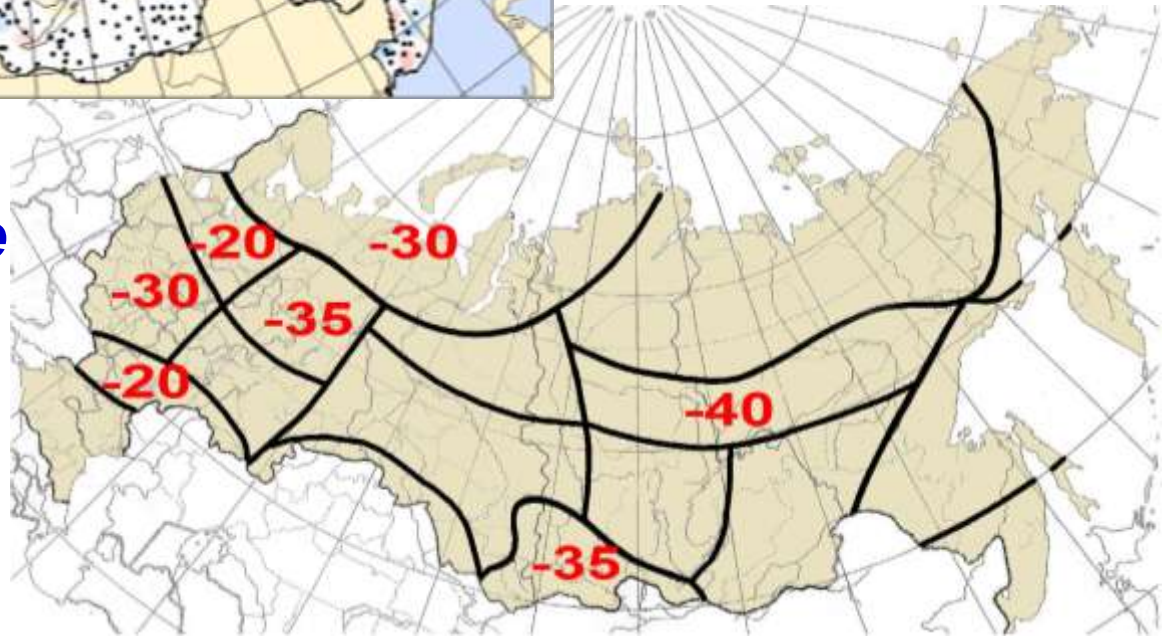
Graphs: Regionally averaged time series; linear trend (-4.6 mm/10yr) is shown only for the forest routes

Maximum basal ice layer depth during the cold period over Russia along the “field” routes

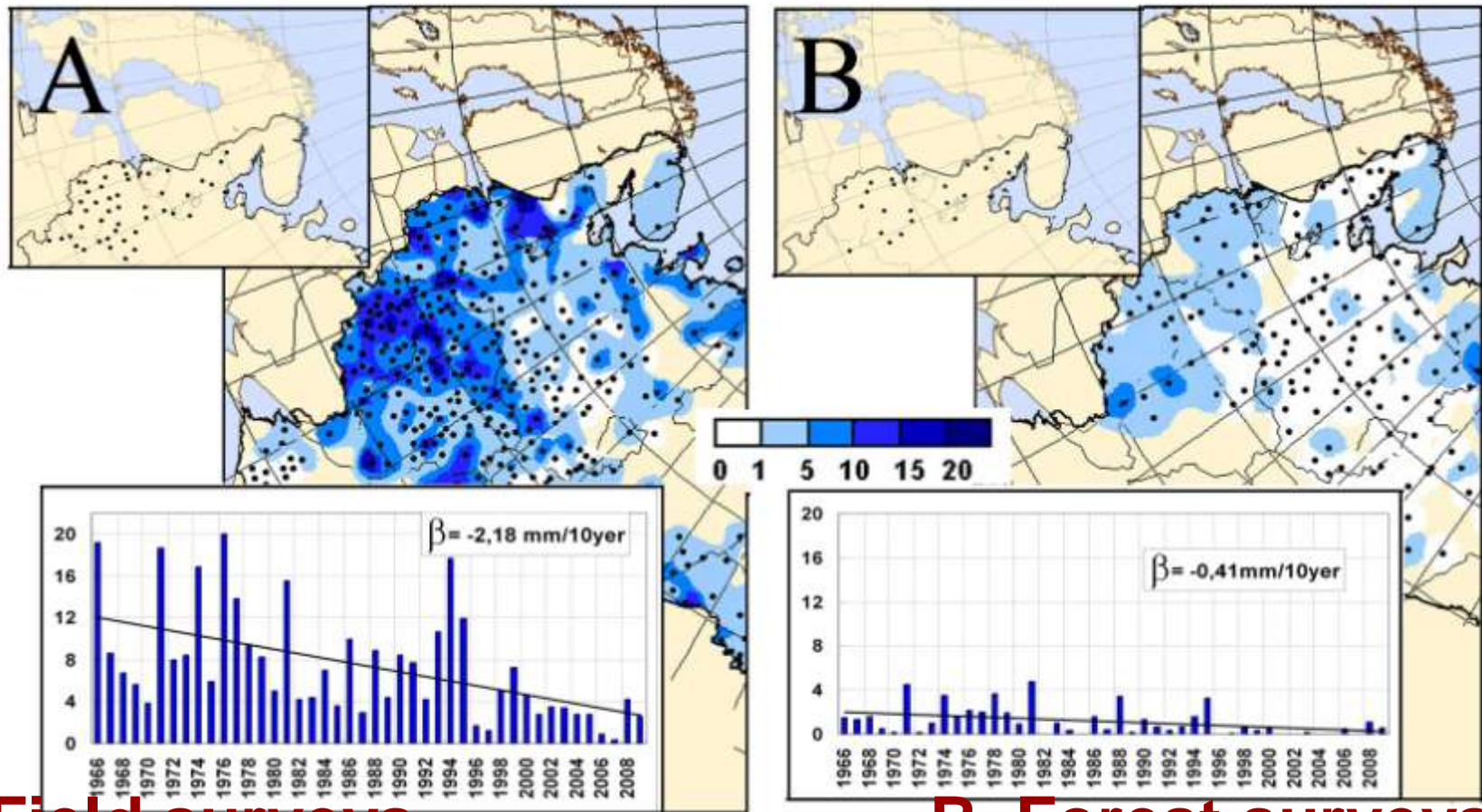


Pattern of the linear trends of the depth in mm per 10 years and their regionally-averaged values in % per 10 years.

Regional trends are presented only for the regions where they were statistically significant at the 0.05 or higher level.



Maximum basal ice layer over the Baltic Sea Basin within the Russian borders



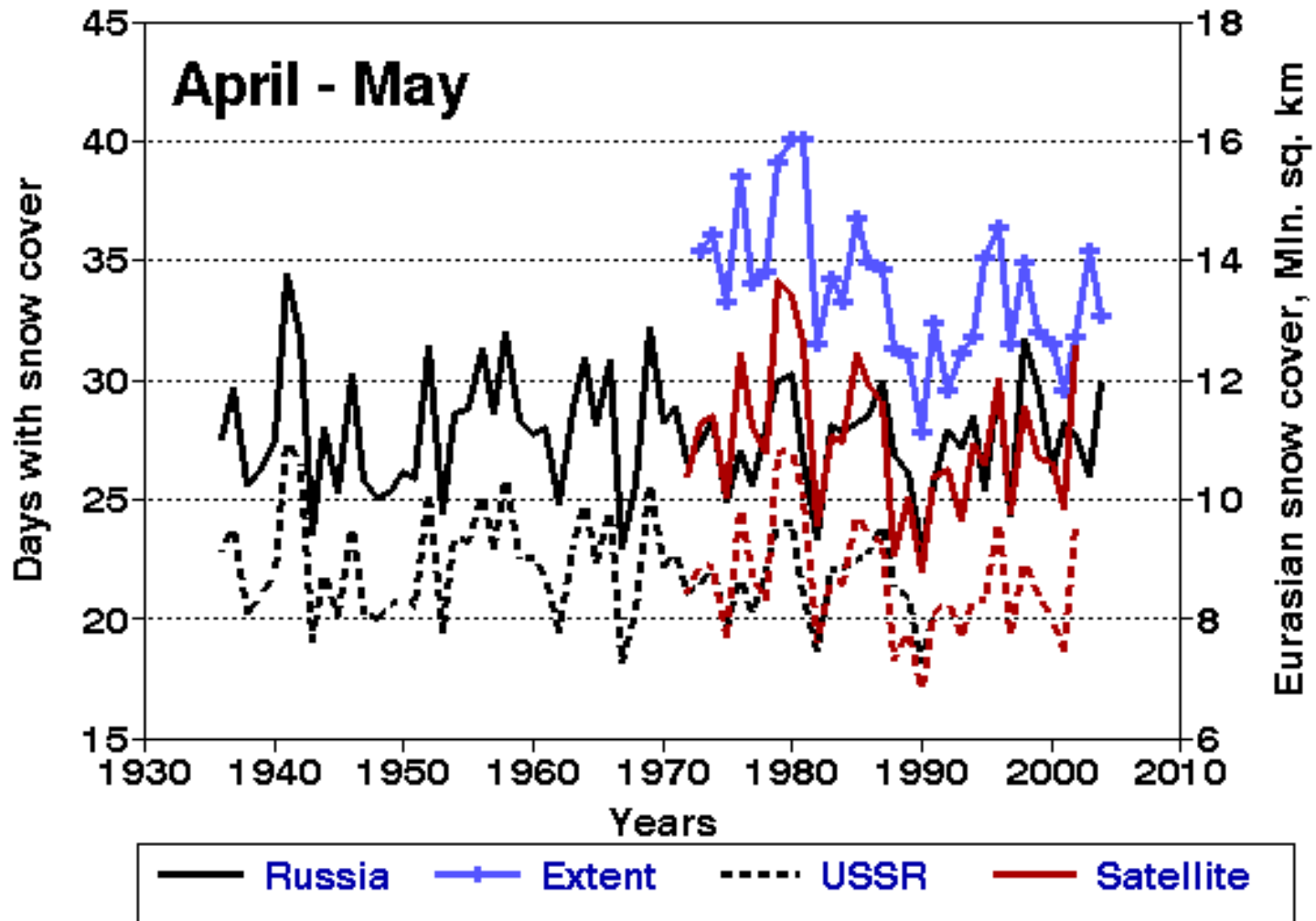
A. Field surveys

B. Forest surveys

Maps: Station distribution and climatology (mm) for the 1967-2007 period

Graphs: Regionally averaged time series

Spring snow cover duration over the former USSR (dashed lines) and Russia (solid lines) as derived from satellite (red lines, Groisman et al. 1994 updated) and in situ observations (black lines)



Conclusions

- Over Russia, recent snow cover retreat manifest itself mostly by a reduction of days with “remnant snow on the ground” conditions. Satellite and in situ data clearly show a retreat of snow cover extent only in spring.
- Increase in the maximum snow water equivalent and snow depth over the most of Russia north of 55°N is a new phenomenon during the past four decades but it is not observed in the Baltic Sea Basin.
- In the westernmost parts of Russia and Belarus we are observing a dramatic change in the cold season as it was known in the past. In particular, the entire process of spring snowmelt has become shorter in duration.
- There are two competing factors that can cause a systematic change in the ice crust characteristics over the northwestern Russia, i.e., the increase in thaws due to strong regional warming and a potential shortening of the period of snowmelt. The second factor appeared to be more significant during the past 43 years.