Ongoing climatic and environmental change in Northern Eurasia:

The role of the Northern Eurasia Earth Science Partnership Initiative (NEESPI) as a vehicle to accelerate regional research for the global needs

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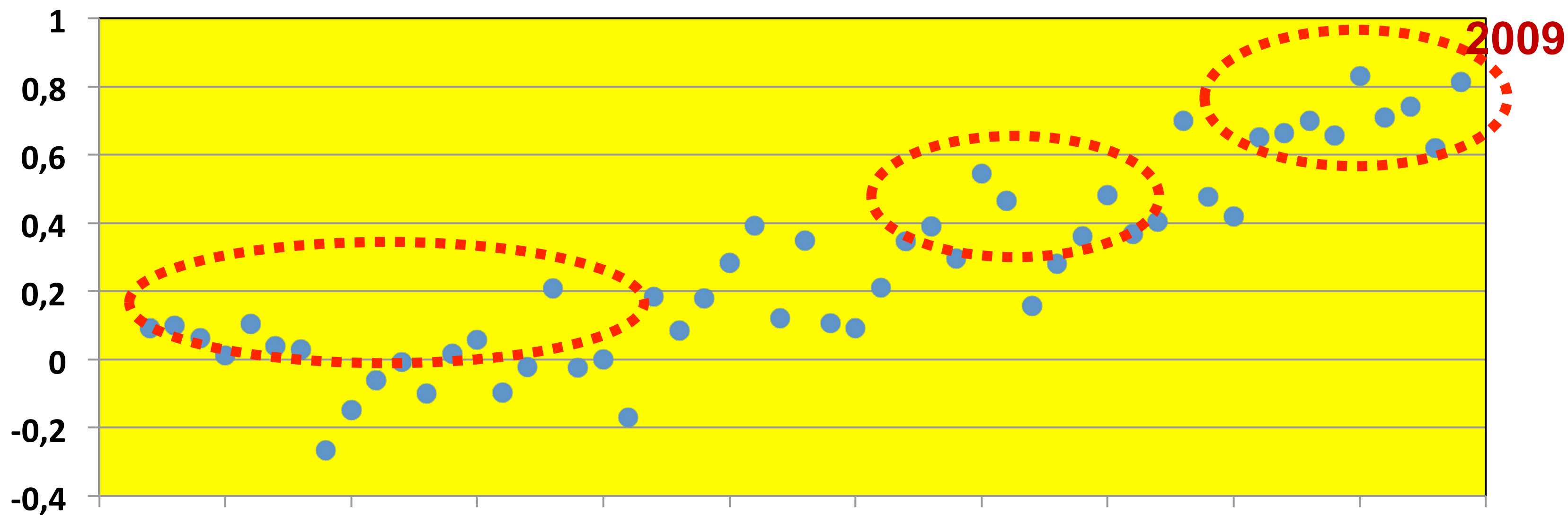
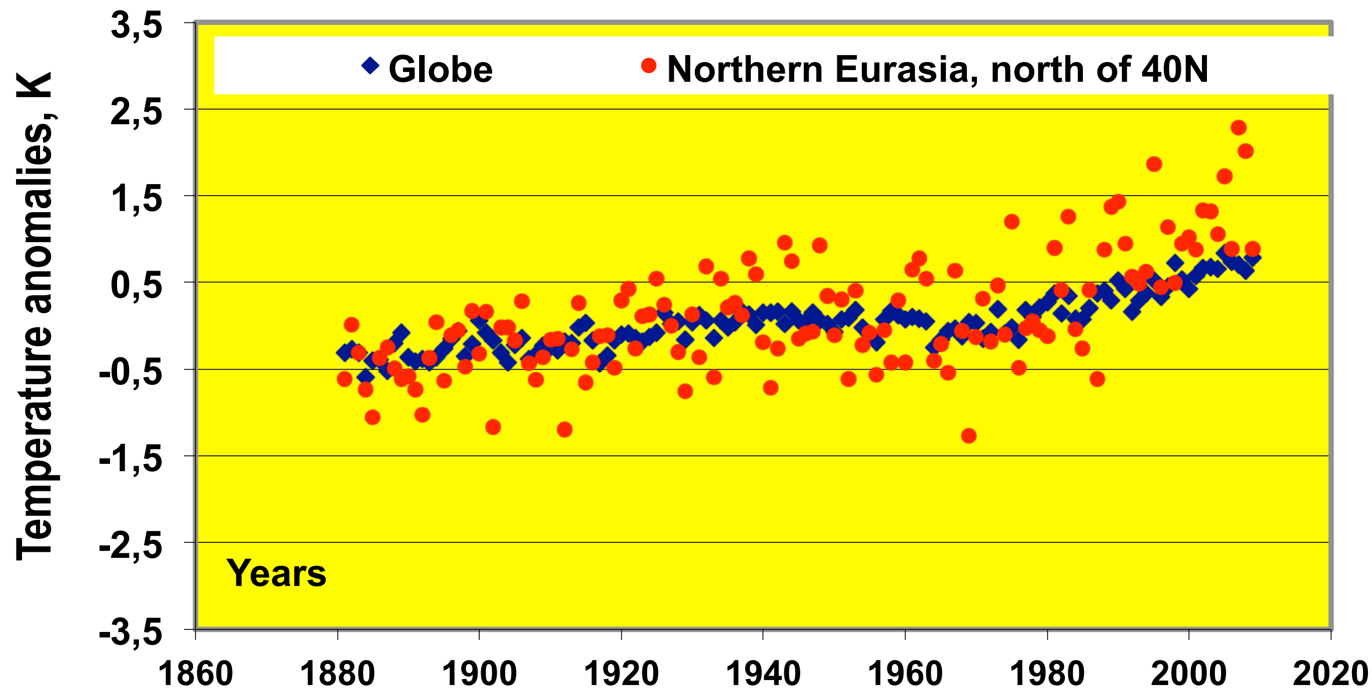
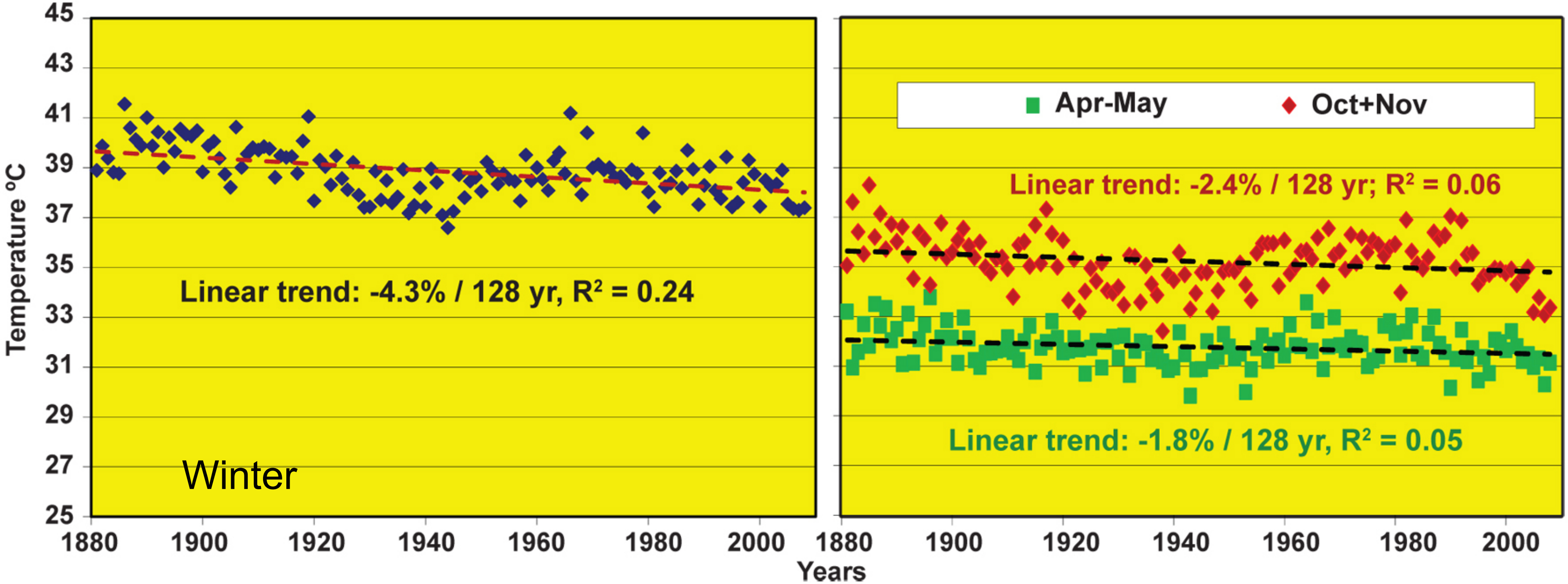
Global Surface Air Temperature Anomalies, °C



Rates of increase of annual temperature for the "globe" (60°S to 90°N) and Northern Eurasia are 0.86 °C/129 yr and 1.4 °C/129 yr respectively. (Lugina *et al* 2007, updated).

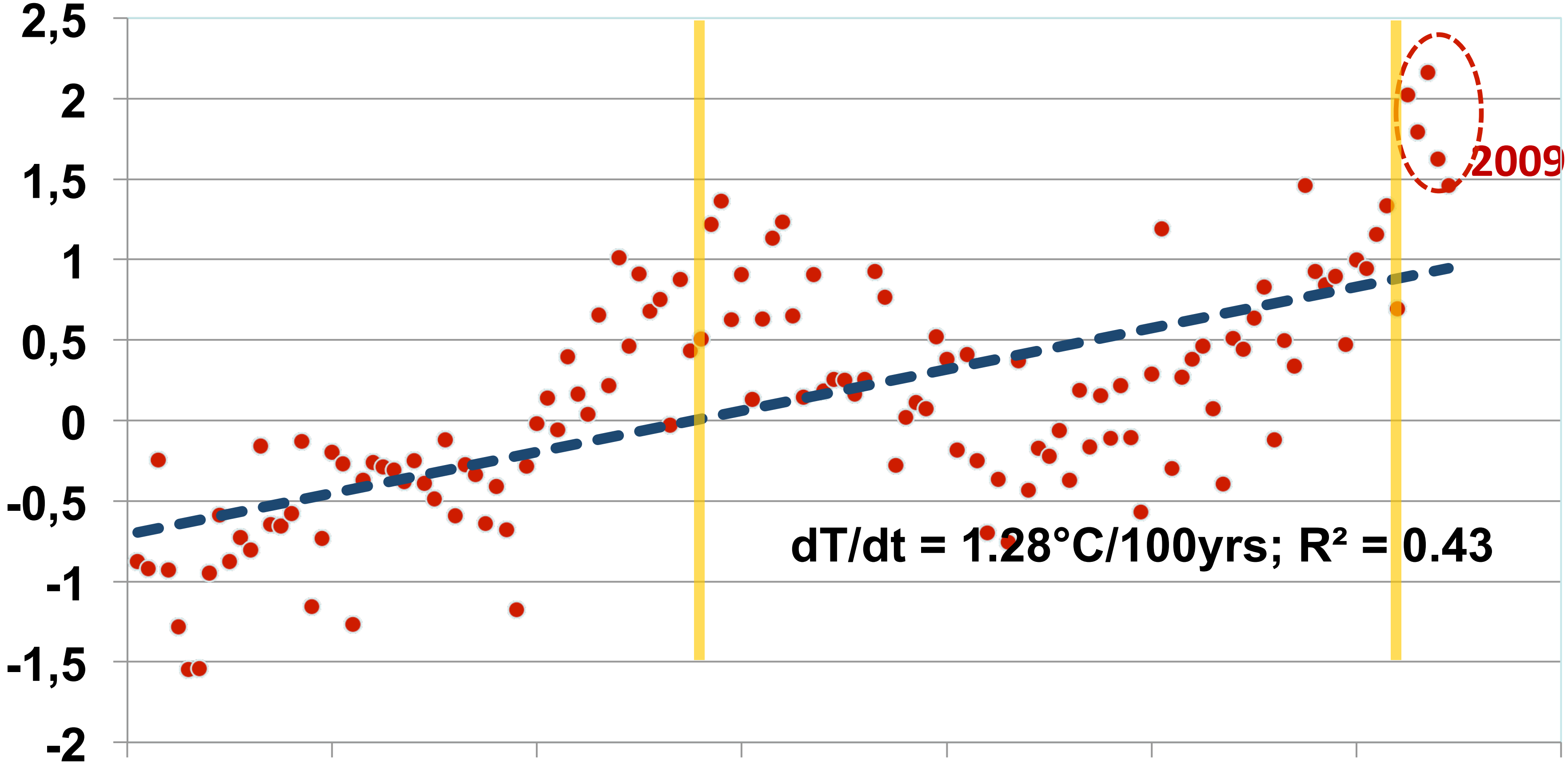


Decrease in surface air temperature meridional gradients over the Northern Hemisphere estimated as a difference of tropical mean zonal temperature (zone 0°- 30°N) and polar mean zonal temperature (zone 60°N - 90°N).



For Northern Eurasia climate, zonal heat and water vapor transport are of critical importance.

Annual surface air temperature area-averaged over the 60°N - 90°N latitudinal zone (Arctic)



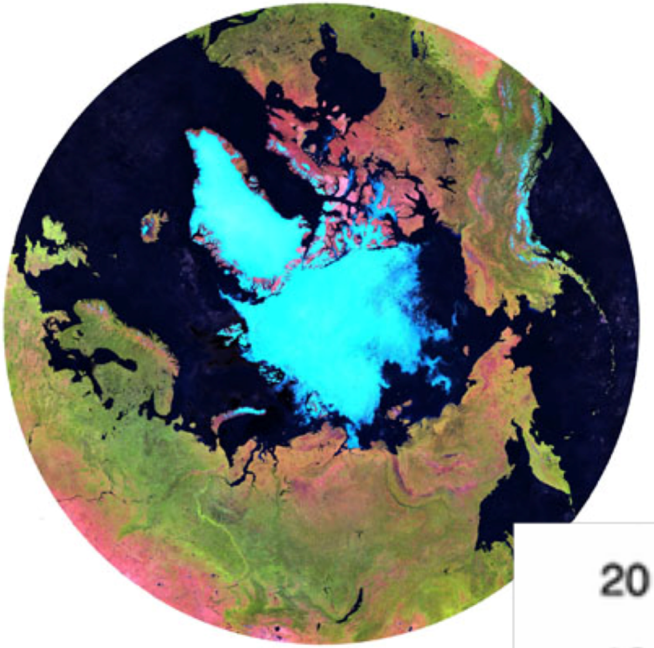
Linear trend for the entire period of instrumental observations is 1.65°C/129 yr (R^2 = 0.43) but there were periods (e.g., 1936-2004) when there was no statistically significant linear trend (Groisman *et al* 2006, updated).

In the absence of the systematic external forcing (e.g., no linear trends in the Arctic temperature) over the northeastern Russia during the 1936-2000 period:

Duration of the period with stable snow cover **has increased by 8 days per 65 years**

Duration of the period with unstable snow cover and/or frozen ground without snow **has decreased by 9 days per 65 years**

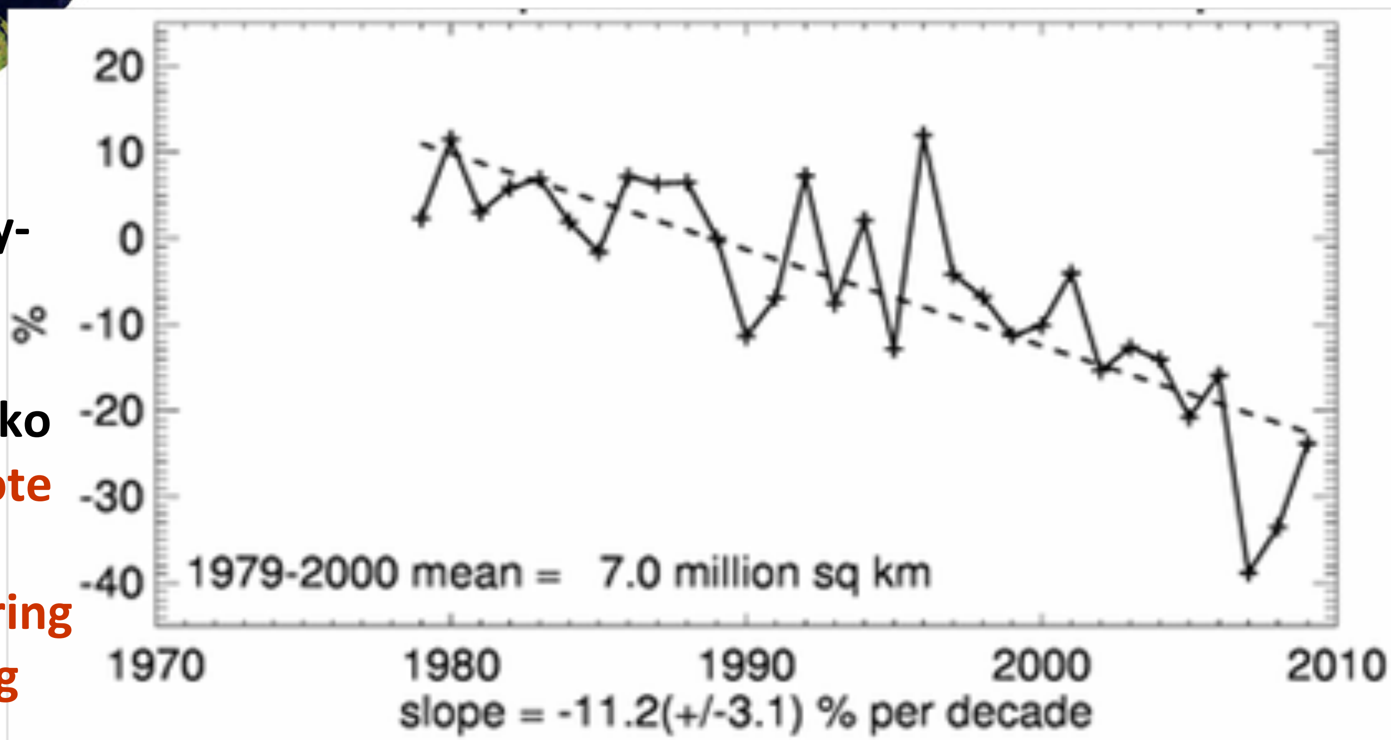
Autumn - Winter



Autumn sea ice extent changes (%)

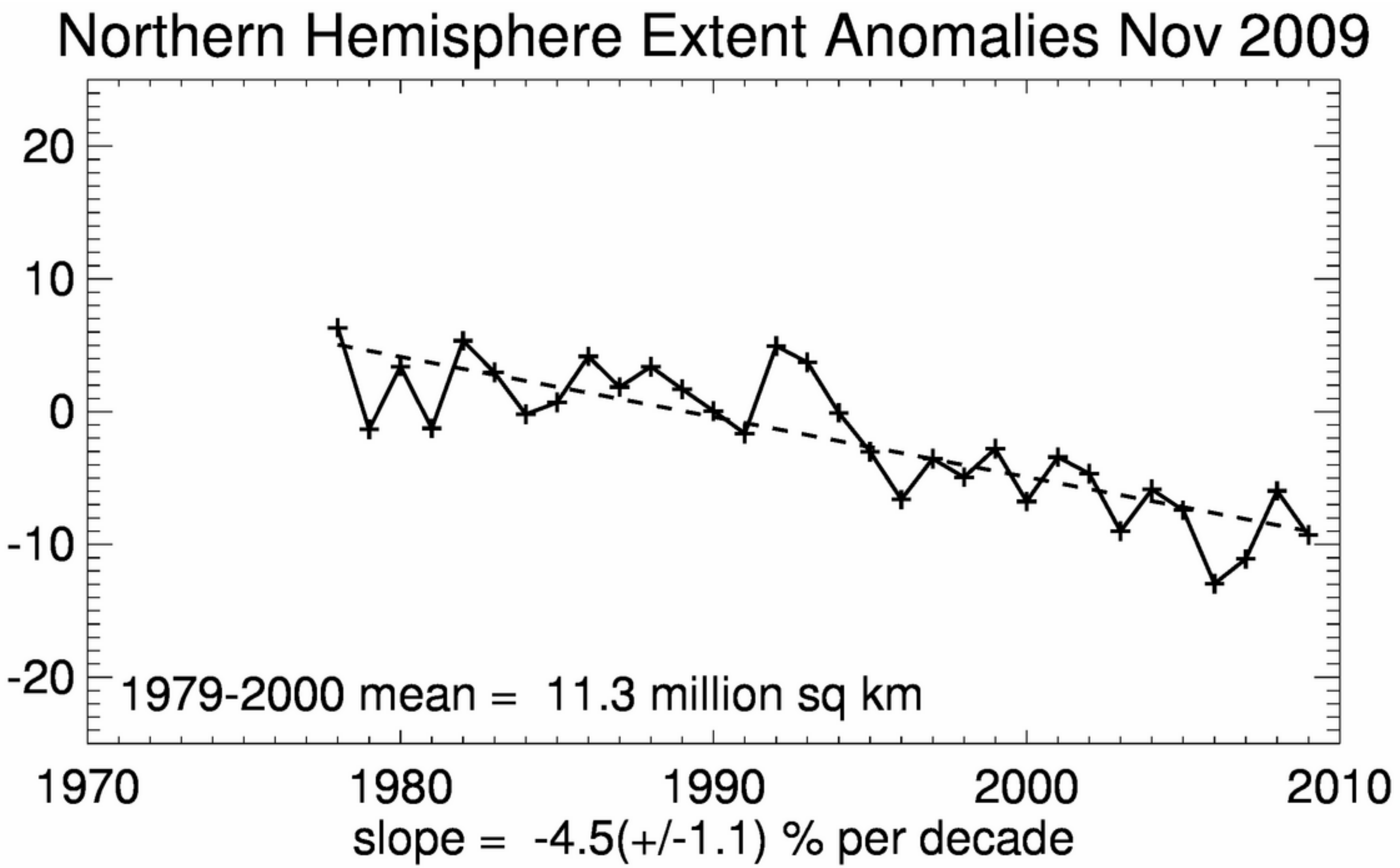
Terra-MODIS RGB, July-Sept 2008, 250 m resolution. Cloud free composite. (Trishchenko *et al* 2009). Please, note large areas of ice-free water in the Arctic during this three-months-long season.

Arctic Sea Ice Extent Anomalies, Sept. (%)



Source: http://nsidc.org/data/seaice_index/

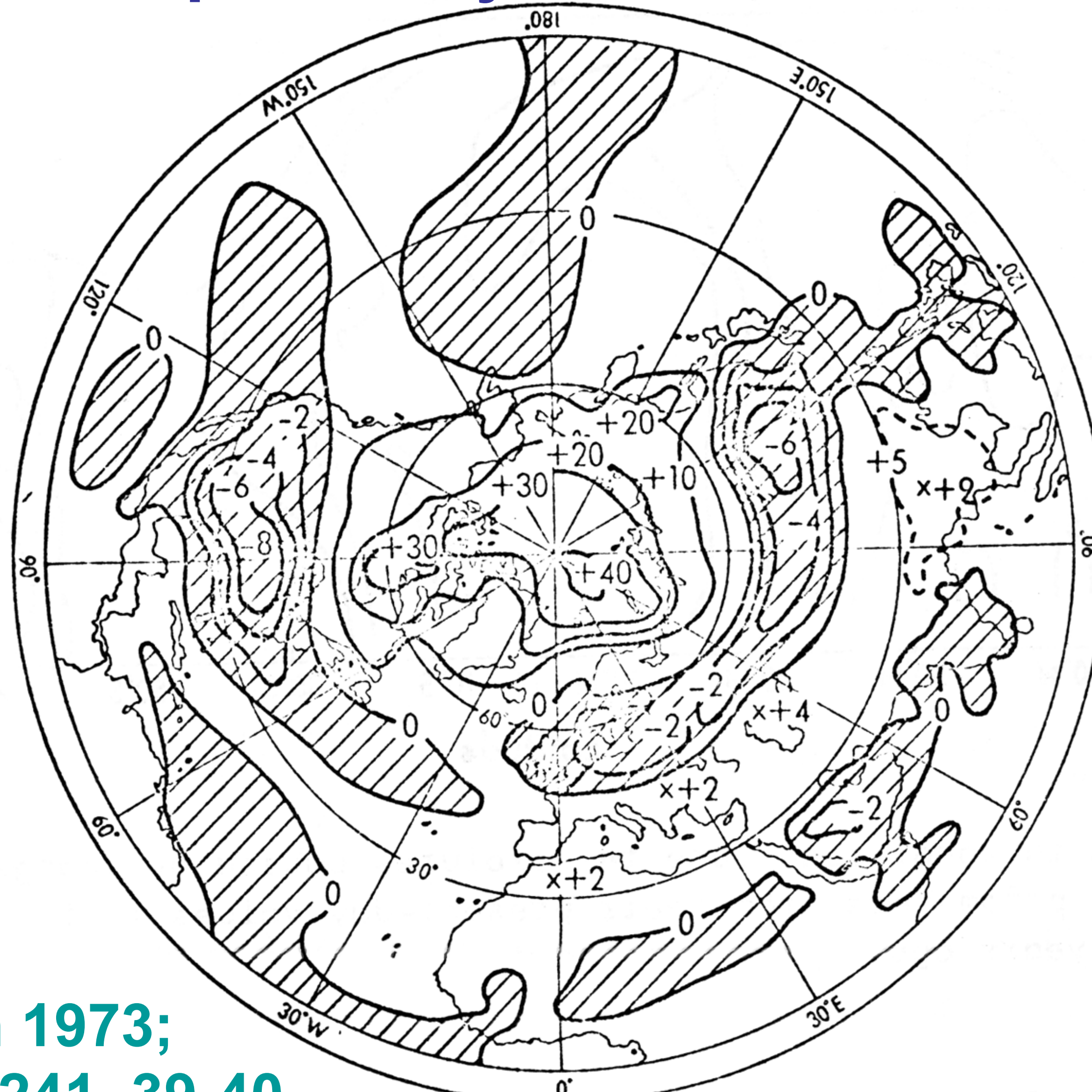
Autumn sea ice extent changes (%)



Source: http://nsidc.org/data/seaice_index/

One of the first UCMO GCM sensitivity experiments with polar ice replaced by water at 0°C

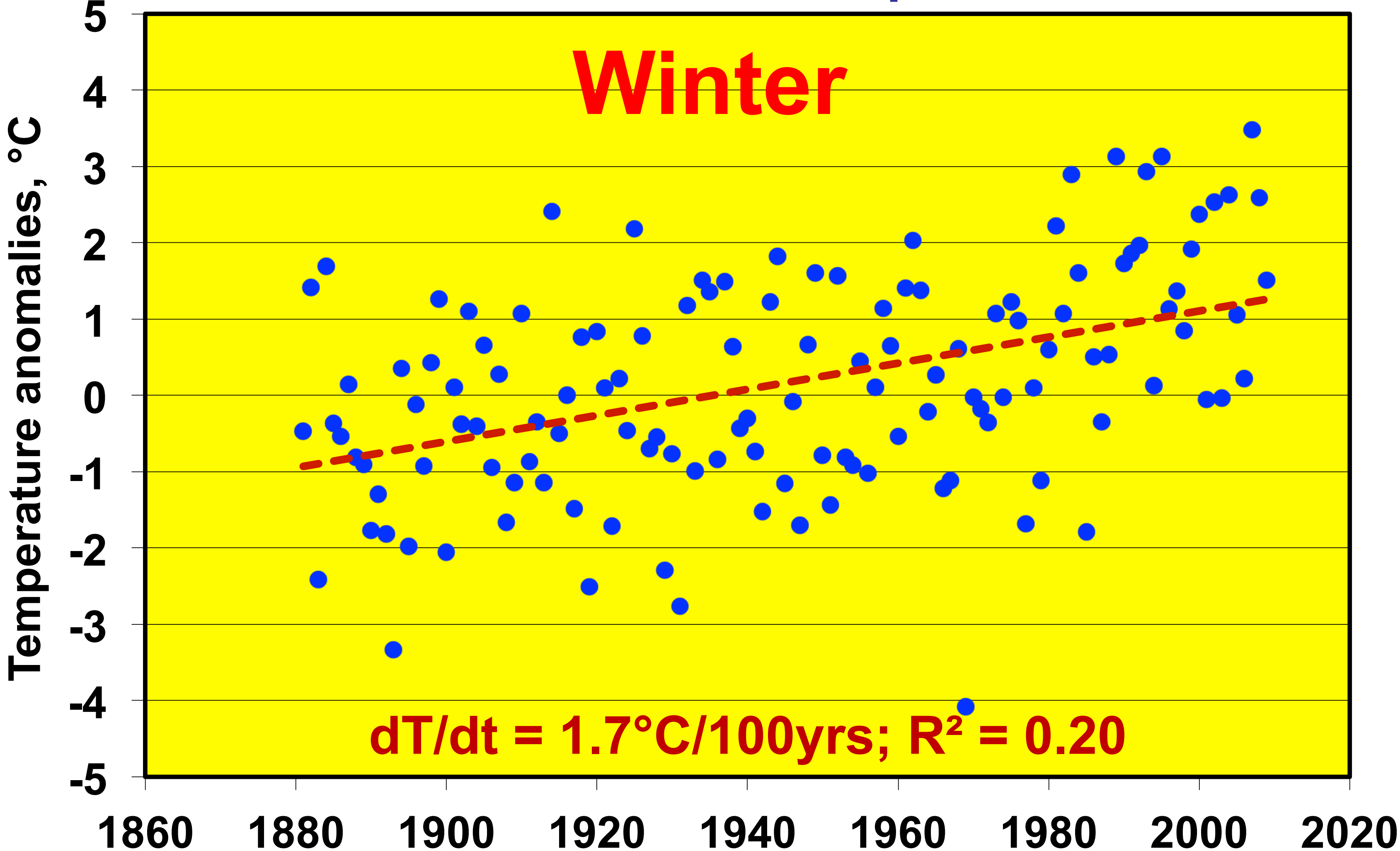
Changes in January surface air temperature. The Arctic becomes warmer by up to 40° C but the latitudinal belt south of 60°N becomes colder by up to 8°C.



Newson 1973; *Nature*, 241, 39-40

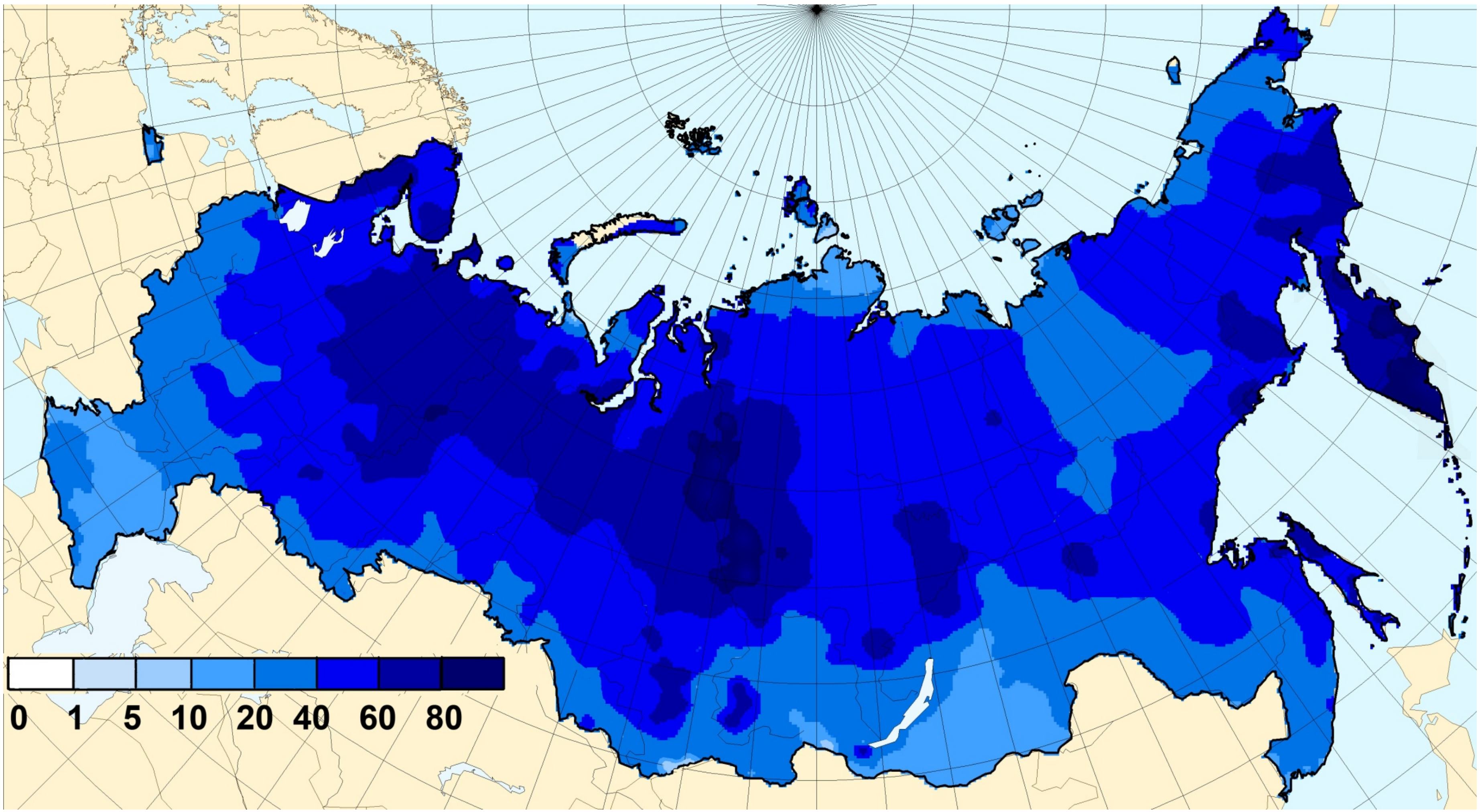
Northern Eurasia, north of 40°N

Temperature anomalies for the past 129 years
1951-1975 reference period



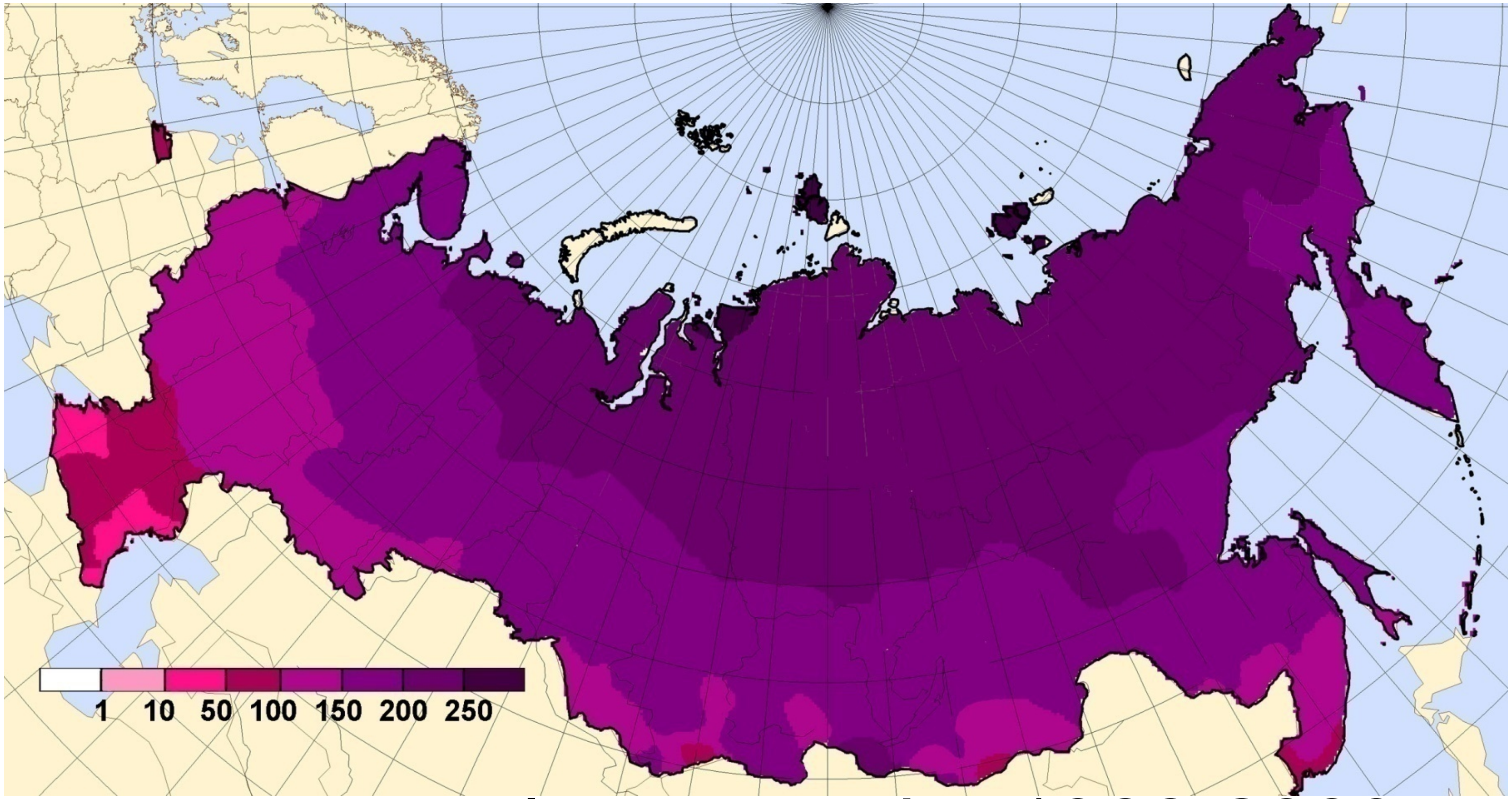
Archive of Lugina et al. 2007, updated

Mean maximum snow depth (cm) at synoptic stations (Bulygina et al. 2009)



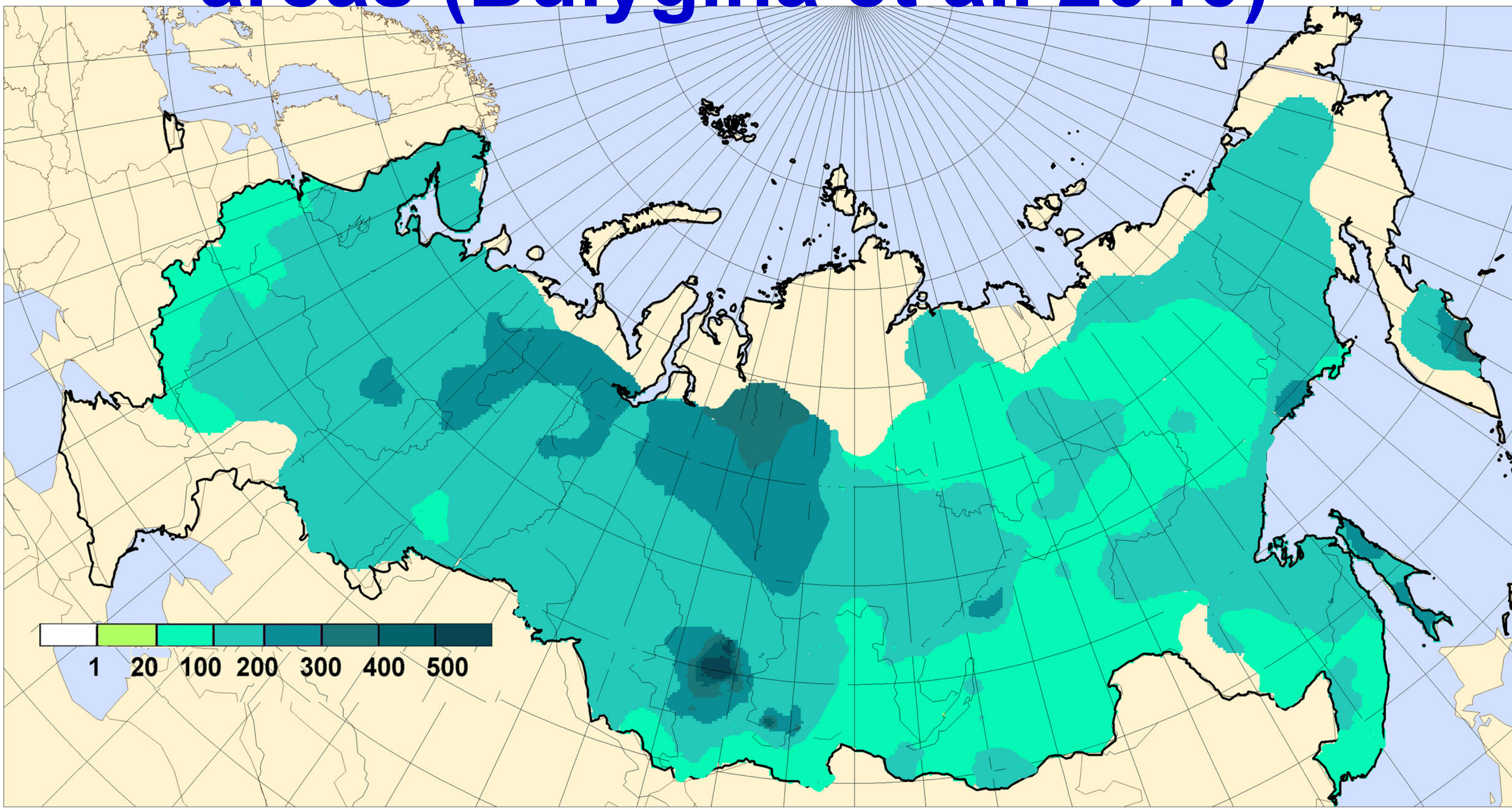
Average mean values over the 1966-2009 period

Mean duration of the presence of snow on the ground (days with >50% of the area coverage) in the vicinity of synoptic stations (Bulygina et al. 2009)



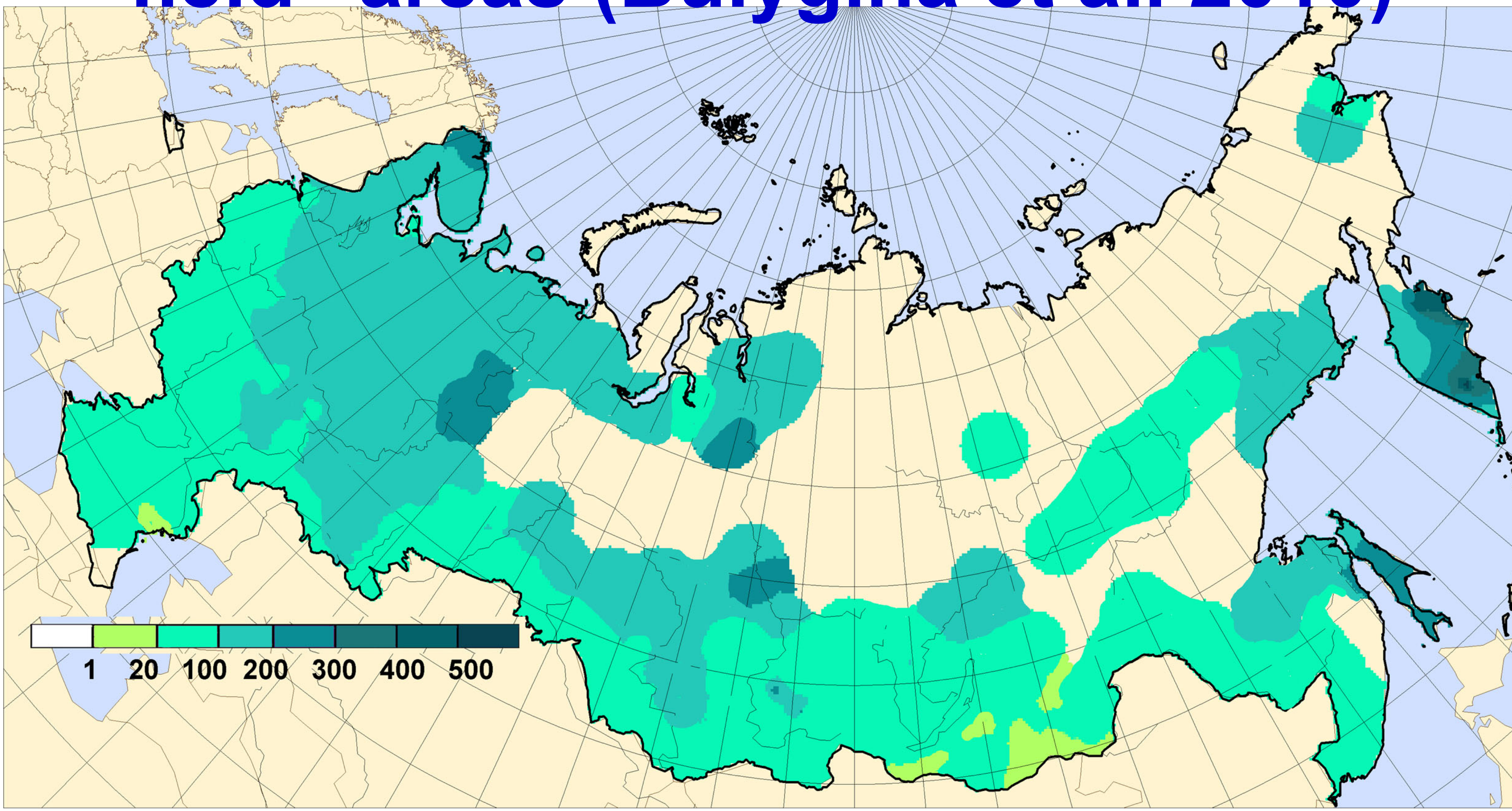
Average mean values over the 1966-2009 period

Maximum snow water equivalent (mm) along the snow surveys in the forested areas (Bulygina et al. 2010)



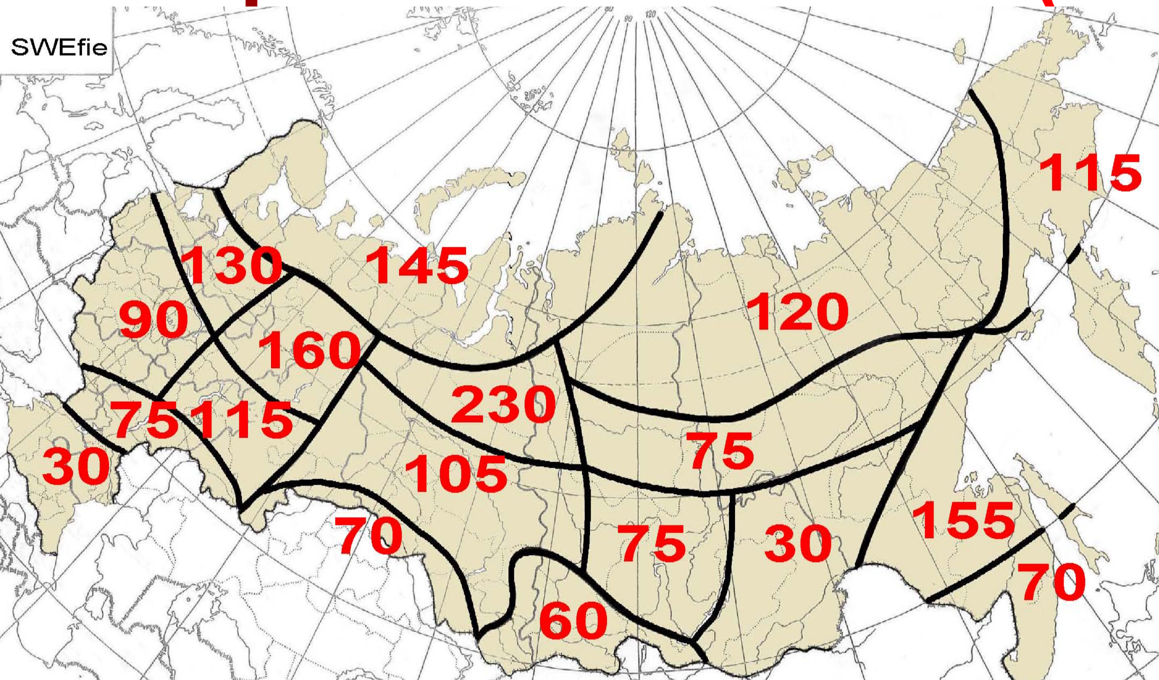
Average mean values over the 1966-2009 period

Maximum snow water equivalent (mm) along the snow surveys in the open “field” areas (Bulygina et al. 2010)



Average mean values over the 1966-2009 period

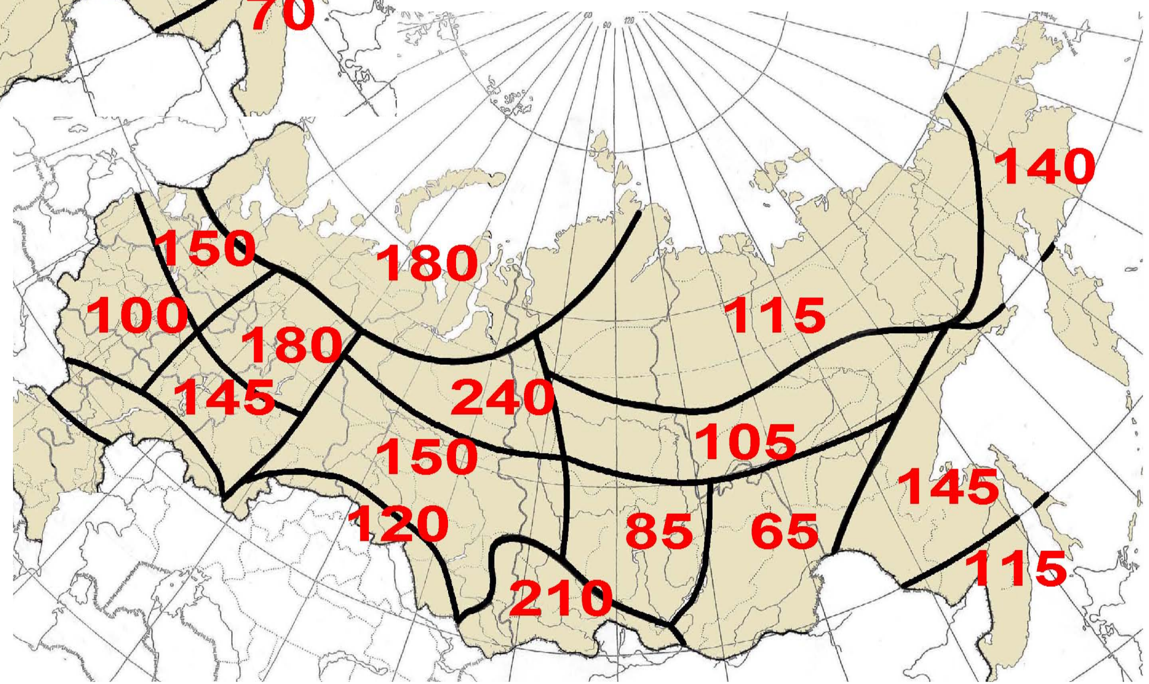
Maximum snow water equivalent during the cold period over Russia (Bulygina et al. 2010)



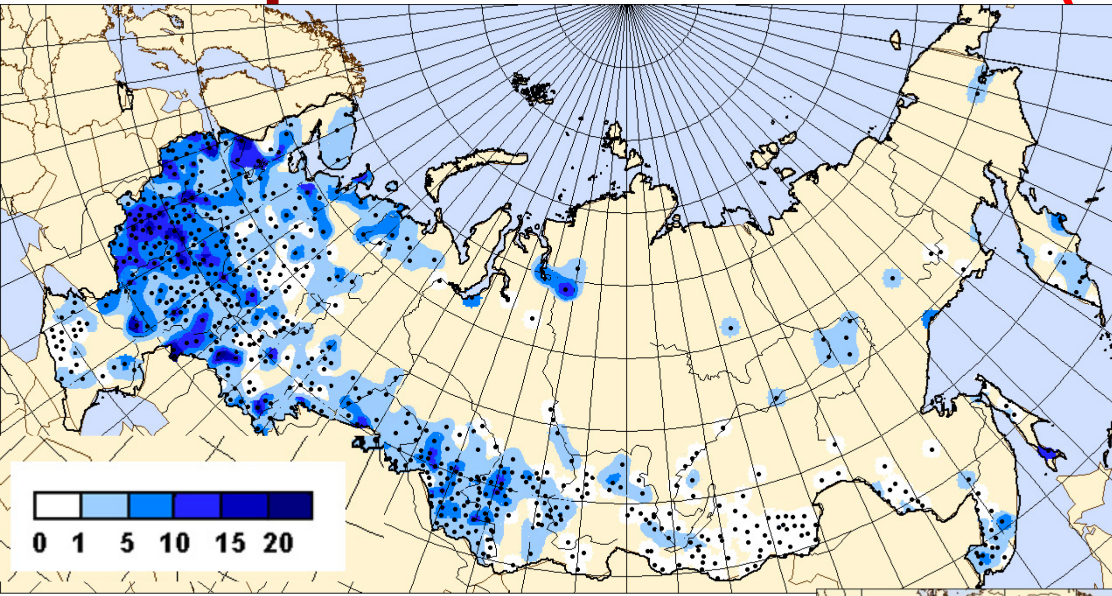
Long-term mean values (mm) along the snow course routes for the 1967-2009

***Top:* "field" courses**

***Right:* forest courses**



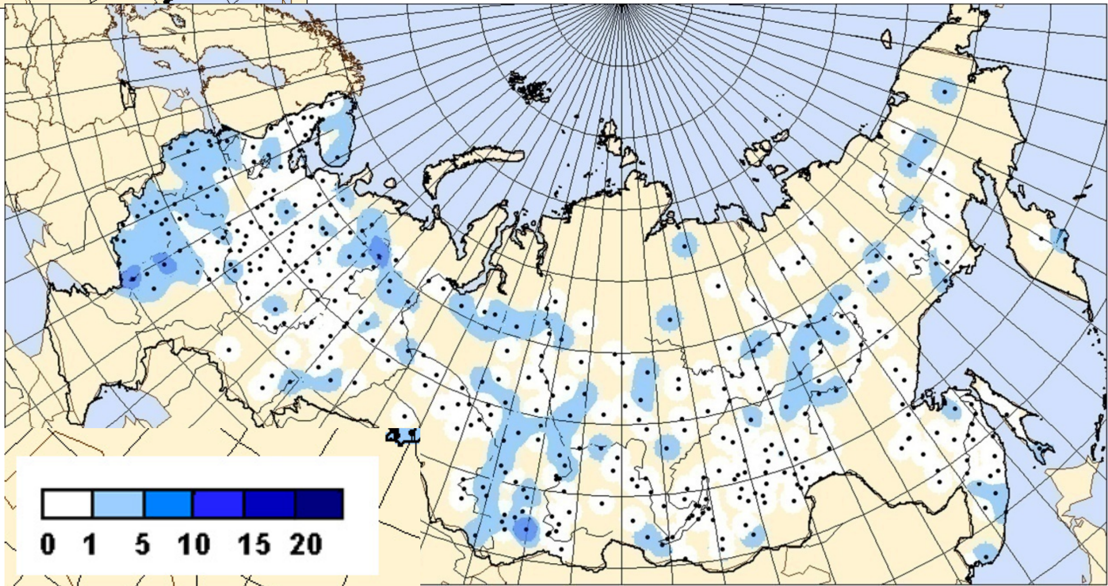
Maximum basal ice layer depth during the cold period over Russia (Bulygina et al. 2010)



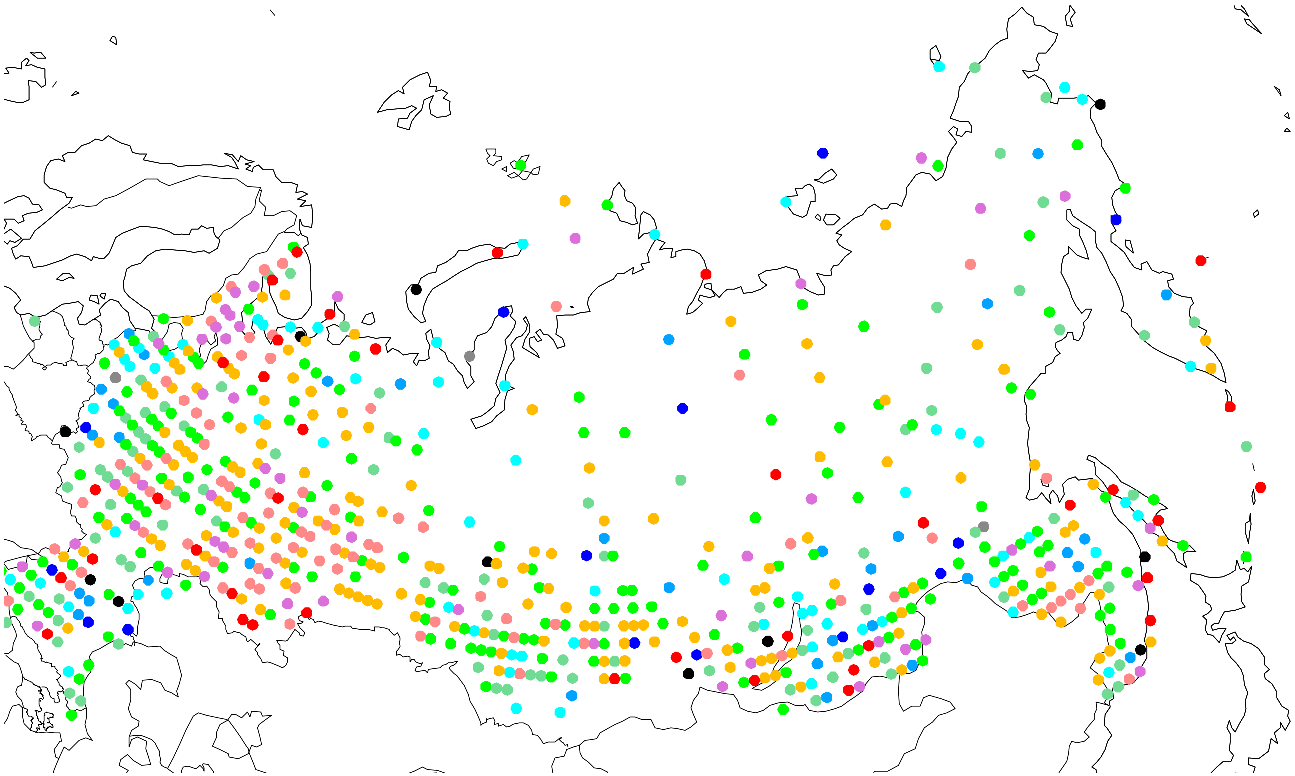
Long-term mean values (mm) along the snow course routes

***Top:* "field" courses**

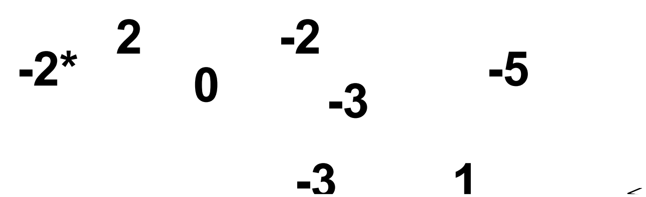
***Right:* forest courses**



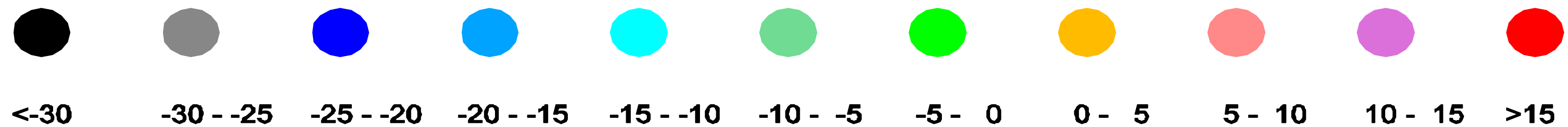
Linear trends in annual number of days with snow cover



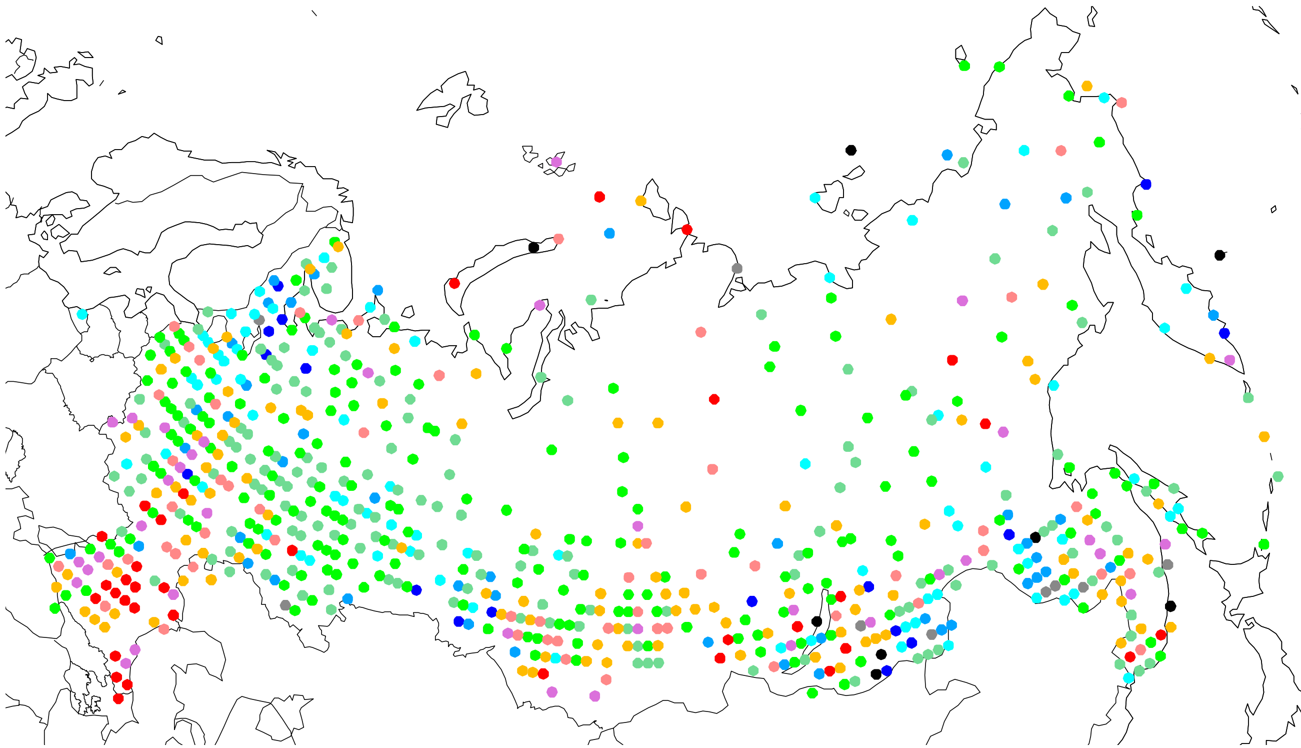
1956-2004 period,
days /49 yrs



No discernable trends



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



1956-2004 period, days /49 yrs

Period of snowmelt is decreasing

-6 -3 -5

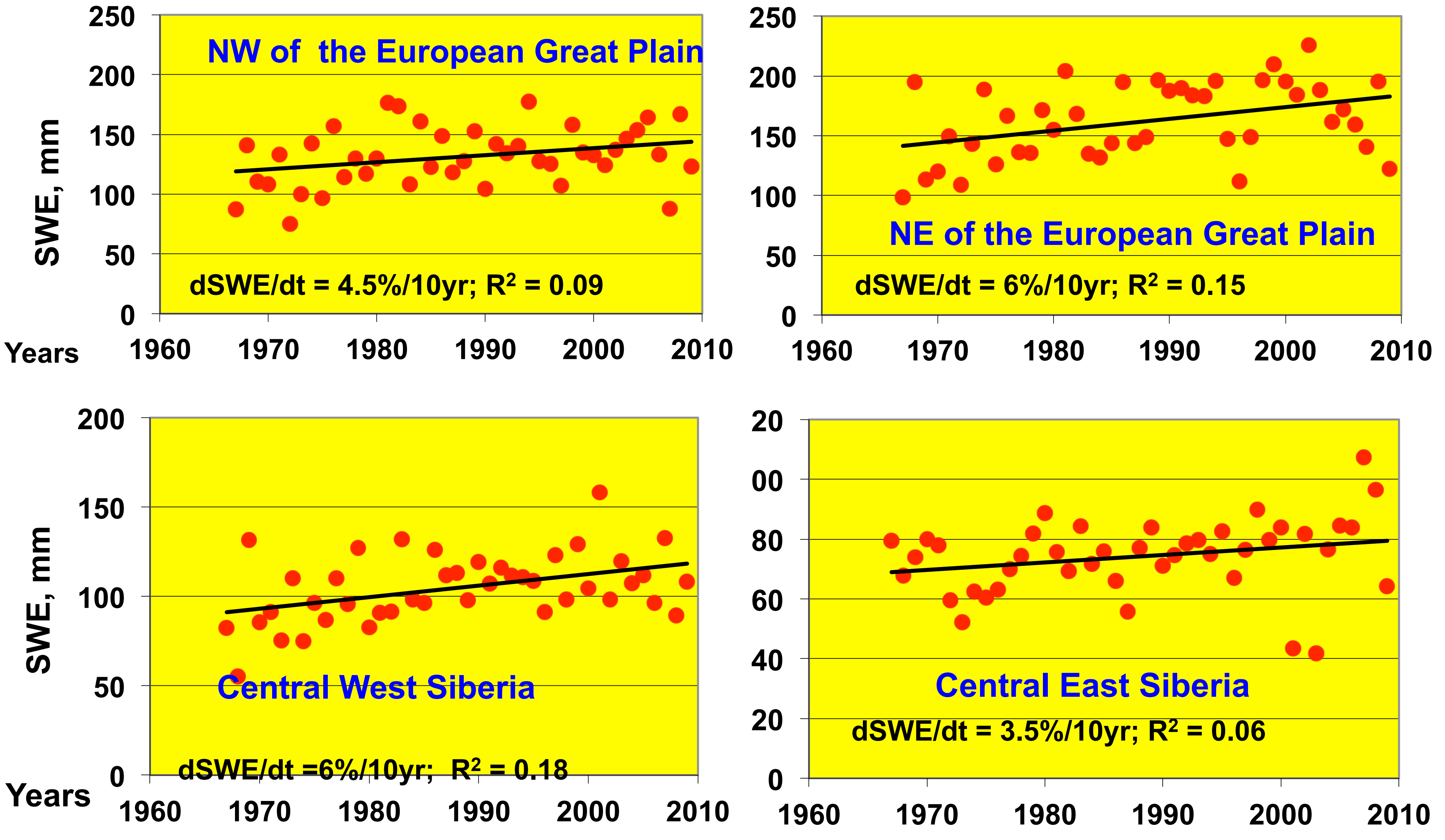
0* -6 -1

-5 -4

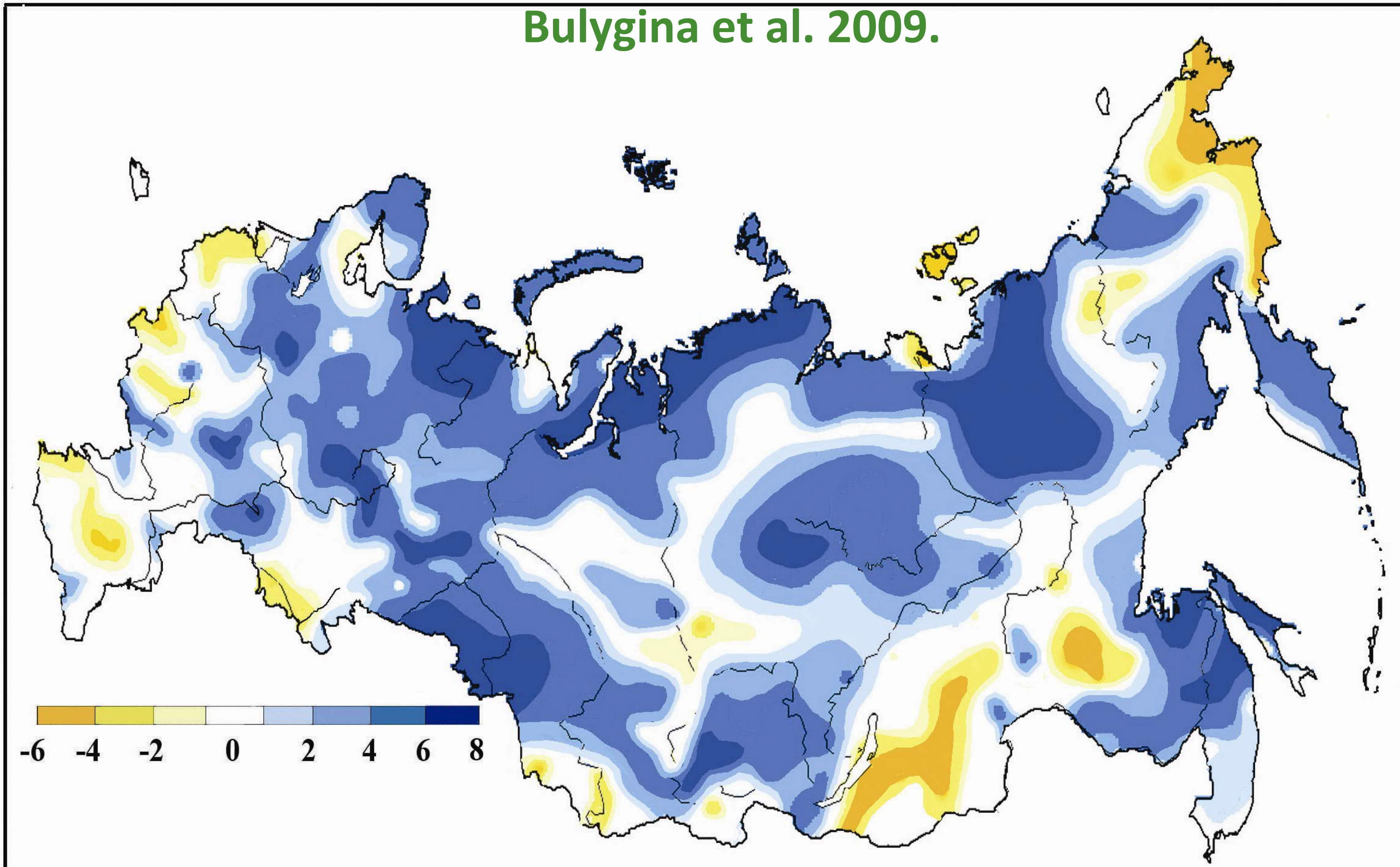
Changes of the maximum snow water equivalent over Russia

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

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

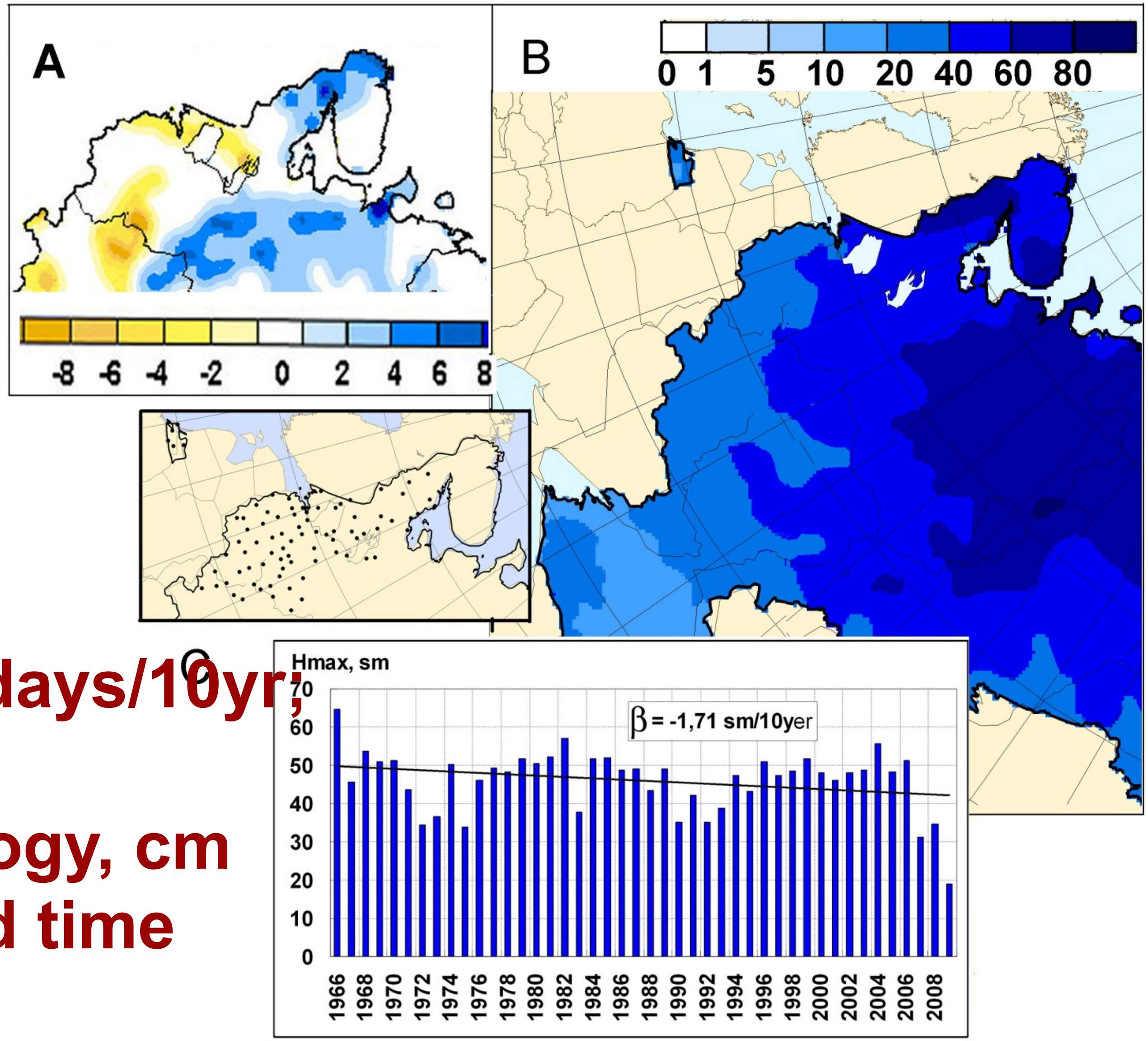


Number of days with deep snow cover on the ground (> 20 cm). Linear trends for the 1951-2006 period; [days/10yr].



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)

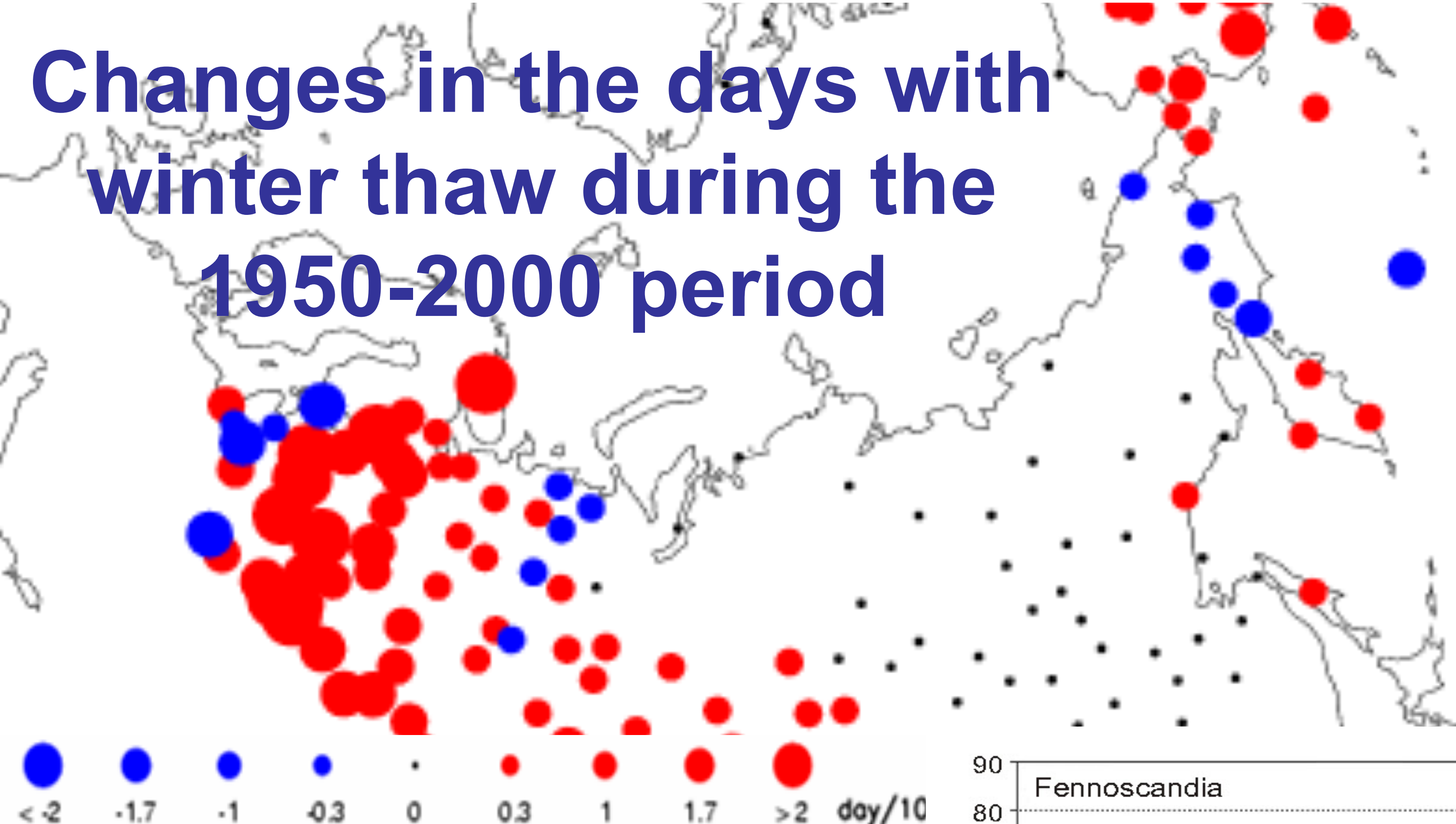


A. Trends, days/10yr; 1966-2007

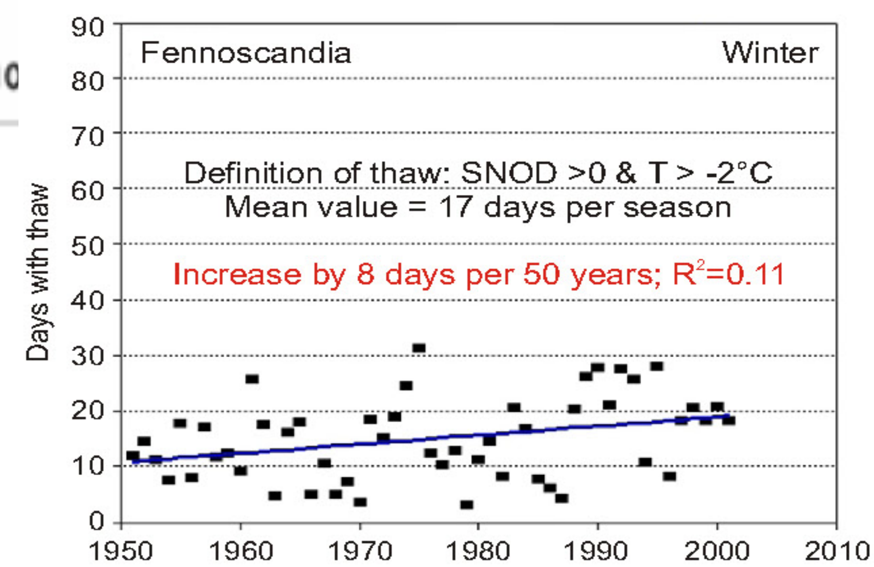
B. Climatology, cm

C. Averaged time series

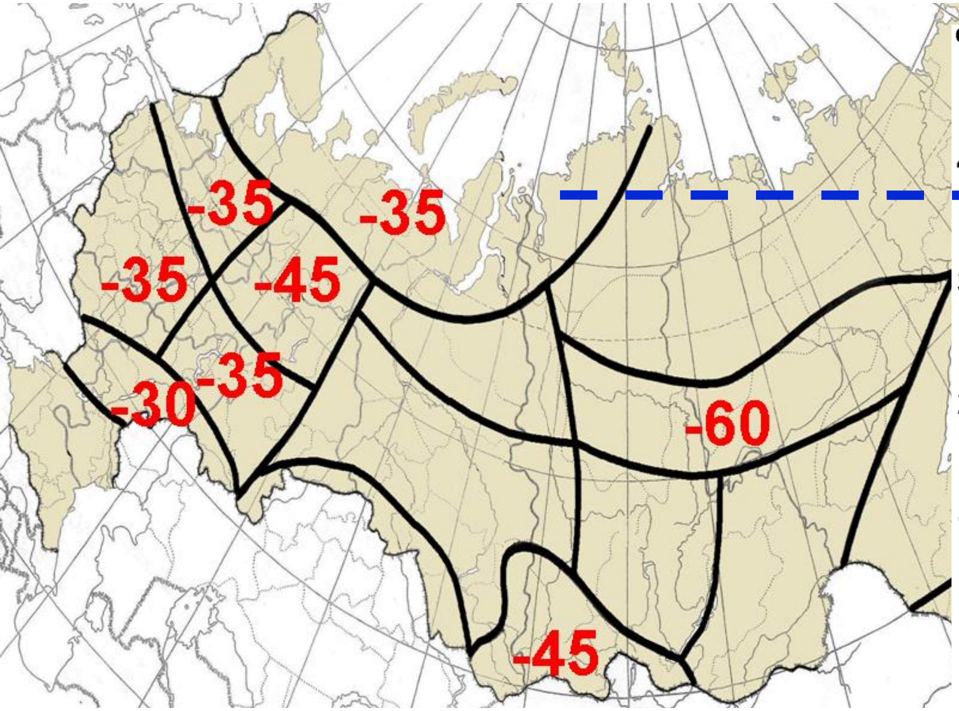
Changes in the days with winter thaw during the 1950-2000 period

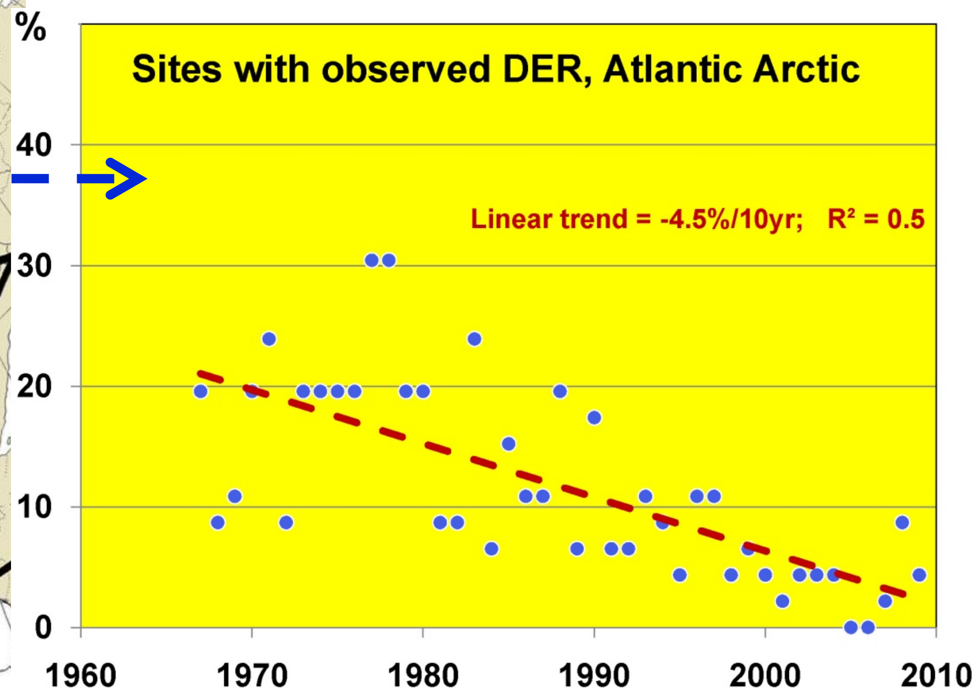


Top. Linear trend estimates in the seasonal number of days with winter thaw (days/10yr) (Groisman et al. 2003). **Right.** The same, but regional time series for Fennoscandia (Groisman et al. 2009)



DER, dangerous events for reindeer husbandry: basal ice layer above 5 mm during 10 consequent days over the “field” routes

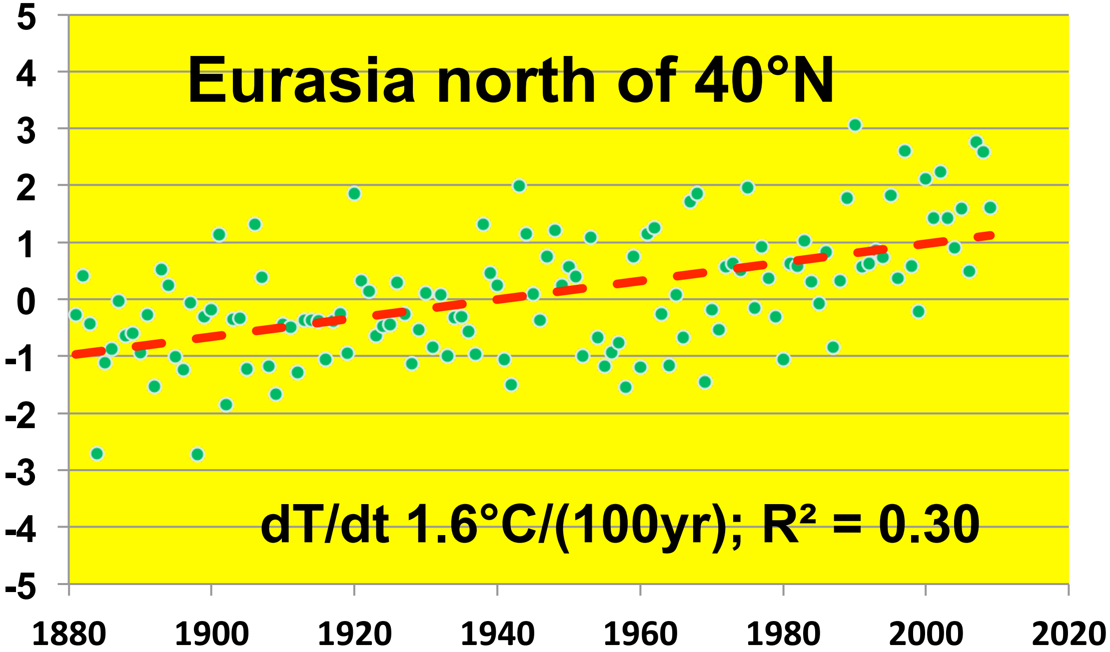




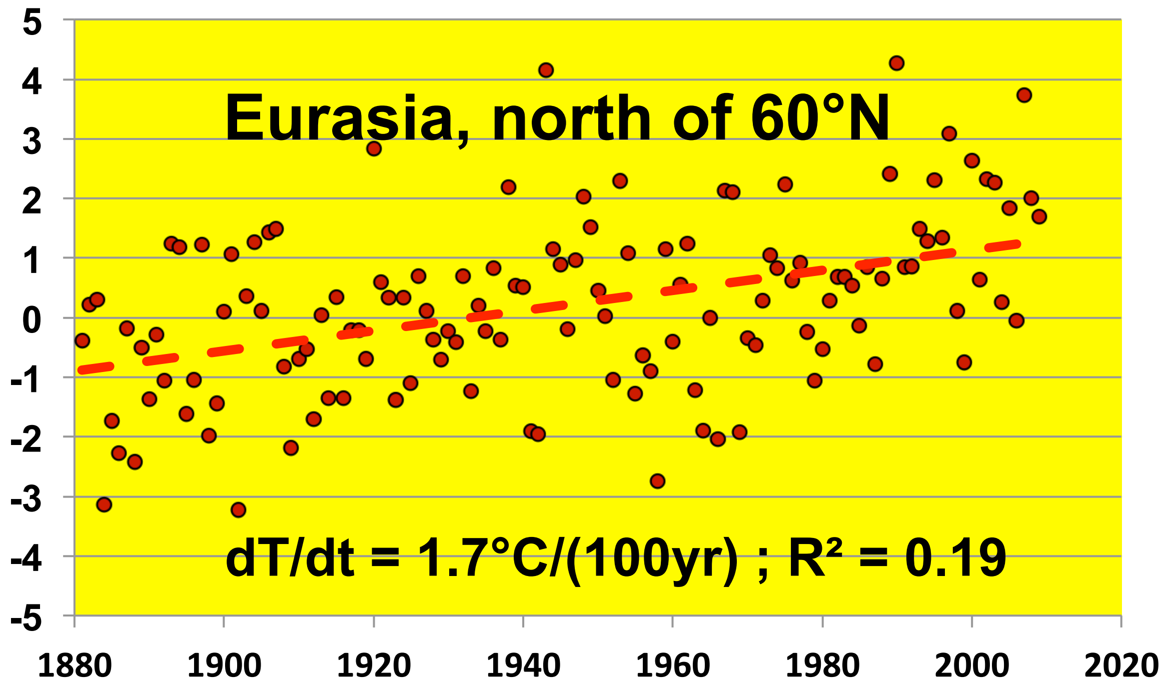
- ***Left.*** ***Regional trends (% per 10 years) that are presented only for the regions where during the 1967-2009 period they were statistically significant at the 0.05 or higher level.***
- ***Right.*** ***Annual variability of the percent of stations where the DER events were observed in the Atlantic Sector of the Russian Arctic.***

Spring

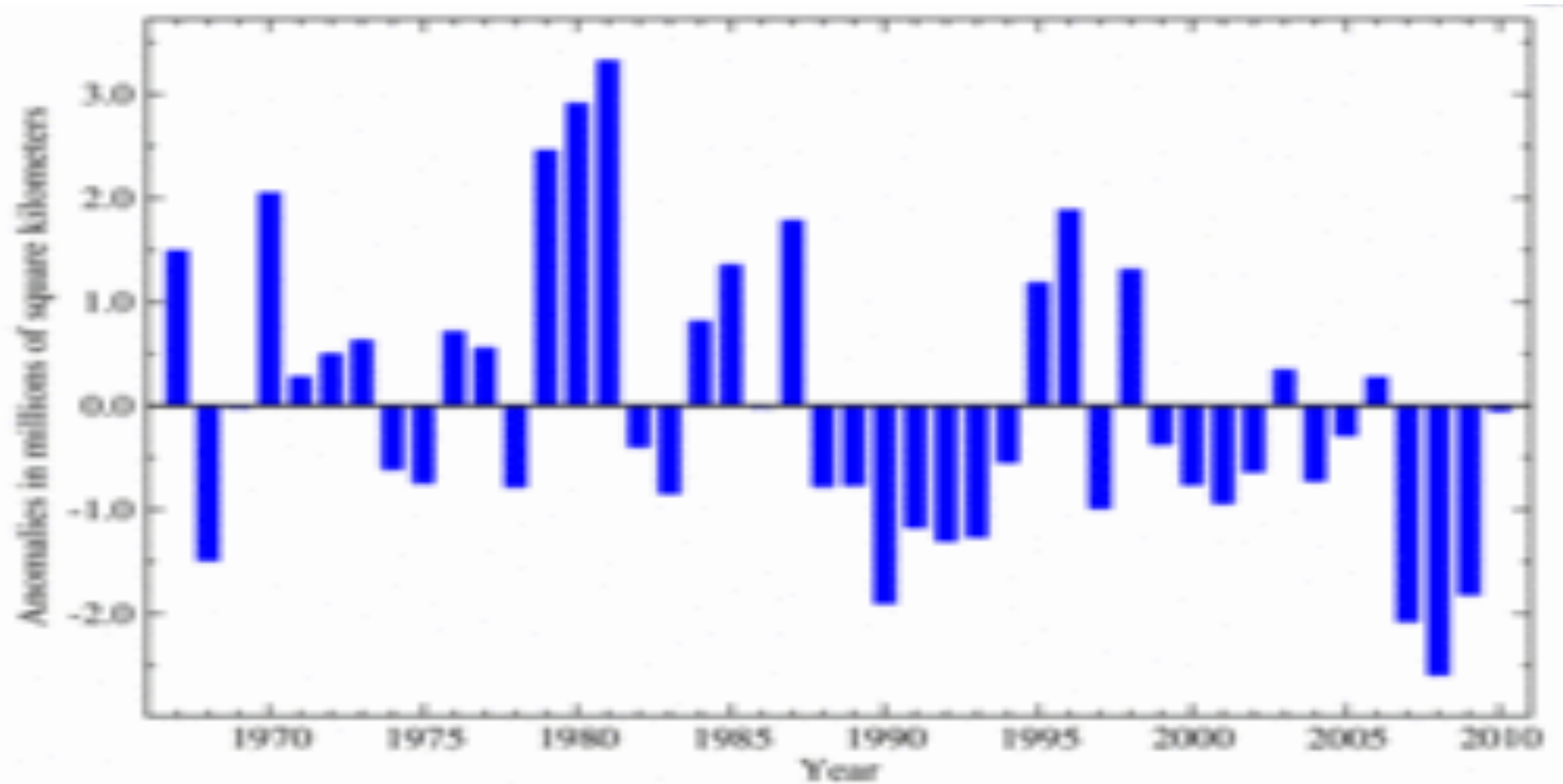
Spring temperature changes over North Eurasia



Temperature anomalies (°C) from the mean for the 1951-1975 reference period.
Archive of Lugina et al. 2007, updated

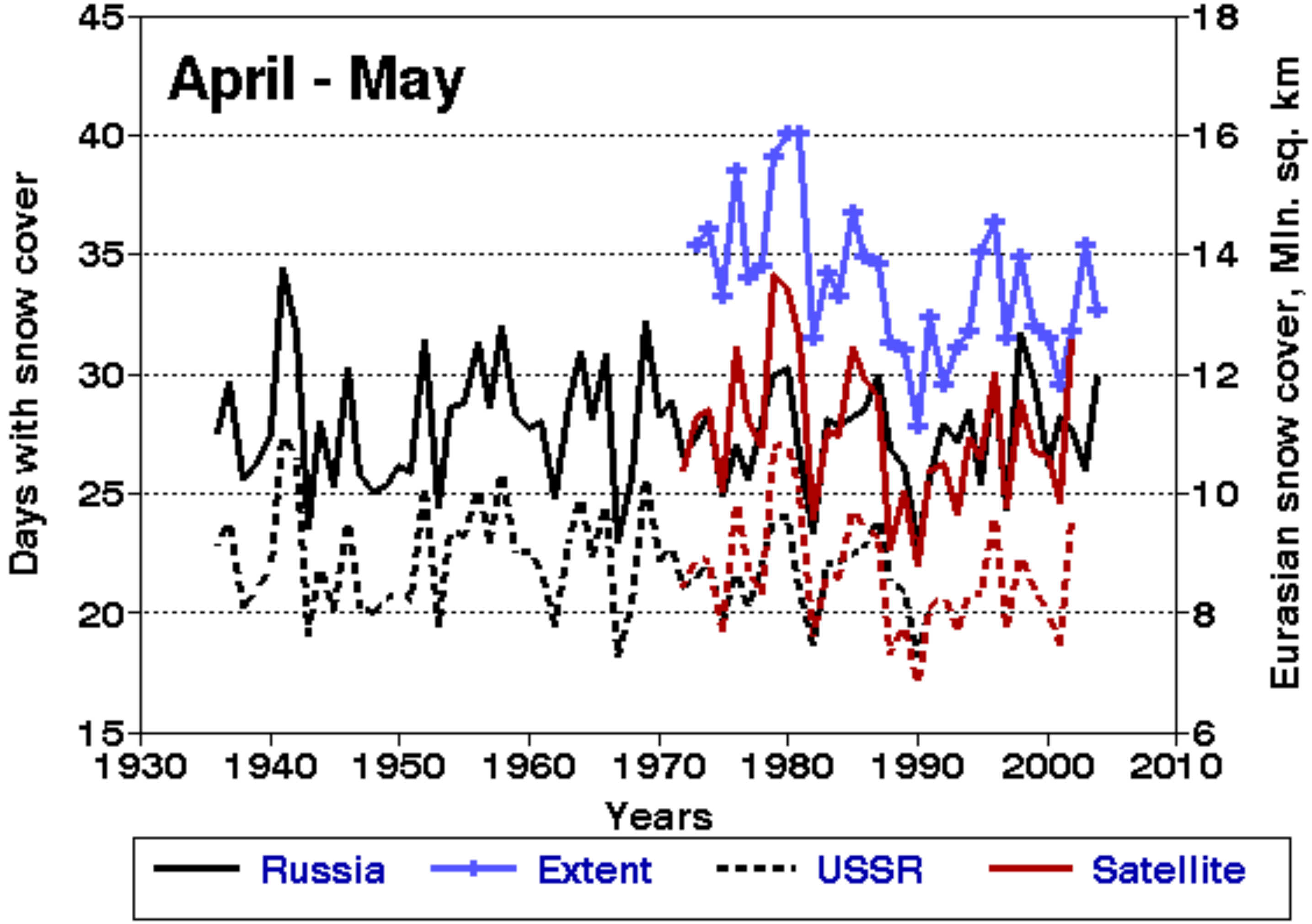


April snow cover extent anomalies over Eurasia

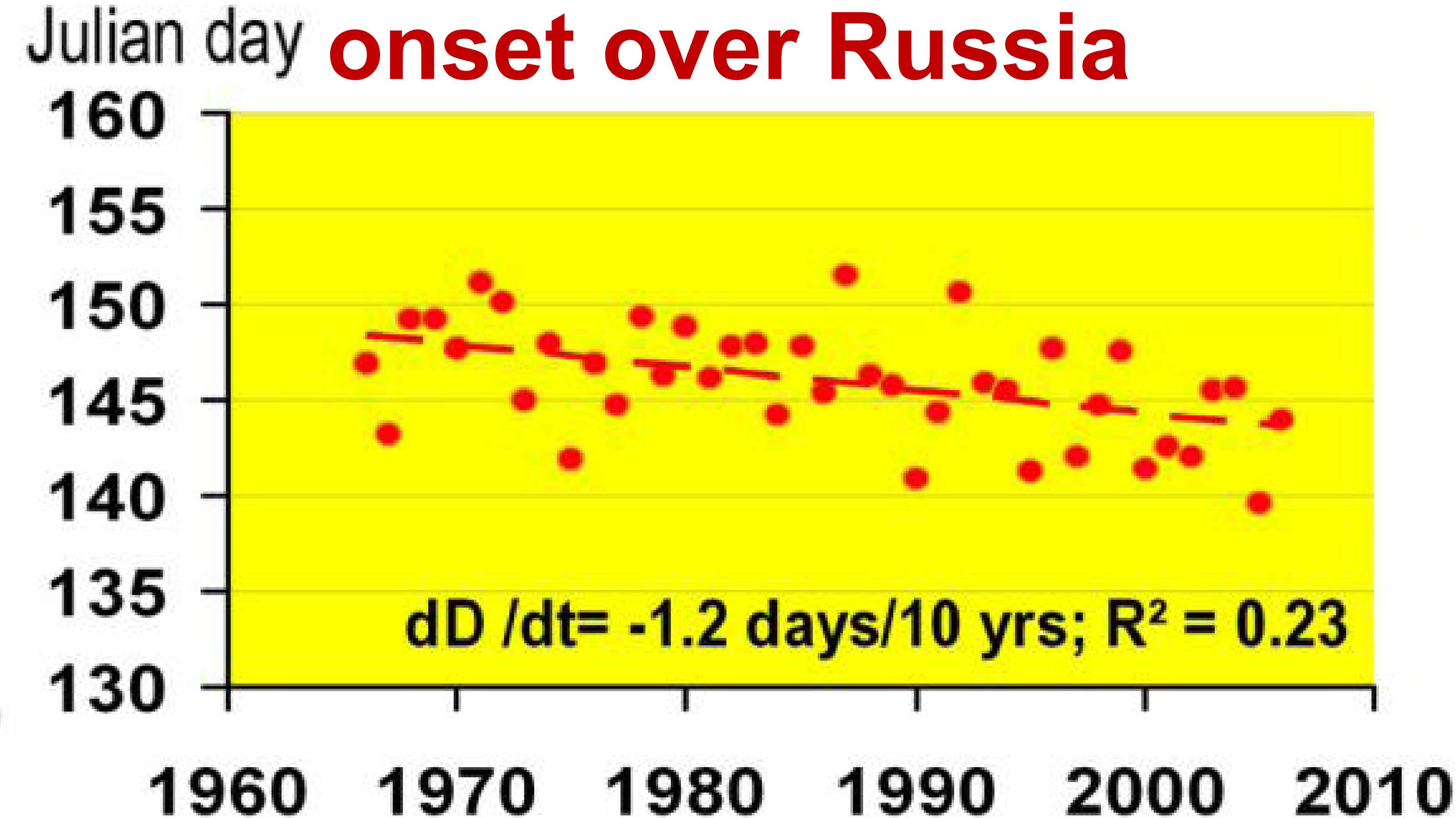


Snow cover extent from NOAA satellites for 1967-2010. NOAA NCDC 2010: State of the Climate Global Analysis April 2010. [Available at *http://www.ncdc.noaa.gov/sotc/index.php?report=global&year=2009&month=4*]

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)



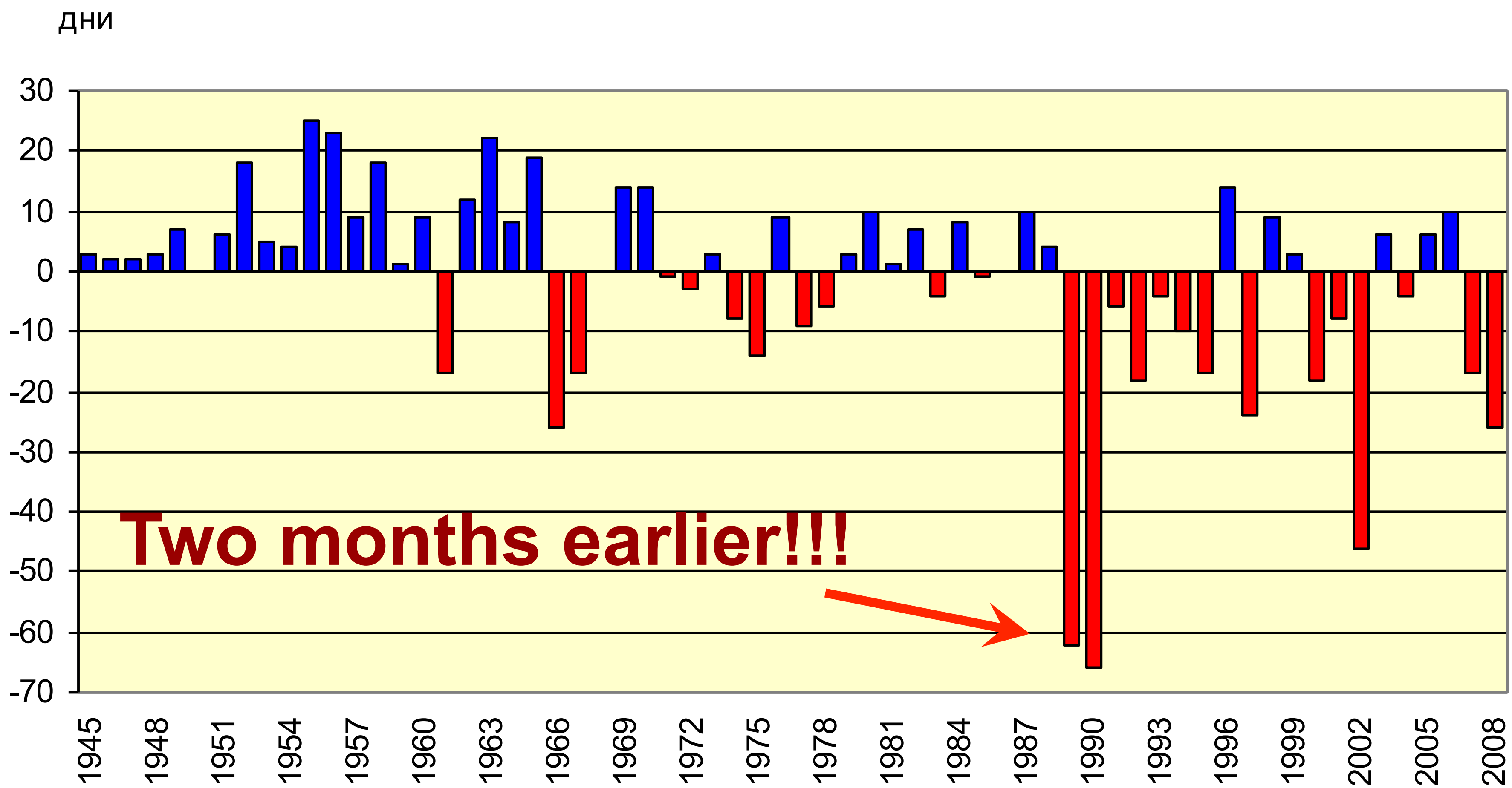
Area-averaged dates of the spring onset over Russia



D is defined as a spring date when mean daily temperature stably passes 5°C (nationwide mean D-date is ~ May 25th). During the past four decades changes in D have not matched with changes in the dates when the snowmelt start (defined as a late winter date when mean daily temperature stably passes -5°C; nationwide mean date is ~April 15th).

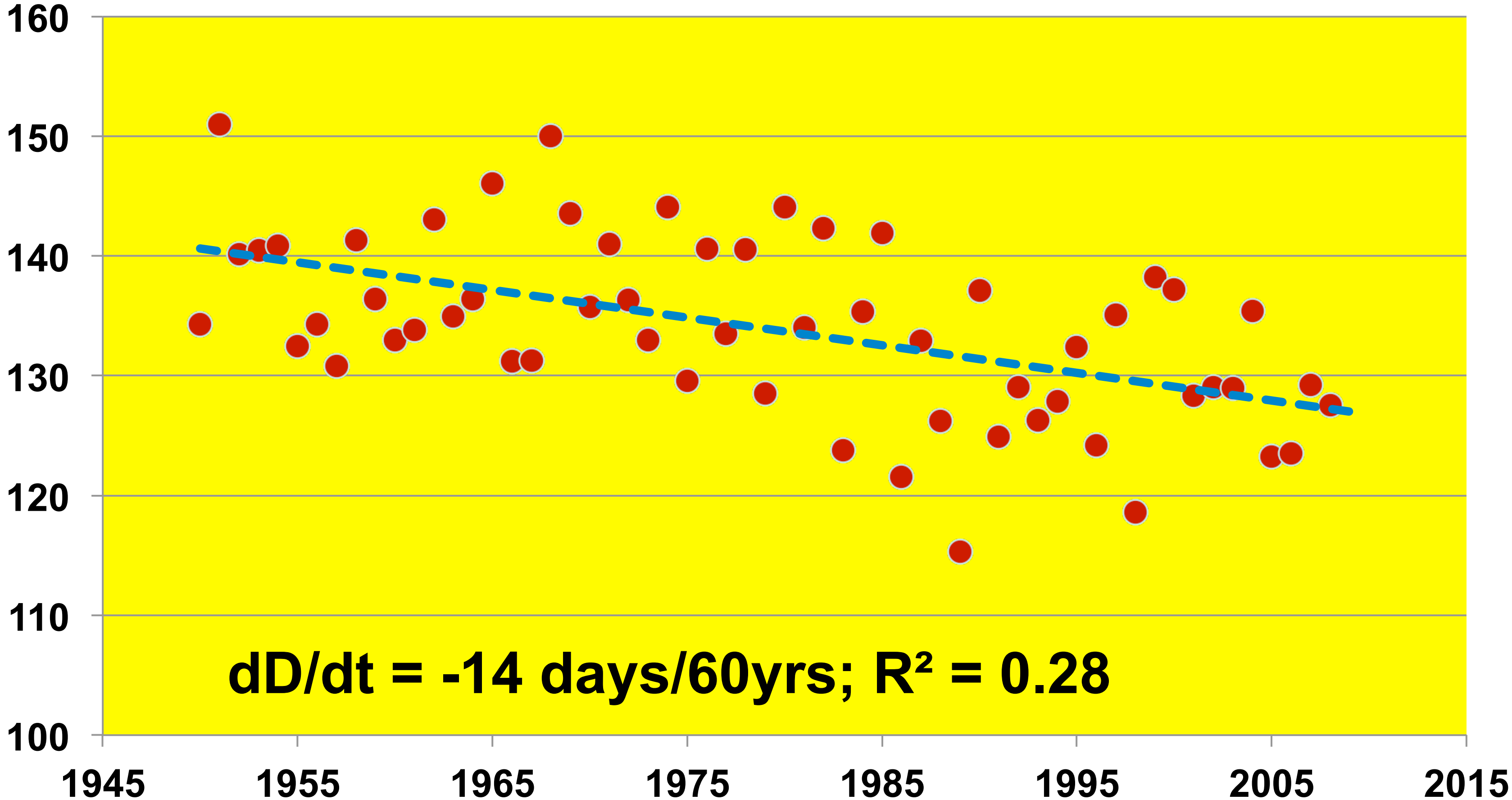
Belarus. The period with stable snow cover is 75 days in the southwest and 125 days in the northeast of the country. Average snow depth between Southwest and Northeast varies from 15 to 30 cm respectively.

Anomalies (days) of the spring dates of daily surface air temperature transition through 0°C from the mean long-term values in central Belarus



Elena V. Komarovskaya, 2009; Personal communication

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



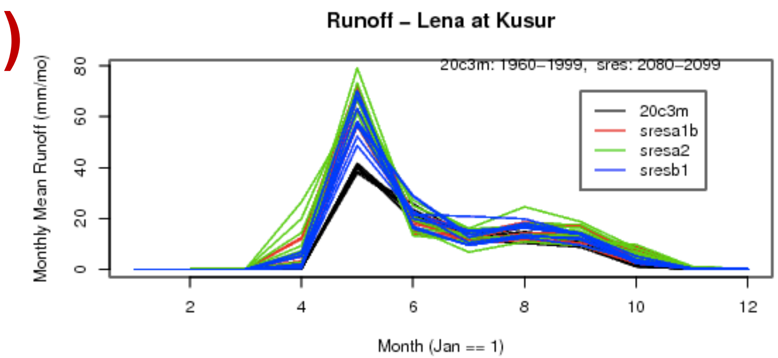
Mean date is May 15th. Change is by 2 weeks per 60 years.

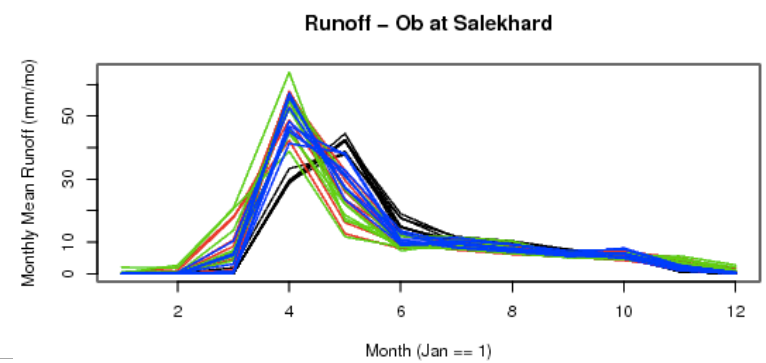
Pan-Arctic Ocean Drainage

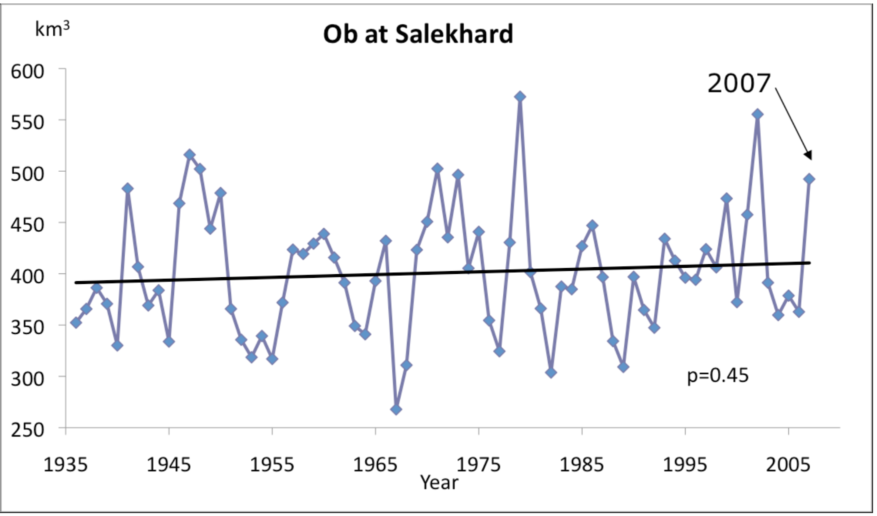
Runoff changes in the deltas of three major Siberian rivers. Observations and future projections

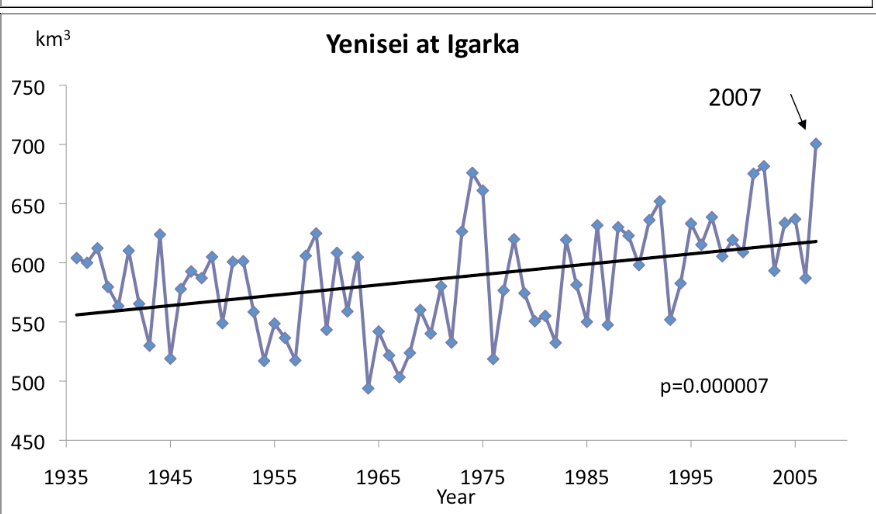
Lammers and Shiklomanov (2009)

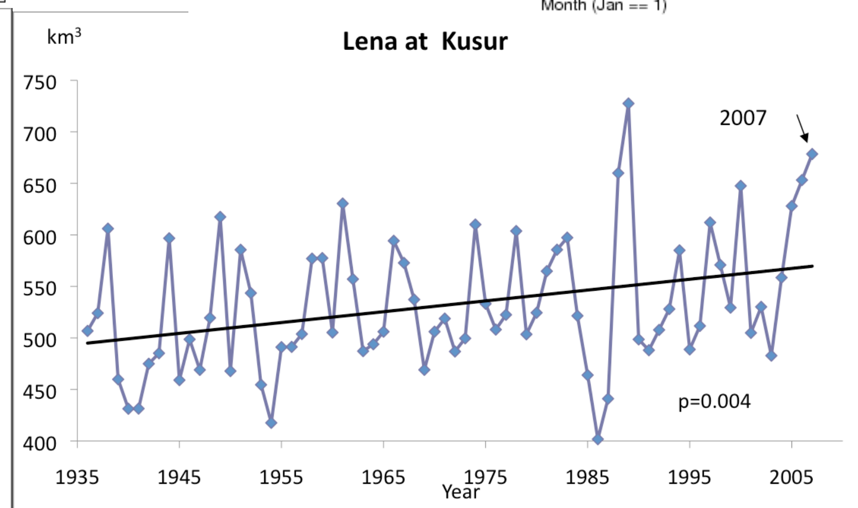
Slide is a courtecy of Dr. A. Shiklomanov











Summary of the cold season changes

During the past 129 years, the annual surface air temperature in Northern Eurasia has increased by 1.5°C (over Northern Asia by 1.8°C and in the winter season by 3°C).

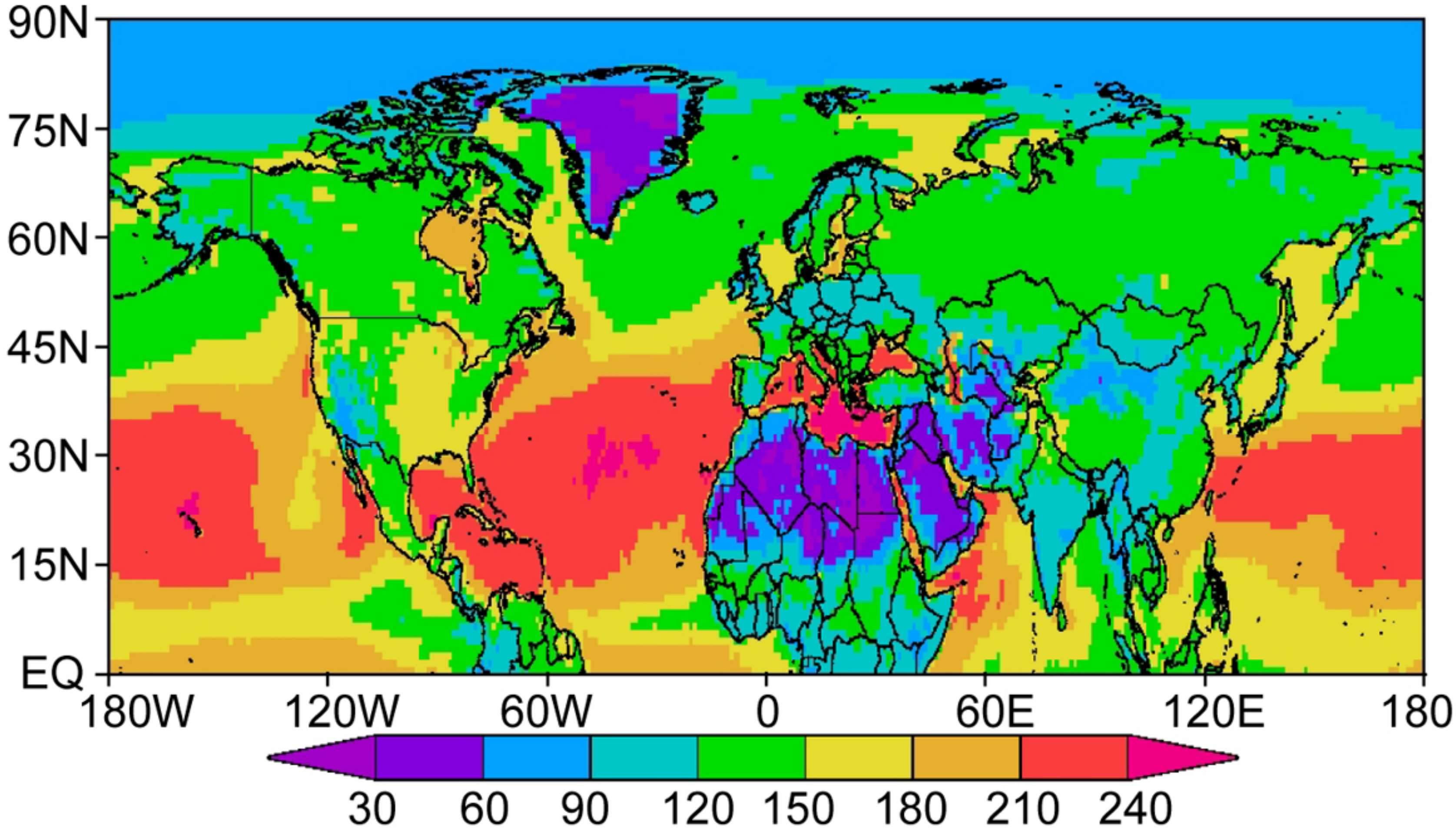
The late summer sea ice extent decreased by 40% exposing a near-infinite source of water vapor for the dry Arctic atmosphere in early cold season months.

- **As a result of these changes, (a) in autumn the dates of the onset of snow cover have not changed noticeably despite the strong temperature increase in this season; (b) in late spring, snow cover extent has decreased, retreating by 1 to 2 weeks earlier during the past 40 years; (c) in the cold season maximum snow depth and SWE (at open areas) have increased over most of Russia; and (d) more early and devastating floods were documented in Siberia.**
- **In the western half of Eurasian continent days with thaw became more frequent. For example, in Fennoscandia in the second half of the 20th century, the number of days with winter thaw increased by 6 days in 50 years, or by 35% changing the winter season as it has been known.**

- **The entire process of the spring snowmelt has become shorter in duration and (taking into account a parallel rise in the snow depth across most of Russia) more intense. This might contribute to increasing frequencies and severity of spring floods, and require further studies.**

Summer

July total net irradiance (solar net + thermal infrared net)

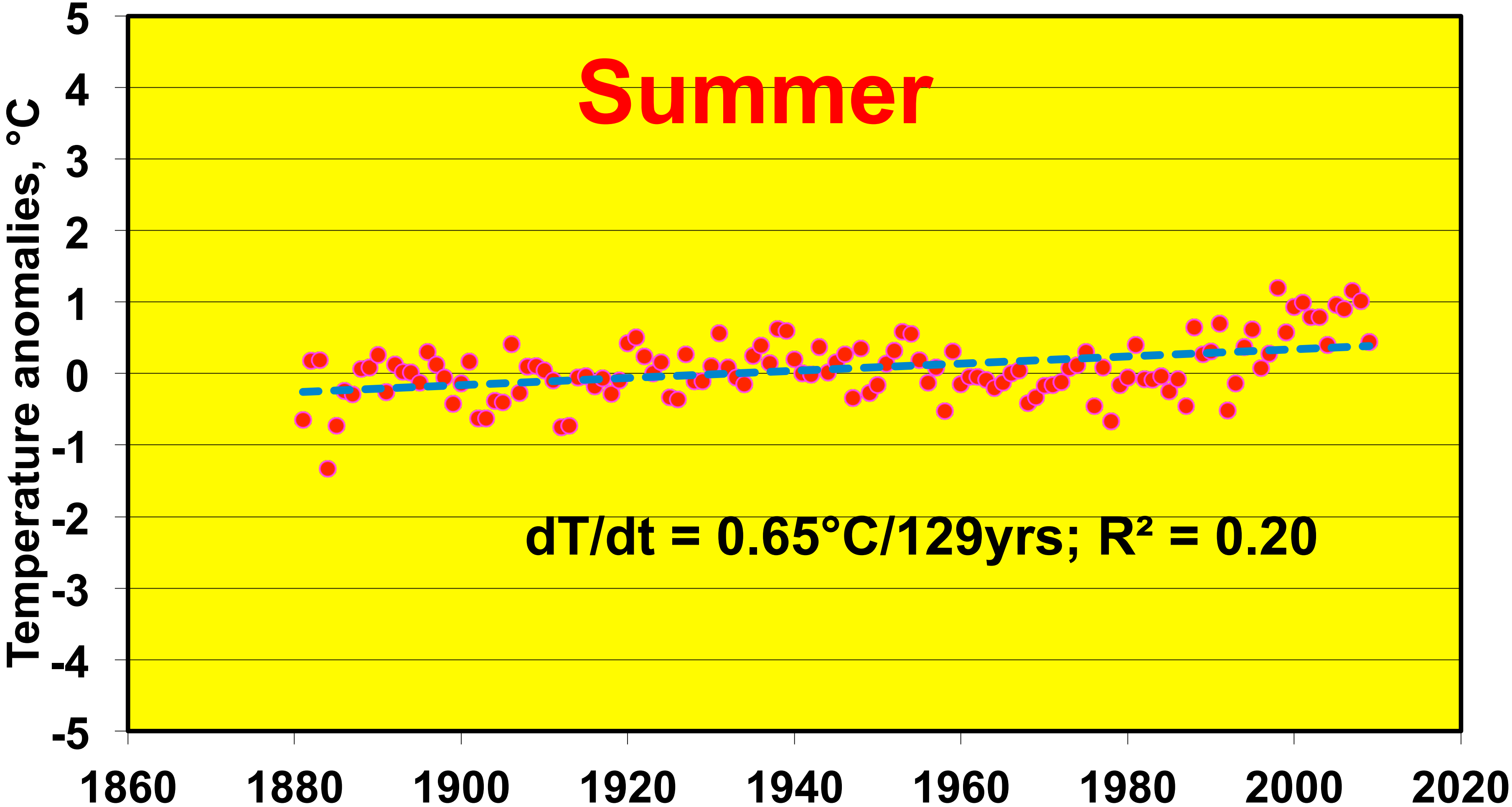


The 22 year average from the NASA/GEWEX Surface Radiation Budget project.

Courtesy of Paul Stackhouse Jr. and Colleen Mikovitz, NASA Langley Research Center

Northern Eurasia, north of 40°N

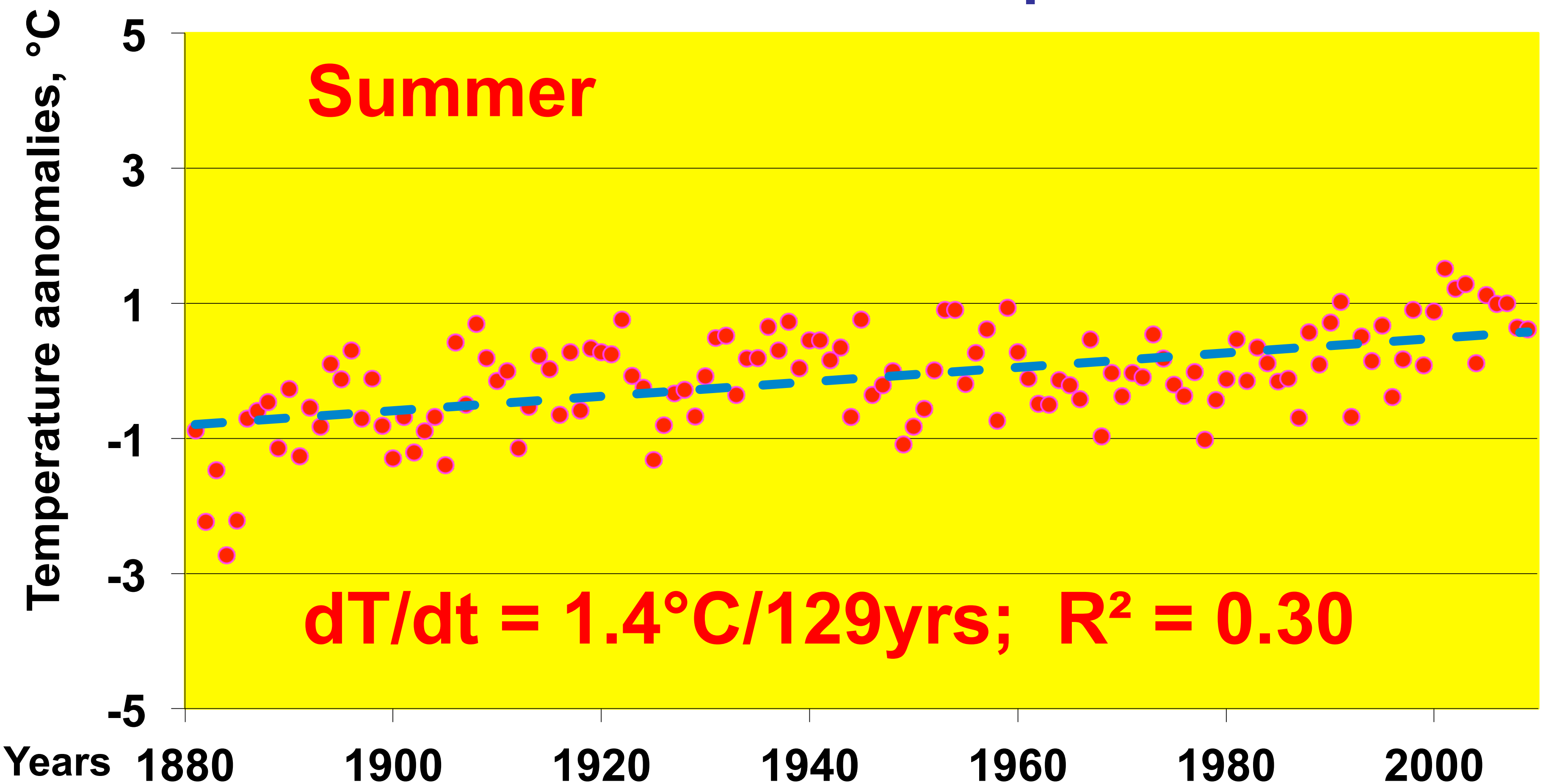
Temperature anomalies for the past 129 years; 1951-1975 reference period



Archive of Lugina et al. 2007, updated

Northern Eurasia, north of 60°N

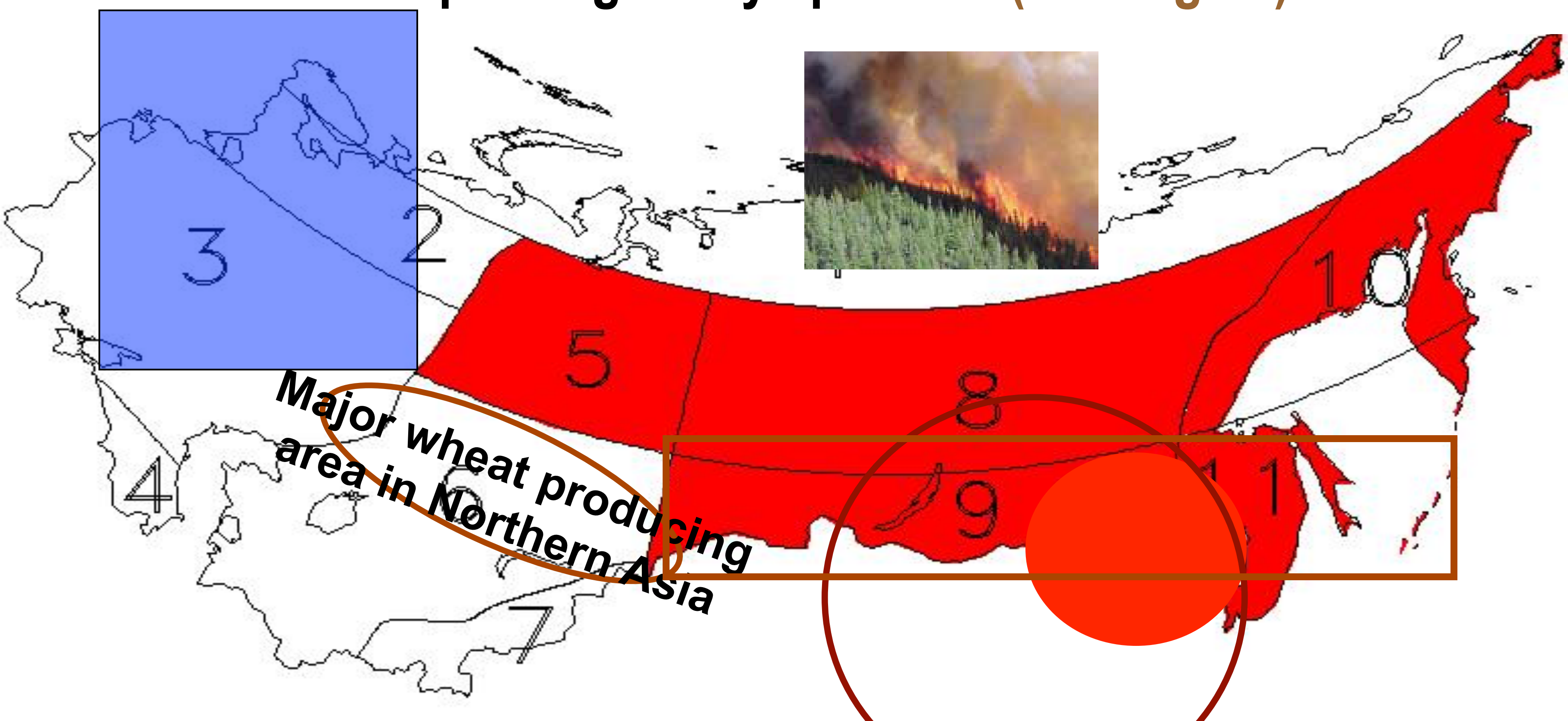
Temperature anomalies for the past 129 years; 1951-1975 reference period



Archive of Lugina et al. 2007, updated

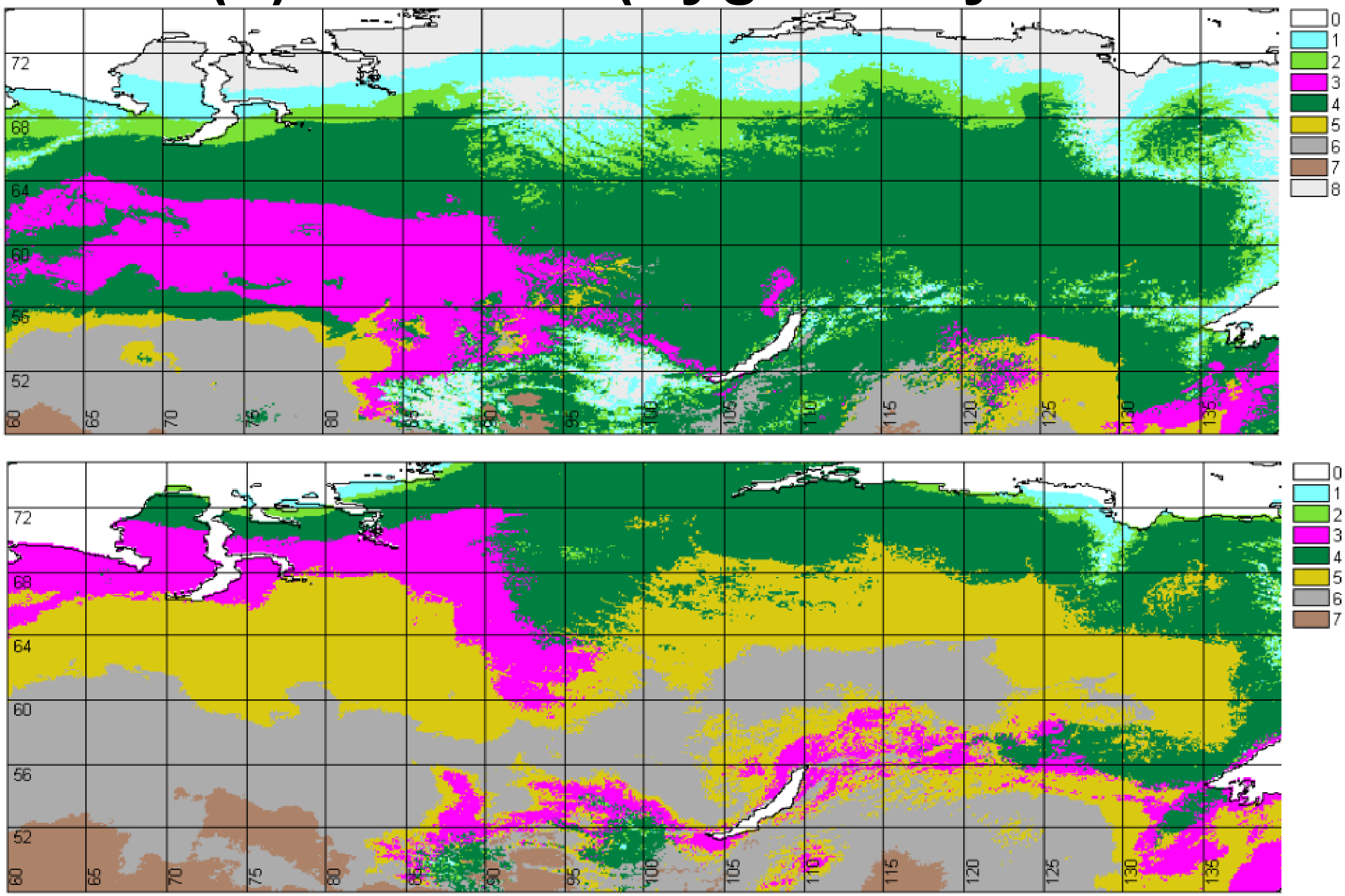
Changes in the surface water cycle over Northern Eurasia that have been statistically significant in the 20th century

More humid conditions (blue),
more dry conditions (red),
more agricultural droughts (circled),
more prolonged dry episodes (rectangled).



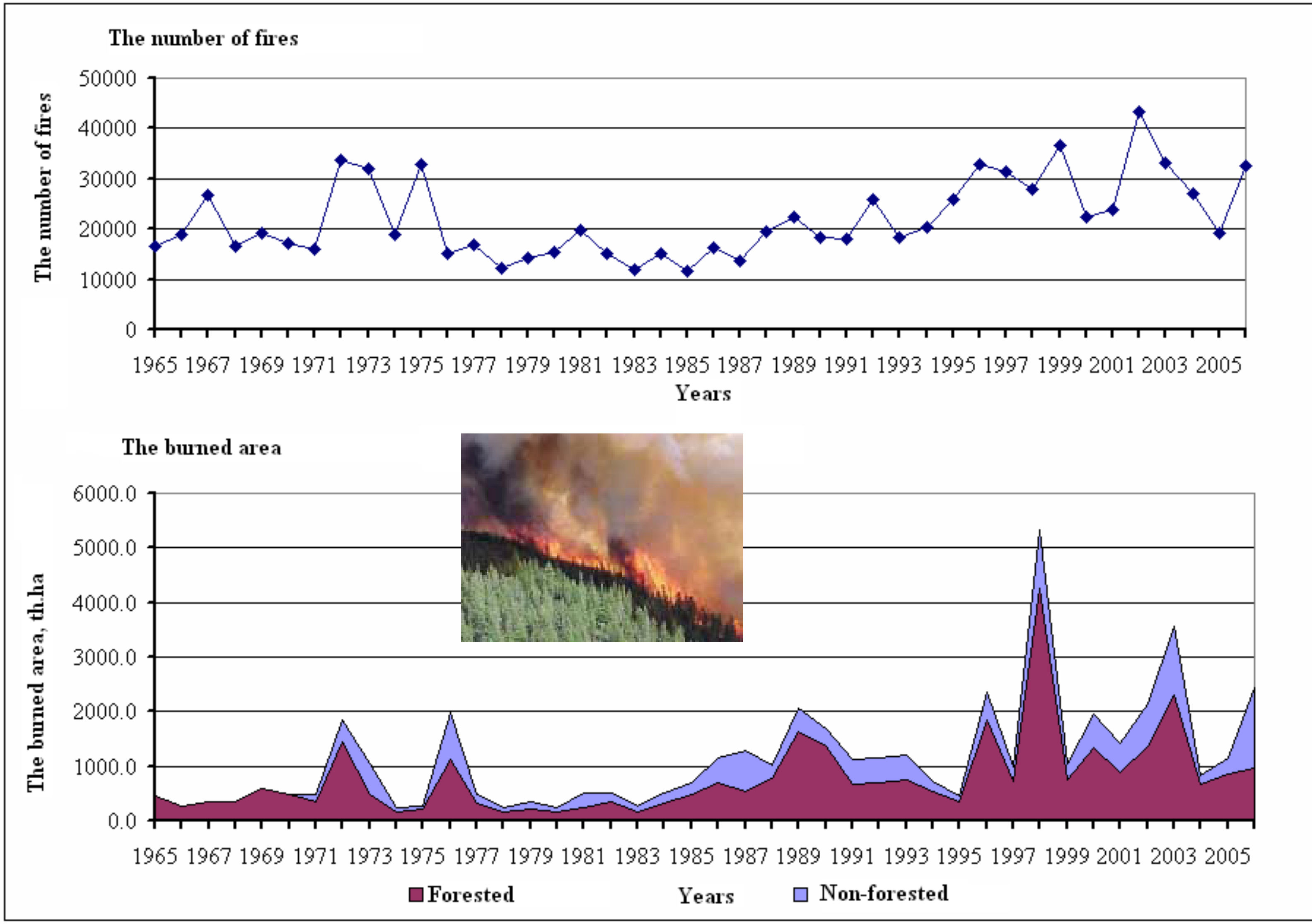
Groisman et al 2009 (Bull. Amer. Meteorol. Soc.)

Biome distribution over Siberia in current (a) and 2090 (b) climates (Vygodskaya et al. 2007)



Water (0),Tundra (1), forest-tundra (2), darkleaf taiga (3) and lightleaf taiga (4), forest-steppe (5), steppe (6), semidesert (7), and polar desert (8).

DYNAMICS OF FIRES NUMBERS AND BURNED AREA (PROTECTED TERRITORY OF RUSSIA)



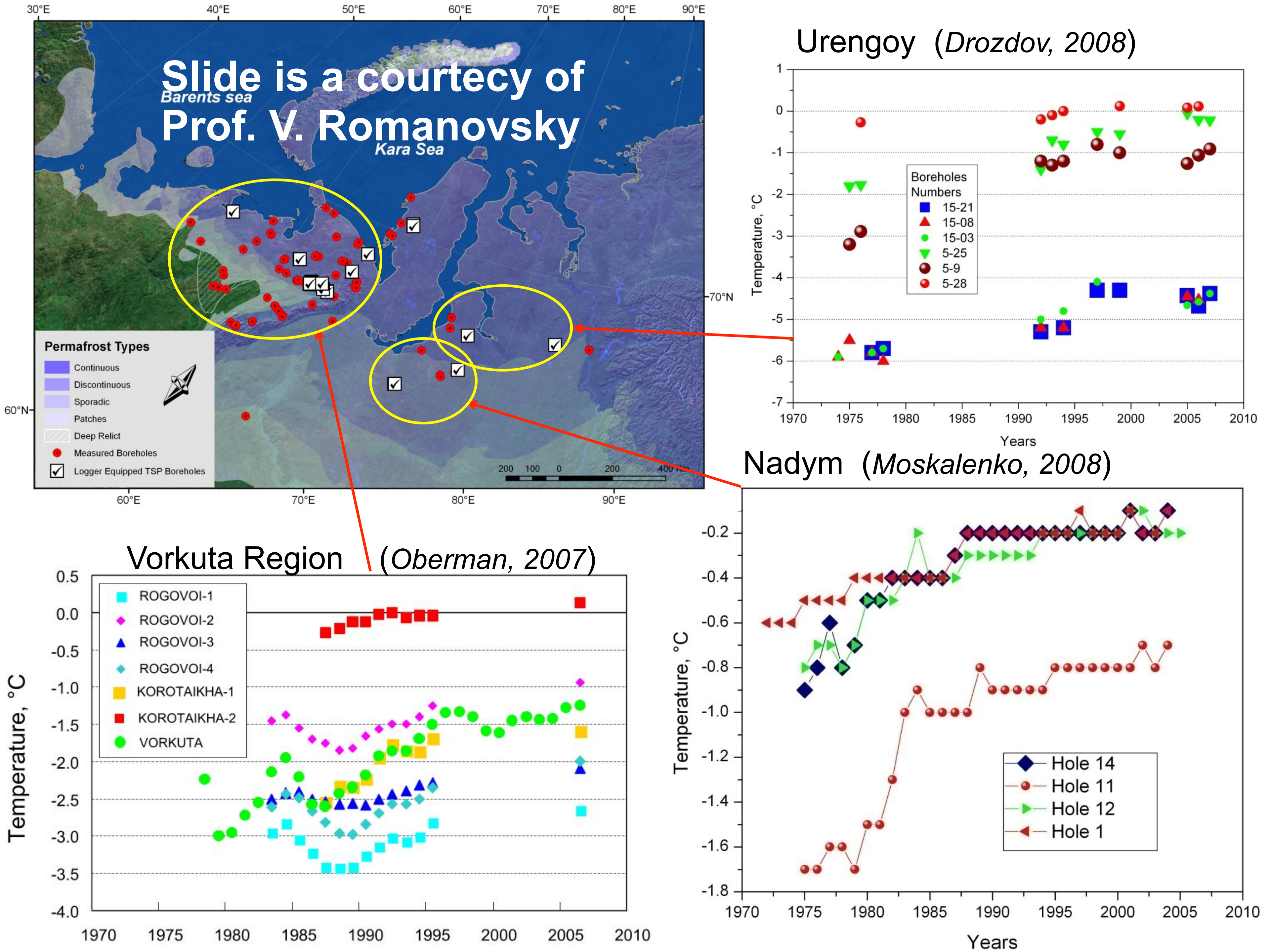
Korovin and Zukkert 2003, updated

Intense fire in a *Pinus sylvestris* forest, resulting in a likely conversion to steppe

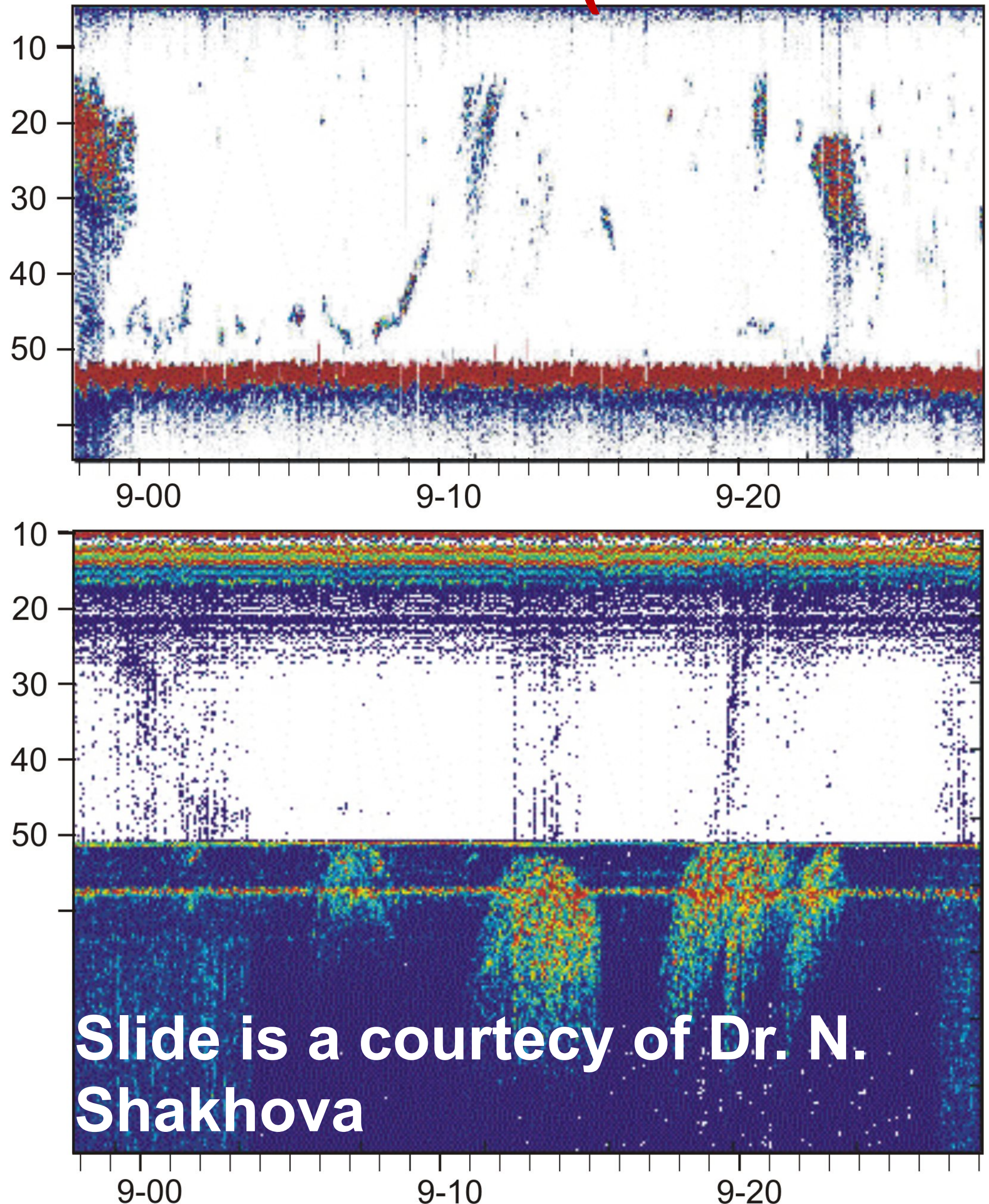
- **Left**, no regeneration after several years; **right**, no regeneration after 20 years (Siberia) Tchebakova et al. (2009)

Landscape after forest fires

- **Thawing of ice-rich permafrost, triggered by forest fire in Central Yakutia, transforms boreal forest into steppe-like habitats (photo by Vladimir Romanovsky)**


Slide is a courtecy of
Prof. V. Romanovsky
Barents sea
Kara Sea
30°E
40°E
50°E
60°E
70°E
80°E
90°E
70°N
60°N
Permafrost Types
Continuous
Discontinuous
Sporadic
Patches
Deep Relict
Measured Boreholes
Logger Equipped TSP Boreholes
200 100 0 200 400 km
Urengoy (Drozdov, 2008)
Boreholes Numbers
15-21
15-08
15-03
5-25
5-9
5-28
Temperature, °C
Years
Nadym (Moskalenko, 2008)
Hole 14
Hole 11
Hole 12
Hole 1
Temperature, °C
Years
Vorkuta Region (Oberman, 2007)
ROGOVOI-1
ROGOVOI-2
ROGOVOI-3
ROGOVOI-4
KOROTAIKHA-1
KOROTAIKHA-2
VORKUTA
Temperature, °C
1970 1975 1980 1985 1990 1995 2000 2005 2010

Methane bubble release from the seabed in the East Siberian Sea (Shakhova et al. 2009).



Bubble clouds
in the water column

Gas-charged sediments
and bubble clouds
in the water column

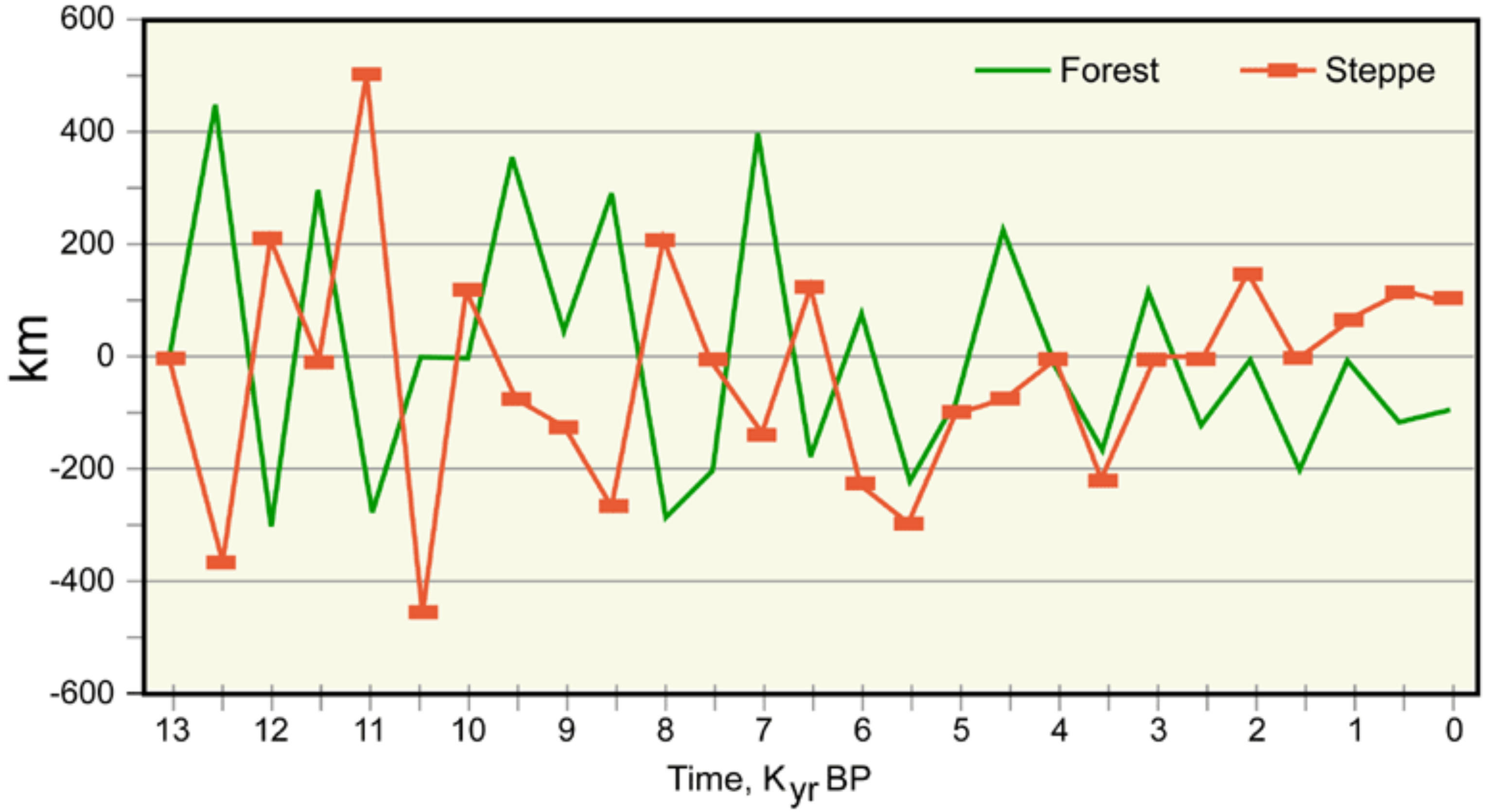
Sea depth~50m

Why we have to be expedient in our research?

Firstly,

the changes are already here and they have been large!

... were large in the past...

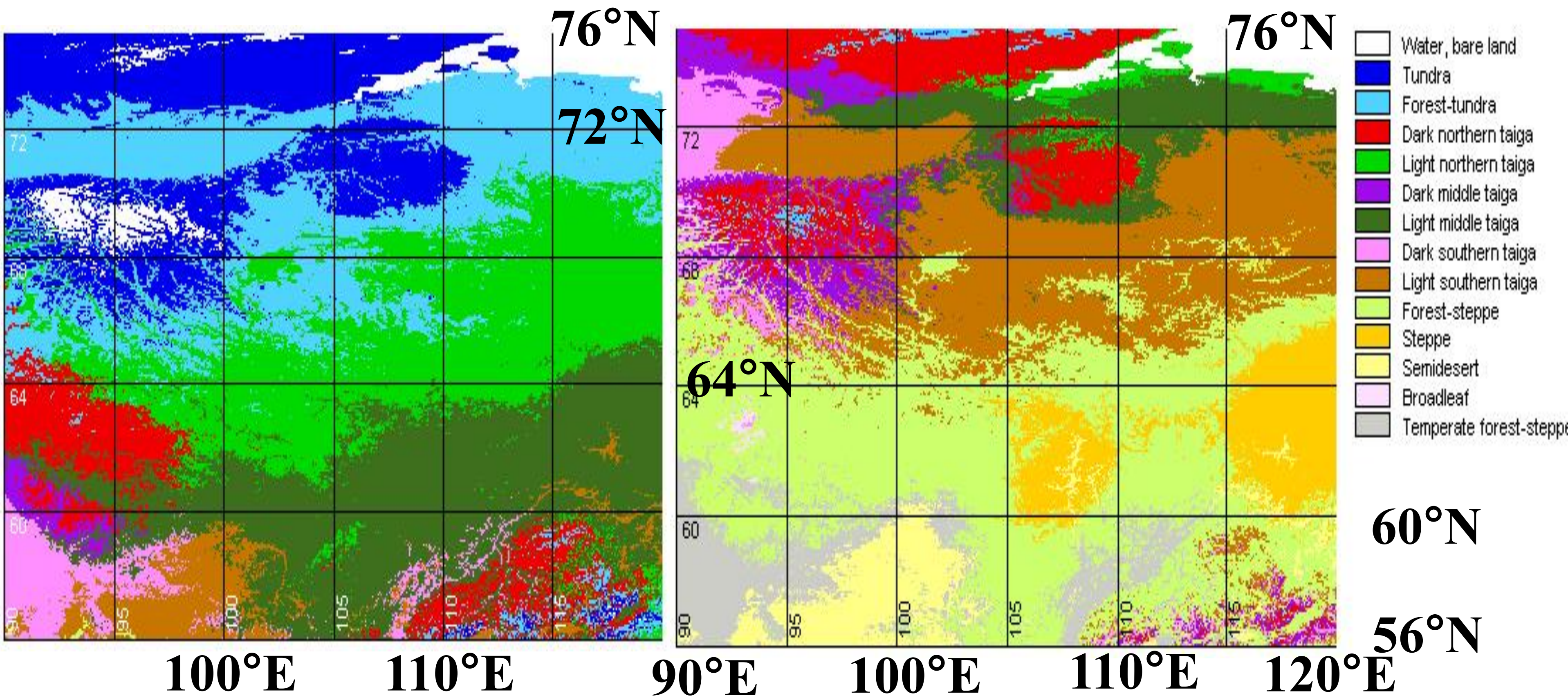


Changes of the northern boundaries of forest and steppe zones along the 39°E (past 13x10^3 years)

(Kozharinov and Puzachenko 2005)

and large changes are projected.

Ecosystems' changes projected for the future



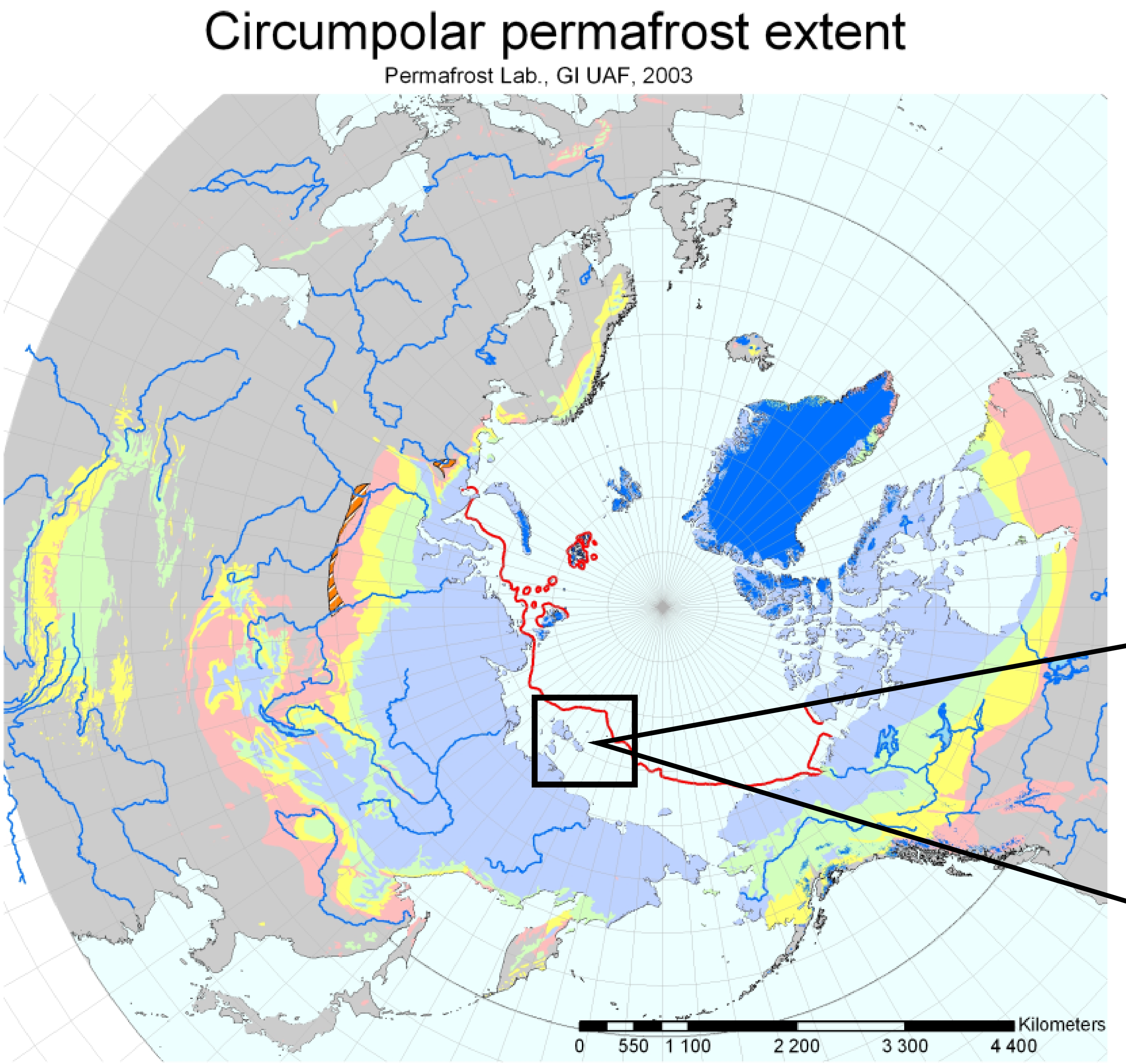
Present In year 2090

Major ecosystems distribution in central and eastern Siberia
(Tchebakova et al. 2003)

Changes affects the carbon cycle over land...

In the area of “wet thermokarst” formation, new and significant sources of CH_4 production are developing.

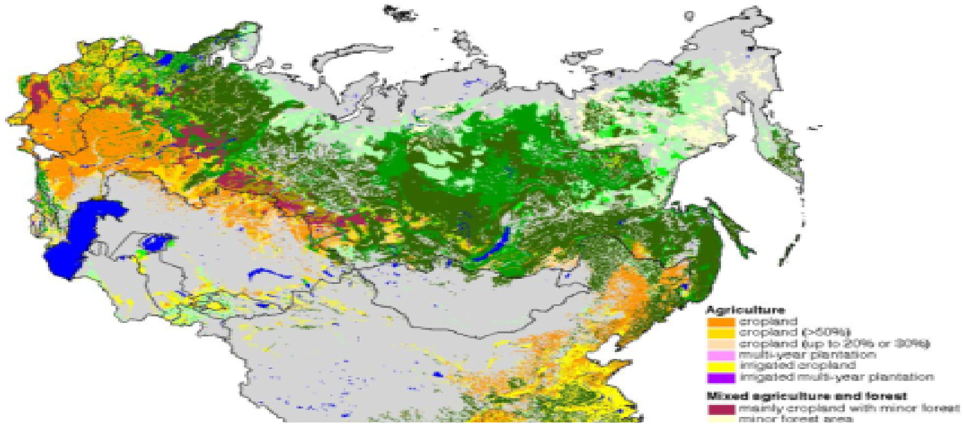
… and in the Arctic coastal zone



Coastal erosion and sub-sea permafrost degradation is a new and potentially very important issue for the global change.

… as well as by the changes caused by human activity:

Example 1:
More than 90% of steppe and forest-steppe zones in Northern Eurasia is currently cropland (orange areas in the map)
[Rozenzweig et al. 2003]



Example 2:
Land use dynamics in the past 60 years in the Volga River Basin show that 13 Mln Ha of agricultural land (or ~20%) have been replaced by forest (10 Mln) and reservoirs (3 Mln)
[Golubev, Speranskaya & Tsitsenko 2003]

… up to the extreme cases that lead to ecological disasters

E.g., …the Aral Sea …


July - September, 1989


August 12, 2003

1989 **2003**

… and put society wellbeing and human health in harm way

Increasing frequency of dust storms and increasing rate of soil erosion.

Air pollution. Fine aerosol particles are responsible for causing the greatest harm to human health.

Specific human dimension

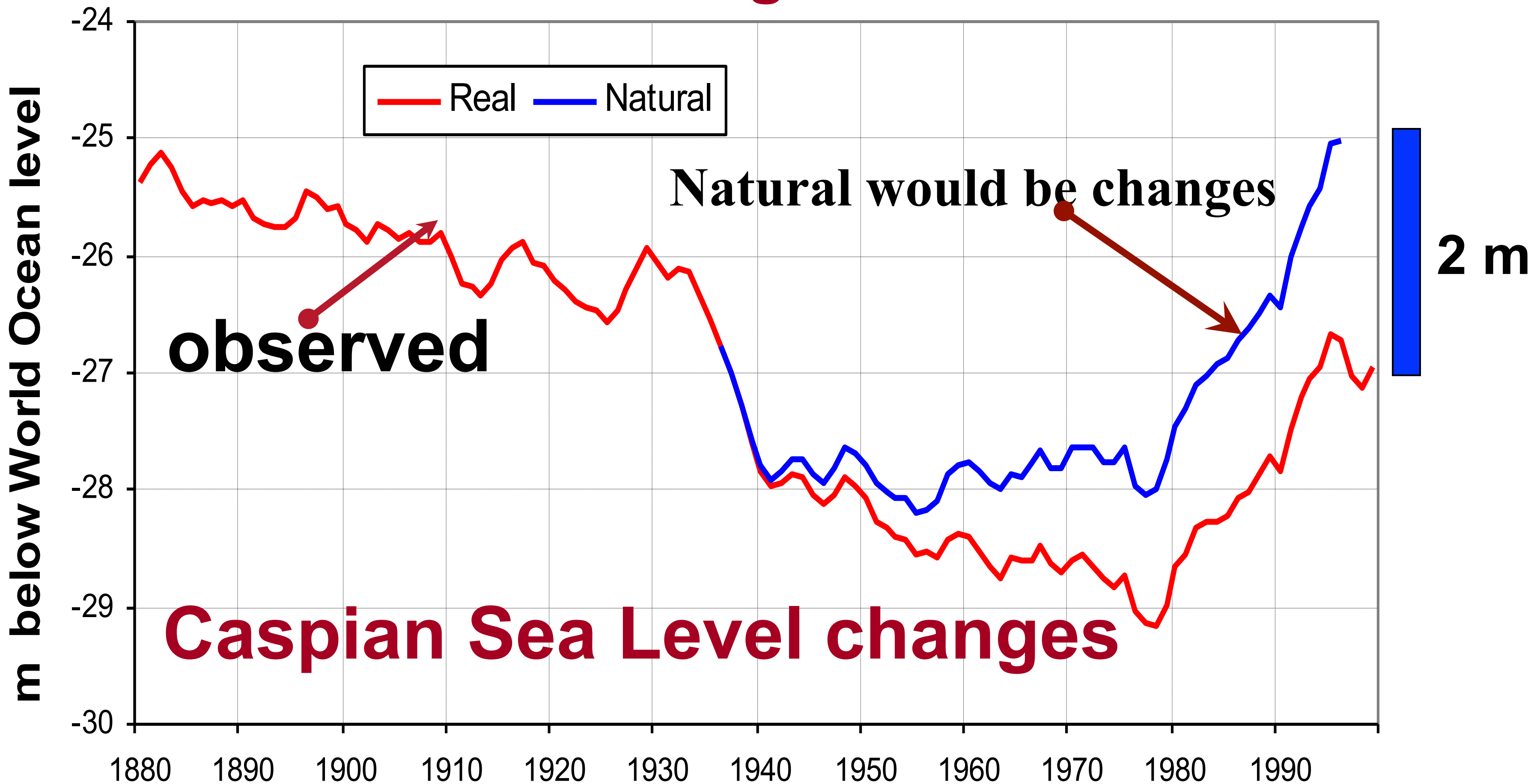
We had "managed" societies in Northern Eurasia and now *social shocks superimposed with environmental changes reduce the resilience of the societies of the region*

- **Political system changed**
- **Land use rules changed**
- **Economics changed**
- **Infrastructure of social services unsupported**

Plus

- "Hot spot" of climatic change
- Biogeochemical feedbacks changing in uncertain ways

Observed and “natural” changes in the level of the largest in the world lake are significant and of similar magnitudes



Source: Shiklomanov (1976)

Update: Shiklomanov and Georgievsky (2003)

Why we have to be expedient in our research?

Firstly:

the changes are already here and they have been large!

Secondly,

- **We are facing a non-linearity in environmental and climatic changes in Northern Eurasia right now due to**
  - **Dramatic retreat of the Arctic sea Ice that is causing**
    - **rampaged coastal erosion (up to 10 m yr^{-1})**
    - **release of carbon (both, methane and CO_2) stored in the frozen shelf and coast (Shakhova et al. 2009), and**
    - **additional source of heat and moisture in early winter**
  - **Impact on the World Ocean thermohaline circulation due to changes in the fresh water inflow into the Arctic Ocean**
  - **Feedbacks to the global carbon budget & climate** due to
    - **Permafrost thaw**
    - **Wetlands transformation**
    - **Land cover changes and**
    - **Ecosystems shift**

Thus, it looks like within Northern Eurasia we have to study:

Human activity changes

Climate system changes

Greenhouse gases changes

Ecosystems' changes

and

their interactions

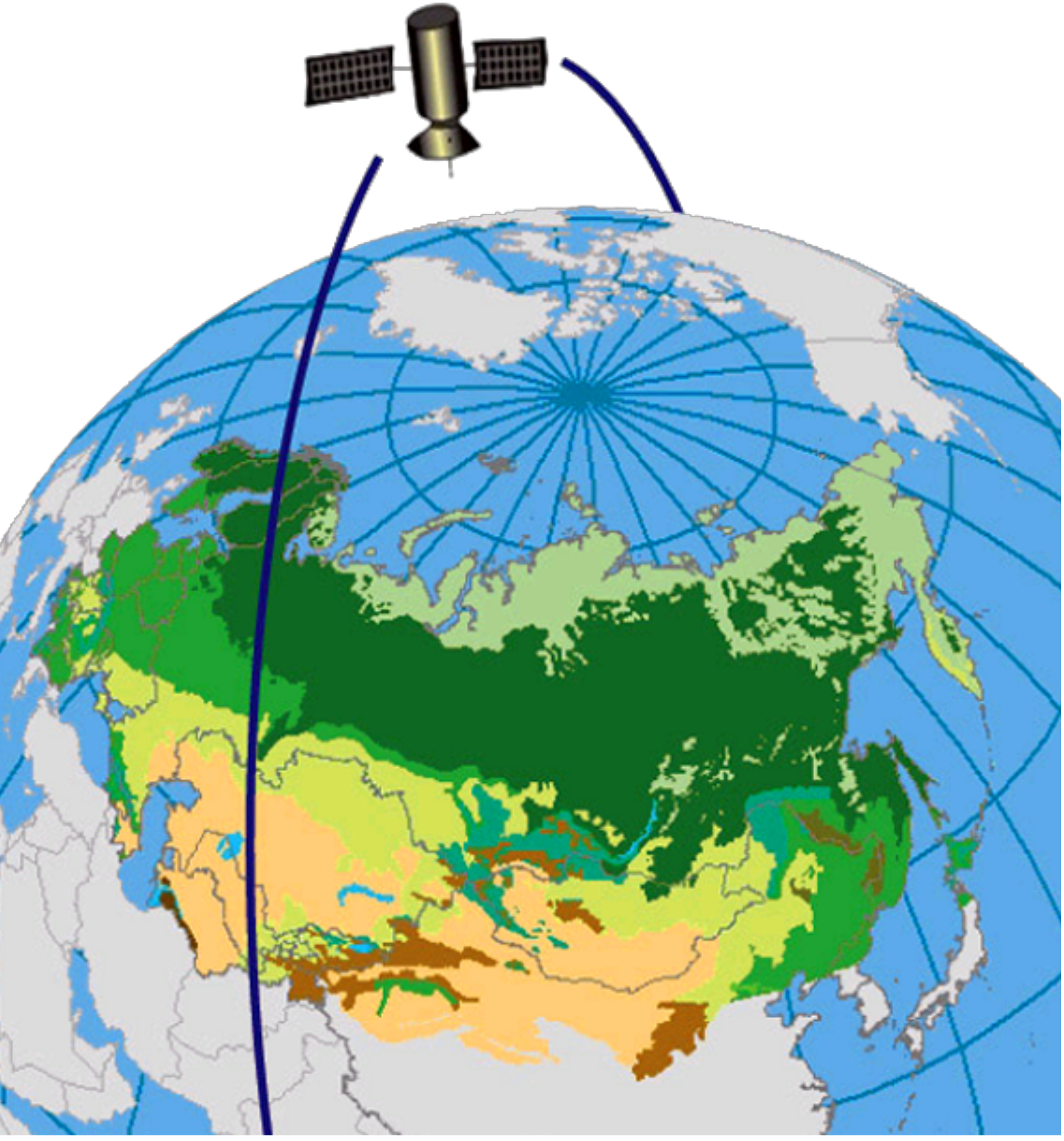
=> A synergetic approach to projections of the future changes is a core of the NEESPI

Problem was not the large changes themselves but understanding of their causes and timely projections

Rationale for NEESPI

1. Strong interactions in the system **terrestrial ecosystem - atmosphere hydrosphere - cryosphere - human society** and feedbacks to **global energy, water, and carbon cycles in the region**

2. **Strong climatic and environmental changes….**



The NEESPI Study Area

NEESPI is an interdisciplinary program of internationally-supported Earth systems and science research that addresses large-scale and long-term manifestations of climate and environmental change.

NEESPI Study Area includes: Former Soviet Union, Northern China, Mongolia, Fennoscandia, & Eastern Europe

NEESPI duration ~ 10 years (started in 2004)

NEESPI AND ITS PAST

NEESPI and the actions to develop its Science Plan were initially promoted by NASA and Russian Academy of Sciences (2003-2004).

RAS

Since early 2005, the NEESPI community has worked to make NEESPI inter-agency (in the U.S.) and international.

The NEESPI Science Plan (available on http://neespi.org) has elements that address concerns of WCRP, IGBP, IHDP, and DIVERSITAS Programs

The overarching NEESPI science question:

- How do Northern Eurasia's terrestrial ecosystems dynamics interact with and alter the biosphere, atmosphere, cryosphere, and hydrosphere of the Earth?

This question can be reformulated in a pragmatic way as:

- How do we develop our predictive capability of terrestrial ecosystems dynamics over Northern Eurasia for the 21st century to support global projections as well as informed decision making and numerous practical applications in the region?

Our concern is that the changes in this region have the potential to affect the entire Earth System and may already be doing so.

NEESPI Deliverables:

to have in ~10 years

- **A suite of process –oriented models for each major terrestrial process in all its interactions**
- **A suite of global and regional models that seamlessly incorporate all regionally specific feedbacks associated with terrestrial processes**
- **An integrated observational knowledge data base for environmental studies**
- **To bring the Earth System research in the region to the level it deserves**

Current NEESPI Statistics (April 2010):

More than 560 scientists from more than 200 institutions of 30 countries are working on more than 130 individual funded projects under the Initiative umbrella (with annual budget ~$15M), several more projects are in the process of joining NEESPI. Four major sponsors of NEESPI remain: the United States, Russia, European Union, and Japan.

Additionally, NEESPI receives in kind assistance from EU, US, Russian, Chinese, Japanese, Ukrainian and International Agencies and Institutions.

Example of in-kind assistance

To support a Summer Workshop-School in Fedorovskoe (Russia, July 2007) on Boreal Forest Environmental Studies, sponsors from

- Japan (National Institute of Environmental Sciences),
- China (Beijing Normal University),
- Russia (Severtsov Institute for Ecology, Russian Foundation for Basic Research),
- Germany (Friedrich-Schiller-University),
- USA (NASA, Maryland University),
- The International Arctic Research Center, Fairbanks, Alaska, and
- private US and Russian companies

swiftly came together with a 6-digit sum of money.

Two modes of NEESPI expansion

- Dedicated Calls (recent NASA and RAS and perspective in the NIS, EU, and China)
- Freely joined projects
- **Benefits of the NEESPI membership**
  - **Improved links** to collaborators in Northern Eurasia and to US and EU scientists working on similar problems
  - **Exchange** of ideas, datasets, and knowledge with other team members working on similar problems
  - **Synergistic approach in working on complex problems**
  - **Priority access to** remote sensing and in situ **data** collected over Northern Eurasia
  - **Education:** student exchange, doctoral and post-doc positions sharing among the Team Institutions

NEEESPI Outreach, http://neespi.org

During the past 3 years, ~25 dedicated NEESPI Workshops and 6 NEESPI Open Science Sessions at the International Meetings were convened and more than 350 papers and books were published (the total number of publications exceeds 500).

In April 2007: 1st Special NEESPI issue (13 papers) in *Global and Planetary Change*

In December 2007: 2nd NEESPI Special issue in *Environmental Research Letters* (**15** papers)

In April 2009: Book **"***Regional Aspects of Climate-Terrestrial-Hydrologic Interactions in Non-boreal Eastern Europe"* Groisman and Ivanov (Eds.) published by Springer Verlag.

In May 2009: An overview NEESPI paper in *Bull. Amer. Meteorol. Soc.*

In October 2009 through March 2010: the 3rd NEESPI Special issue in *Environmental Research Letters* (**34** papers)

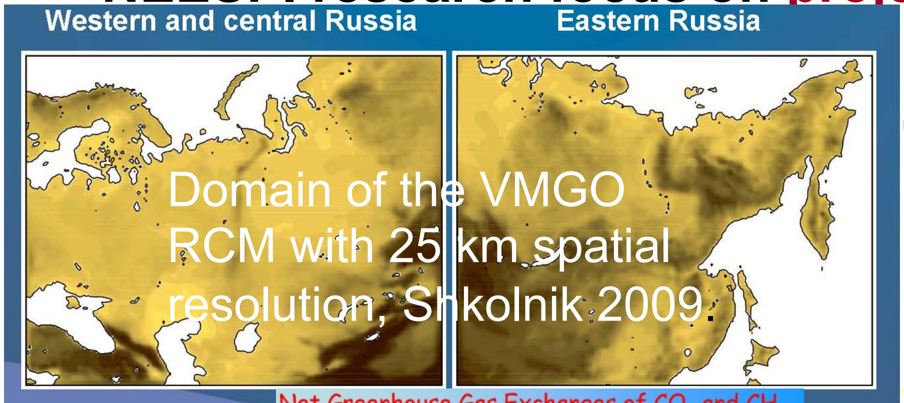
Current situation:

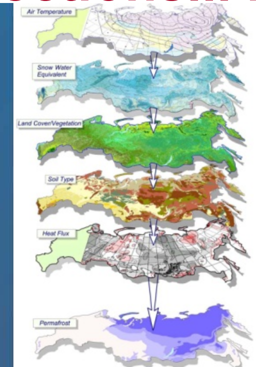
- **Two books are *in press*** *and scheduled for the first half of 2010.* Both of them are devoted to Eurasian Arctic (land and sea shelf)
- Book "Environmental Changes in Siberia: Regional Changes and their Global Consequences" is in preparation

NEESPI is built around two documents

- The NEESPI Science Plan published in 2004 (http://neespi.org)
- The Second Programmatic paper in the *Bull. Amer. Meteorol. Soc*. (Groisman et al. 2009) based on the Aspen Brainstorming Workshop in Aug. 2007.

First phase foci of NEESPI were monitoring and analyses. After the NEESPI Workshop in August 2007 at the Aspen Global Change Institute, a new course was accepted towards strengthening of the NEESPI research focus on **projections... i.e., focus on modeling...**

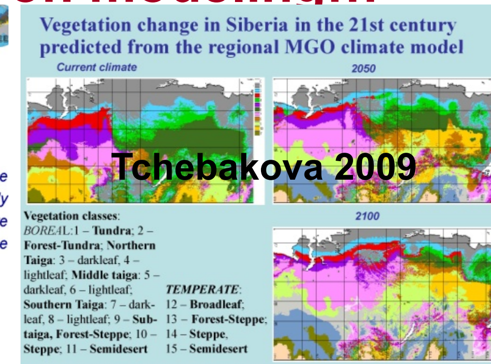




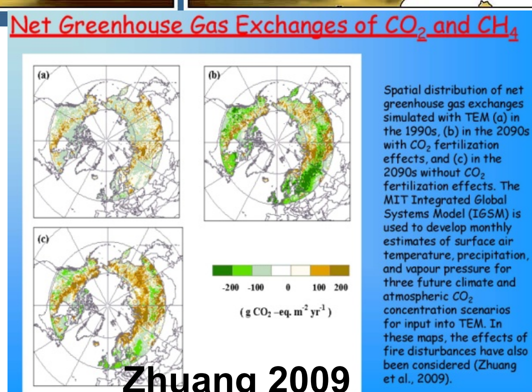
GIPL-2 Model

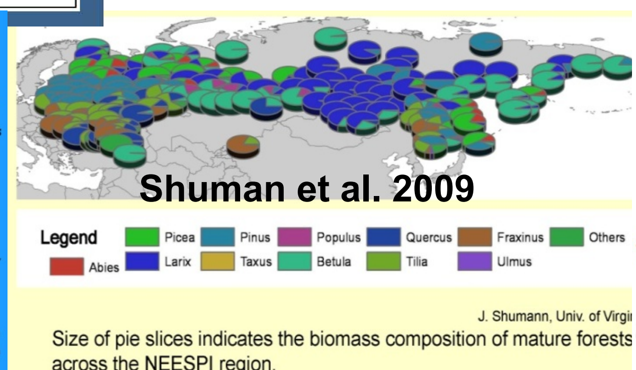
The GIS multi-layered Data Base interactive model for Spatially Distributed Permafrost and Active Layer Dynamics modeling in the Northern Eurasia.

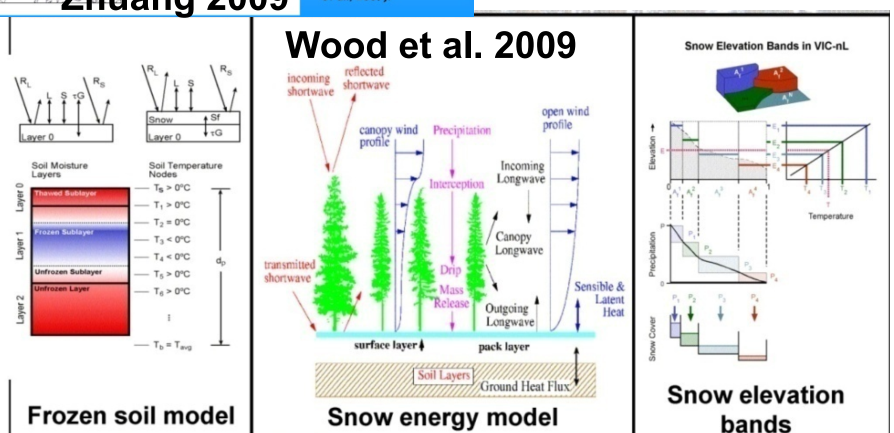
(Marchenko et al., 2008)

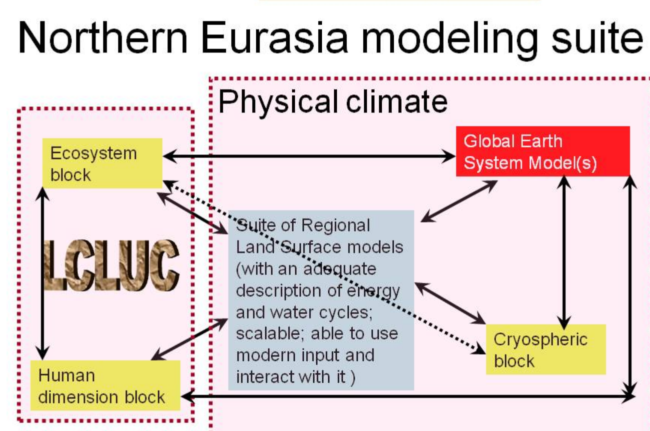


Efforts are made to blend modern RCMs with vegetation, carbon flux, permafrost, hydrological, and dust production models within a North Eurasia modeling suite and link it to the MIT Earth System model.





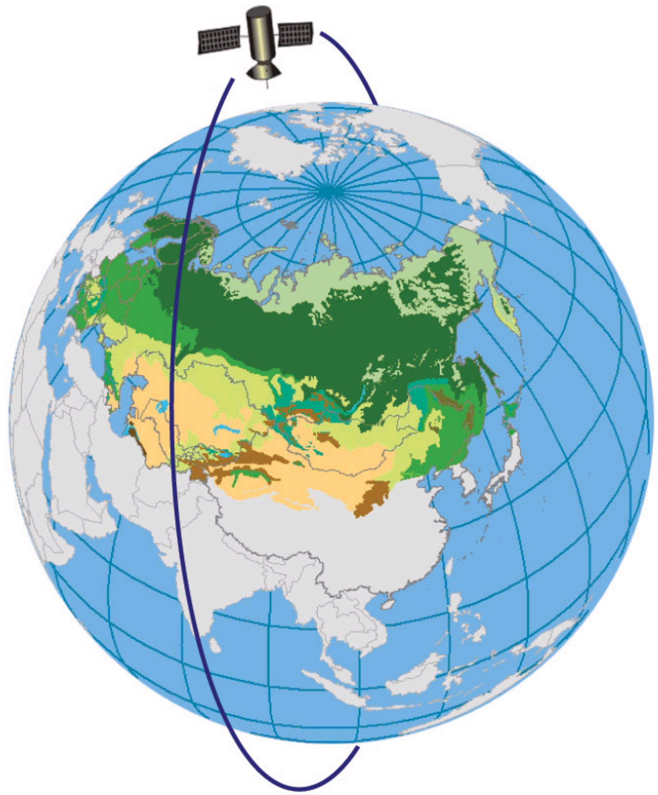




Thank you!

FOR MORE INFORMATION SEE THE NEESPI WEB SITE:

http://neespi.org



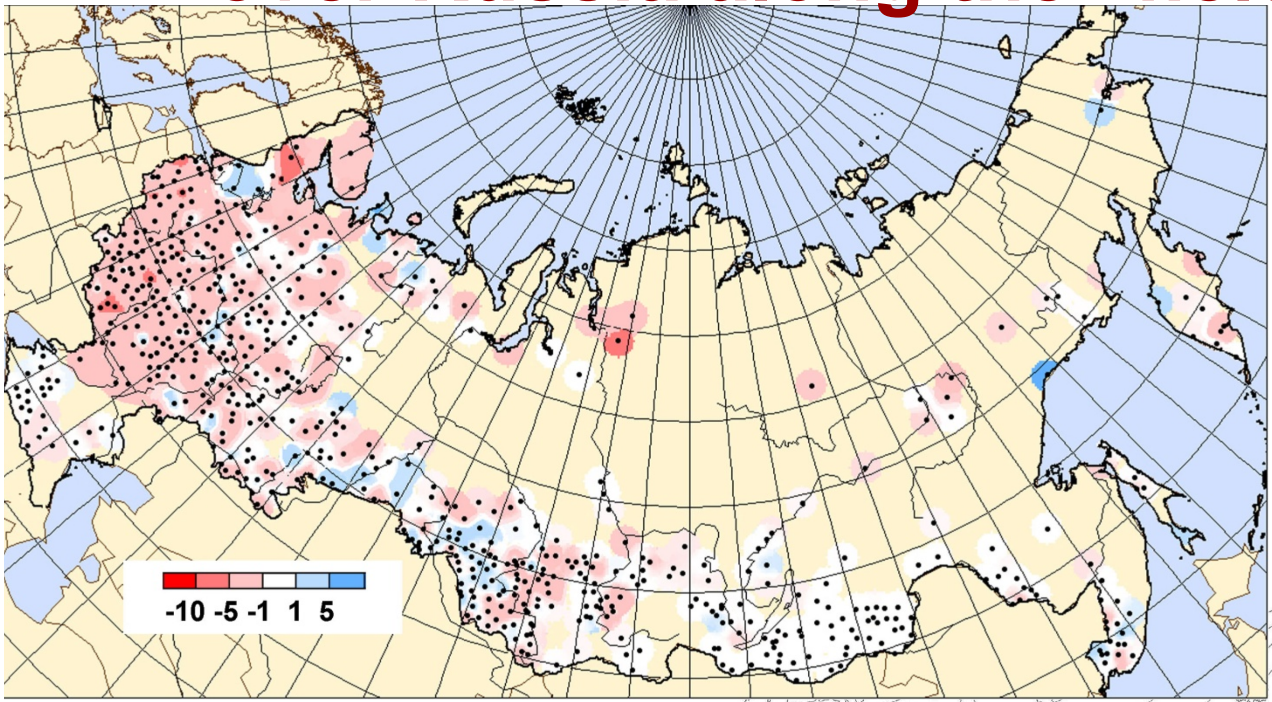
Side Note:

"NEESPI" is pronounced approximately like the Russian phrase for

'Don't sleep "

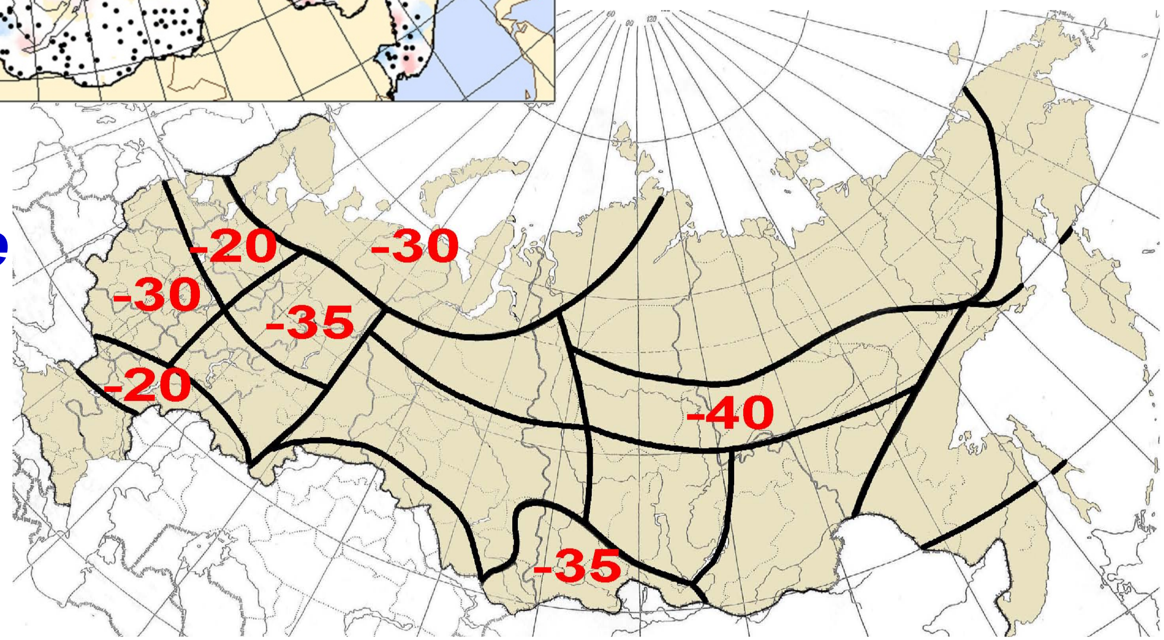
Northern Eurasia Earth Science Partnership Initiative

Trends in maximum basal ice layer depth over Russia along the "field" routes

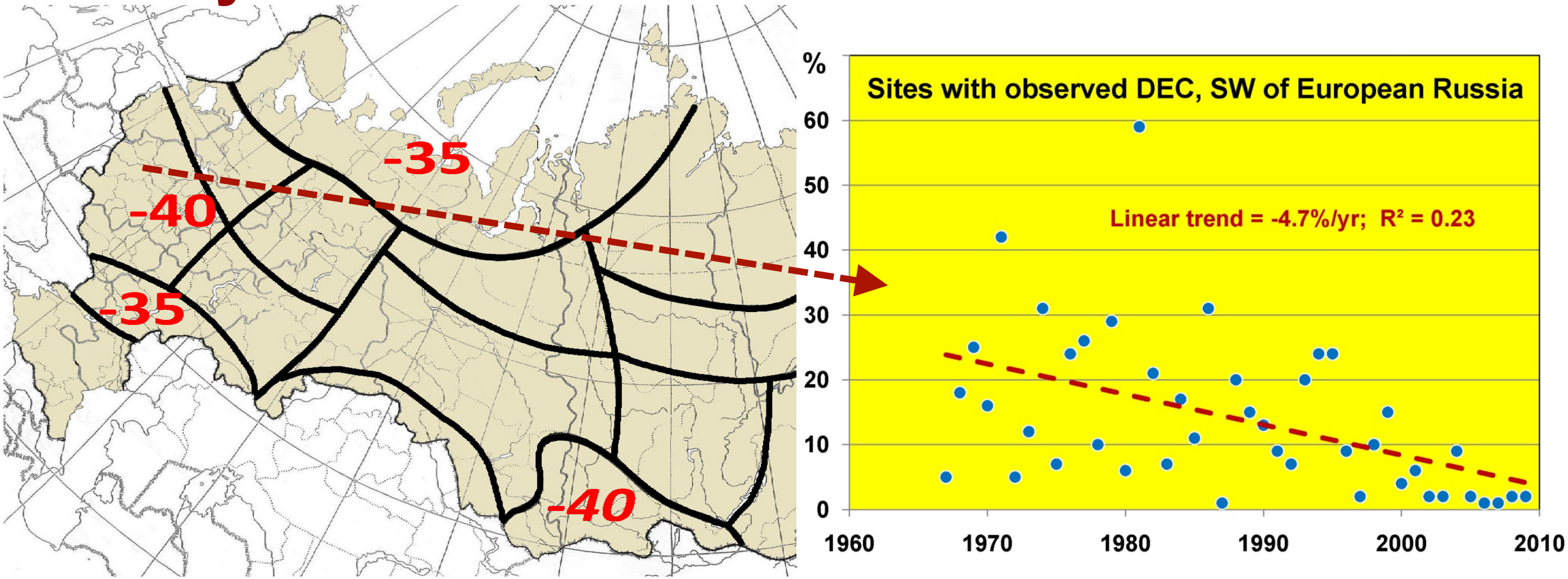


Pattern of the linear trends of the depth in mm per 10 years and their regionally-averaged values in % per 10 years.

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



DEC, dangerous event for winter crops: basal ice layer above 20 mm over the “field” routes



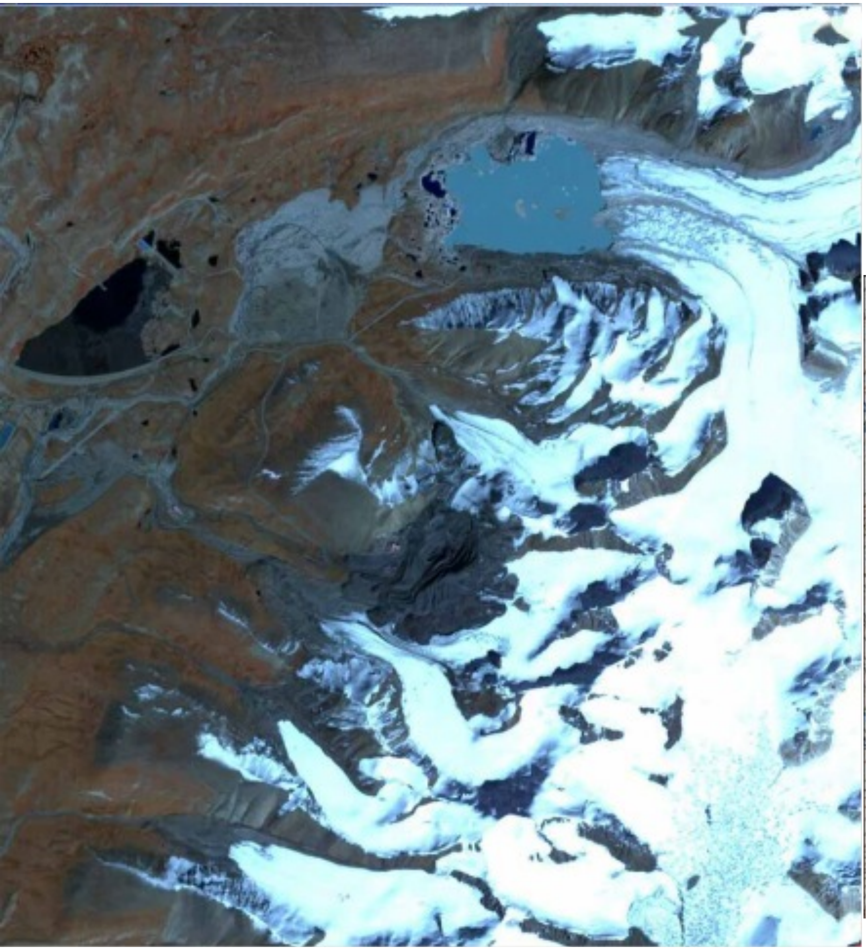
- ***Left.*** ***Regional trends (% per 10 years) that are presented only for the regions where during the 1967-2009 period they were statistically significant at the 0.05 or higher level.***
- ***Right.*** ***Annual variability of the percent of stations where the DEC events were observed in the southwest of European Russia.***

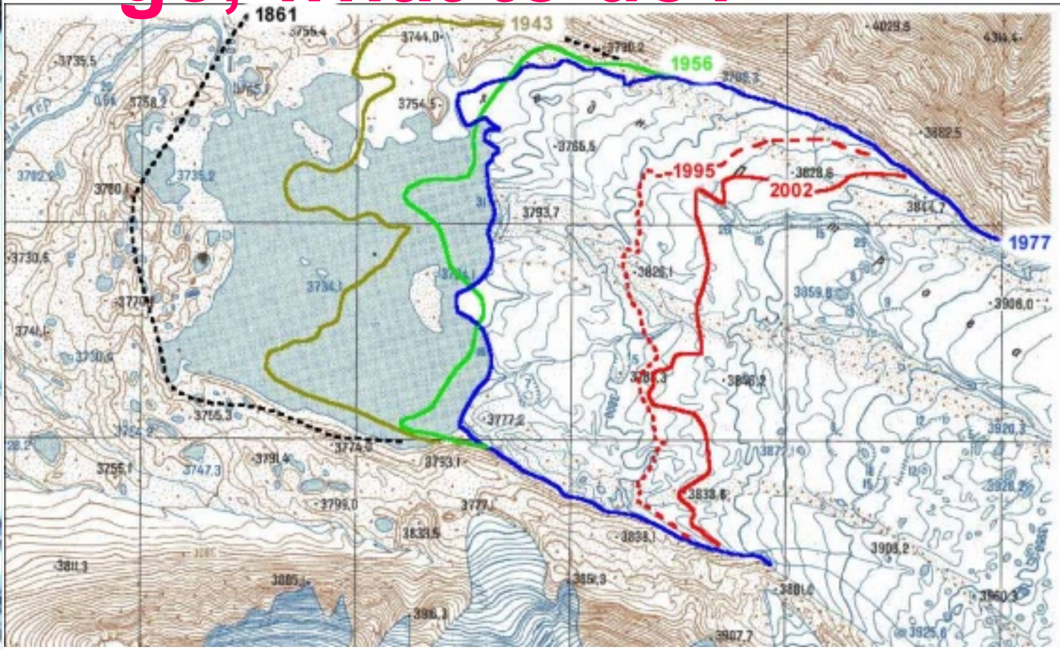
Focus on snow cover characteristics

- **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 layer 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.**

Changes are affecting water supply...

When the millenium-old water storage will go, what to do?





Example. Central Asia *.**Example of a central Tien Shan glacier recession. Petrova Glacier in the Akshiyrak area, ASTER image, September 2002 (A), and instrumental topographic data (B) (Aizen and Kuzmichonok, 2003)***

...land cover...

Two possible scenarios after the permafrost thaw:

Wetlands

Steppe

Radiation balance of forested (RB_f) versus nearby forest-free (RB_0) sites

$$RB_f = a\, RB_0 + b$$ (Rauner 1972)

Conifer forest: $a = 1.10$; $b = 20\ W\ m^{-2}$

Deciduous forest: $a = 1.05$; $b = 15\ W\ m^{-2}$

=> Surface Radiation Budget is strongly affected by "natural" land cover changes:

1962

1997