# **Observed climate changes in Siberia :** regional aspects of contemporary climatology

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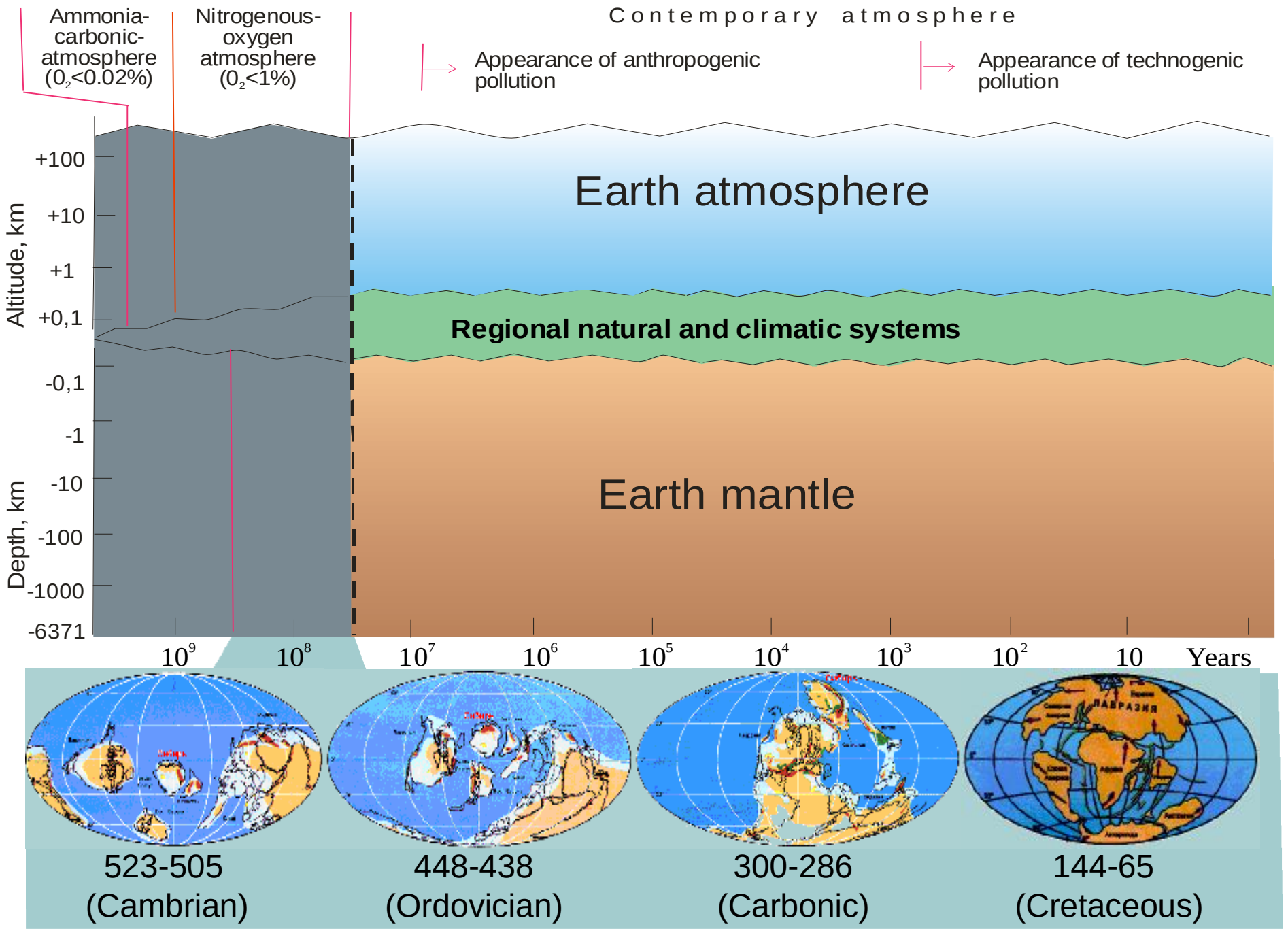
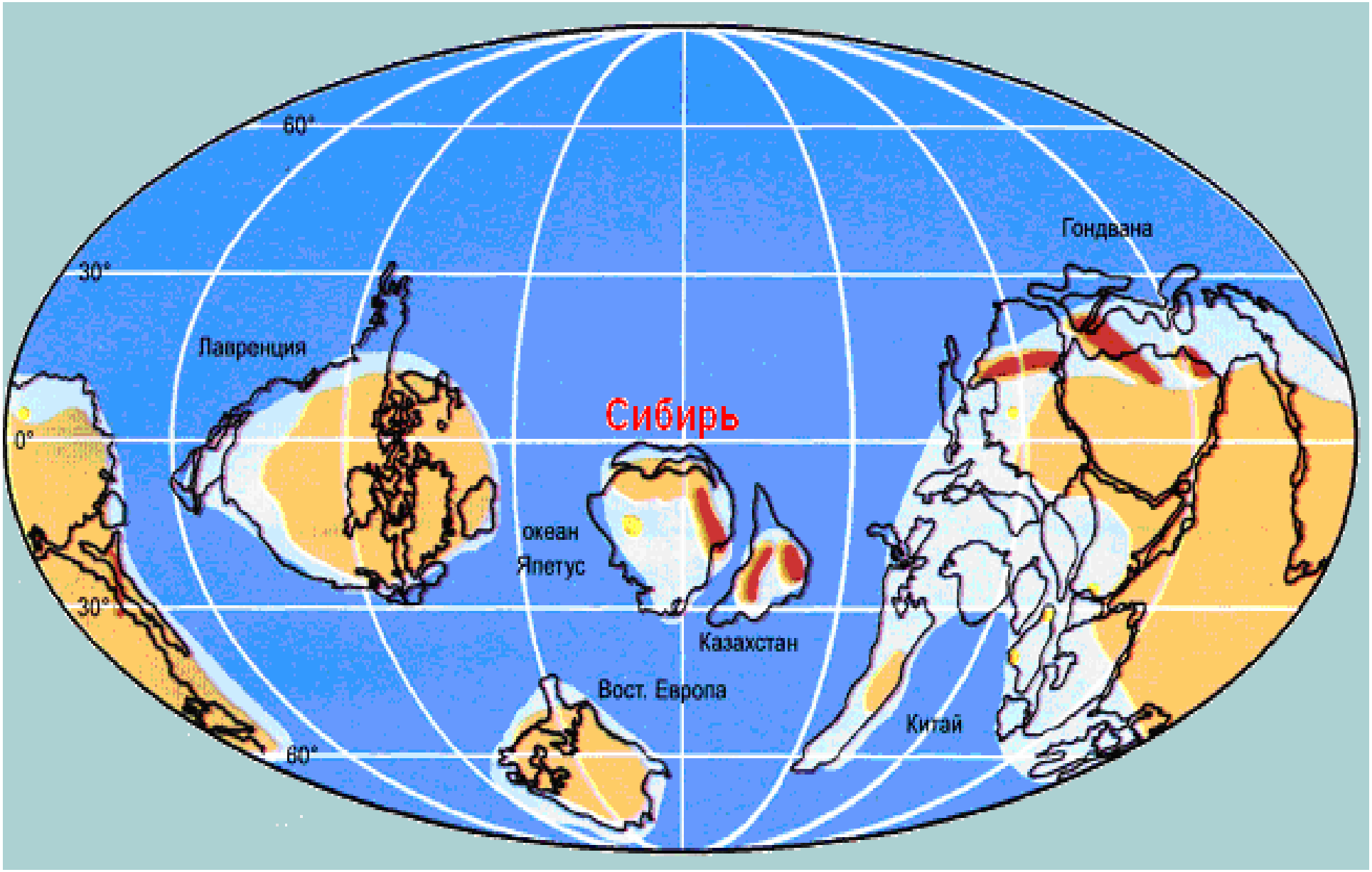
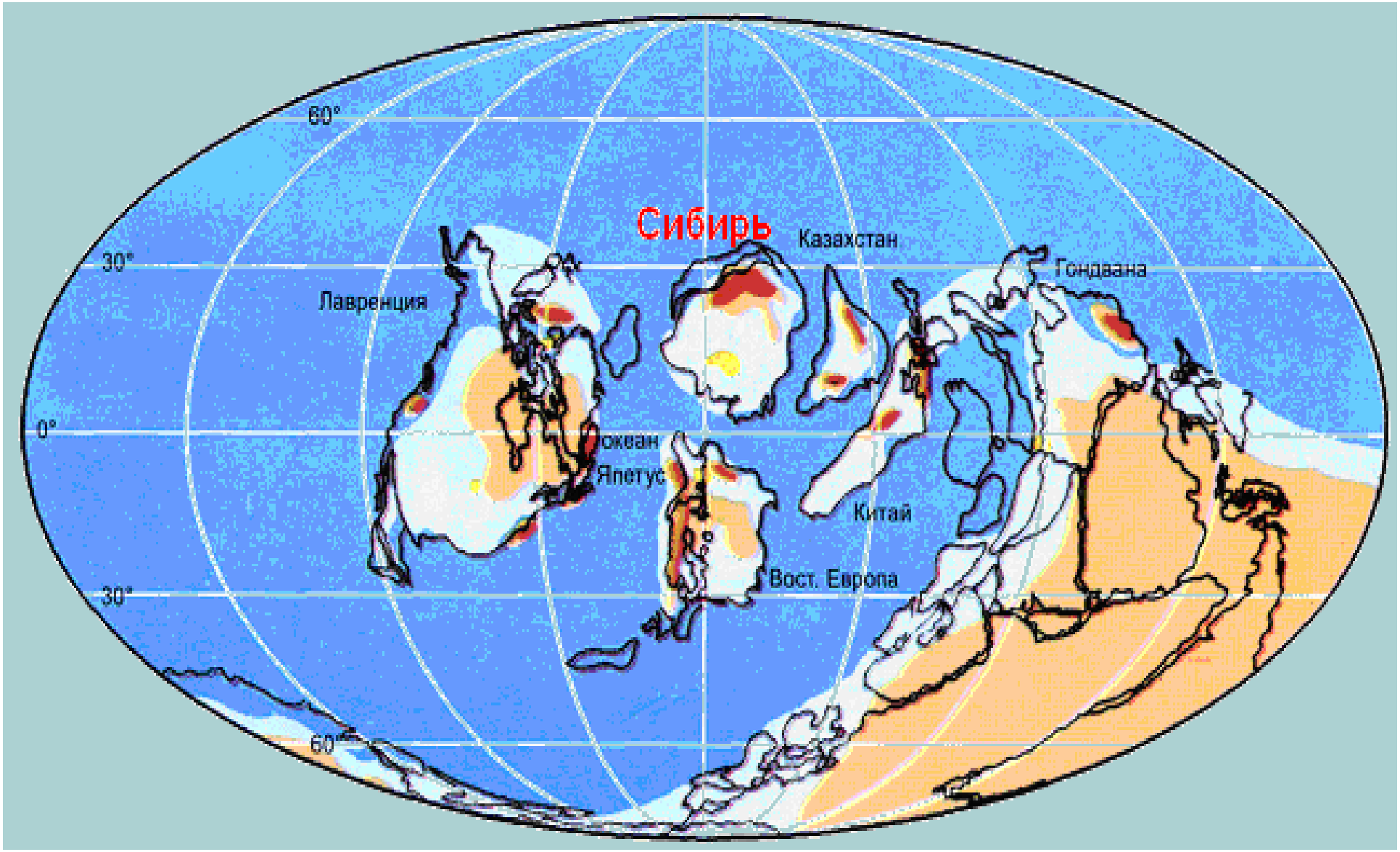
# Evolution of the Earth system on geological time scale

*“The oracle rule": he who can understand the past will be able to predict the future*

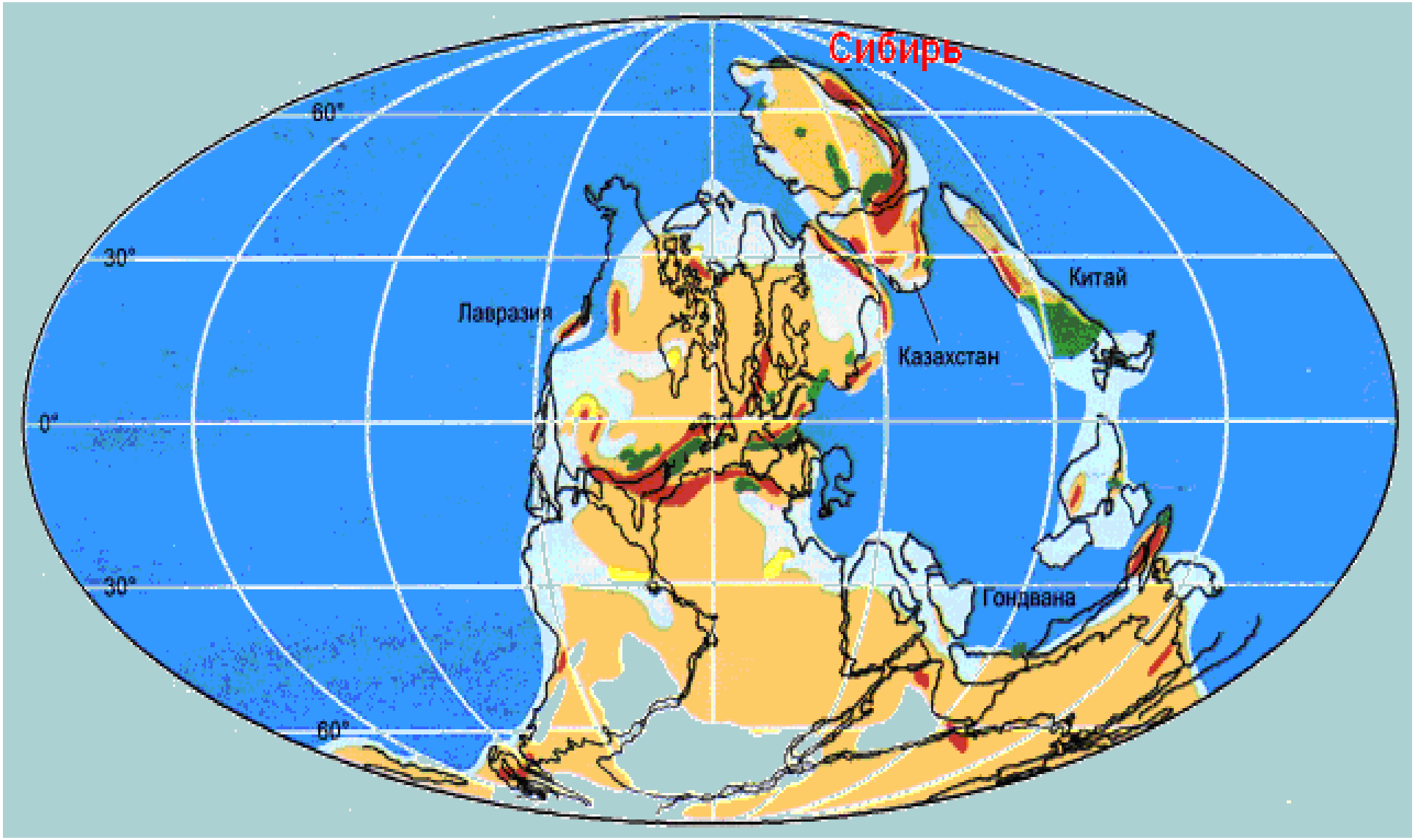

Ammonia-carbonic-atmosphere ($0_2$<0.02%)
Nitrogenous-oxygen atmosphere ($0_2$<1%)
Contemporary atmosphere
Appearance of anthropogenic pollution
Appearance of technogenic pollution
Earth atmosphere
Regional natural and climatic systems
Earth mantle
Altitude, km
Depth, km
+100
+10
+1
+0,1
-0,1
-1
-10
-100
-1000
-6371
$10^9$
$10^8$
$10^7$
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
Years
523-505 (Cambrian)
448-438 (Ordovician)
300-286 (Carbonic)
144-65 (Cretaceous)




**523-505**
**(Cambrian)**




**448-438**
**(Ordovician)**

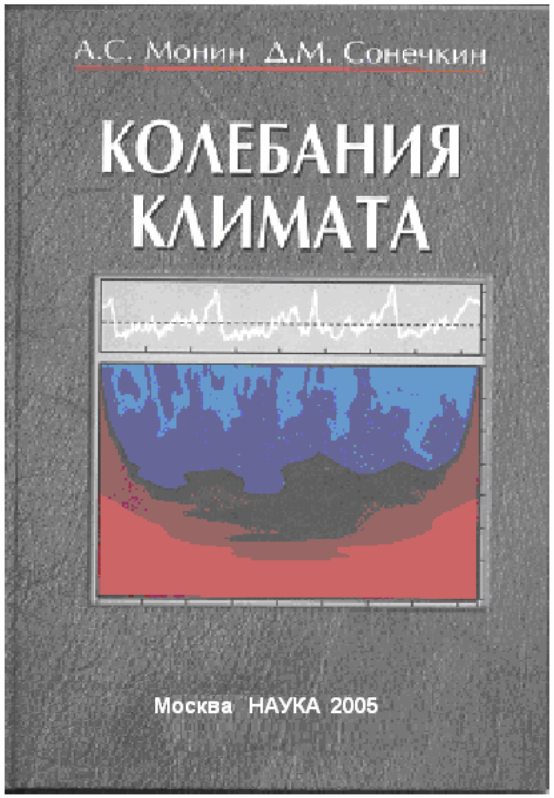



**300-286**
**(Carbonic)**


**144-65**

**(Cretaceous)**

# Climatic cycles revealed




**Glacial cycles (approx. 20, 40 and 100 thousand years).** Insolation variations due to Earth orbital motion in the solar system (Milankovich celestial cycles). They are justified by ice core analysis in Antarctic and Greenland.

**Principal cycle of Holocene (approx. 1500 years).** Coincidence of phases of Principal cycles of the Solar system and (or) fluctuation of Global circulation of the World Ocean.

**Principal cycle of the Solar system (179 years).** Solar motion relative to centre of mass under gravitational interaction between Sun, Jupiter and Saturn.

**Quasi-vicennial cycles (23.7 years).** Change of magnetic field polarity on the Sun during two sun-spots' cycles (11.86 years).

**Quasi-biennial cycles (2.38 years).** This is a result of Chandler mutation of the Earth poles.

**Annual cycle.** Unstable oscillations of climatic system under influence of atmospheric perturbations.

*Conclusion of the section " Evolution of the Earth system …"*

**Evolution of the Earth system in the past significantly influenced** regional climatic changes in all climatic epochs.

**Contemporary** high-precision instrumental **observations** show that **noticeable changes** in positions of the continents as well as atmospheric composition run on. Therefore such researches are still urgent in contemporary climatology, including ones of regional natural and climatic systems.

# Spatial scales of regional natural and climatic systems

## *Horizontal scales*

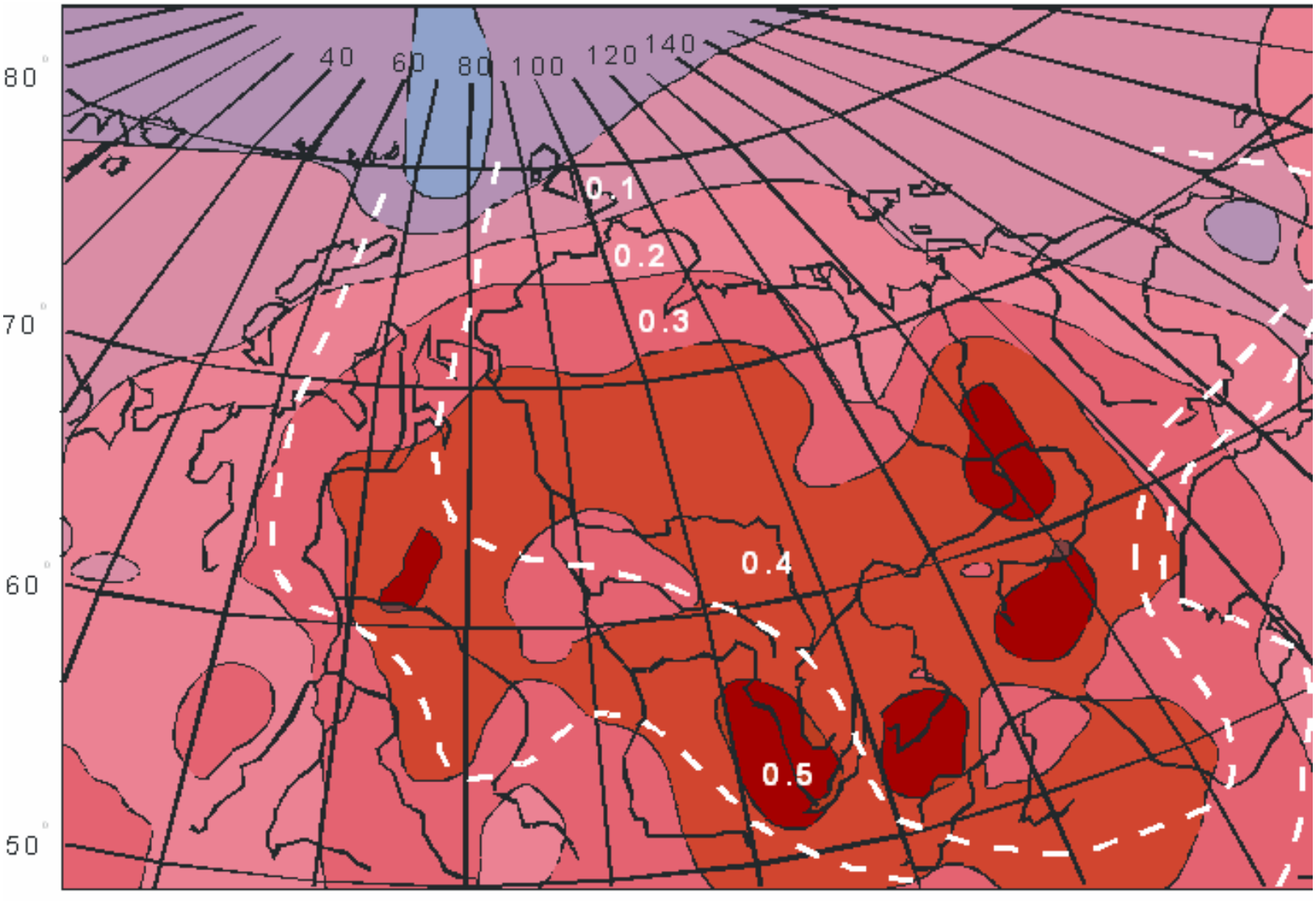
Maps of linear trends of annual mean surface temperatures in Siberia reveal regional and subregional scales.

Maps of thunderstorm activity in Siberia reveal subregional scales both at the 20$^{th}$ century beginning and at its end.

Maps of monthly mean surface temperatures show subregional scales for cooling (in summer) and warming (in winter) effect of Big Vasyugan Bog (area of 53 thou. km$^2$).

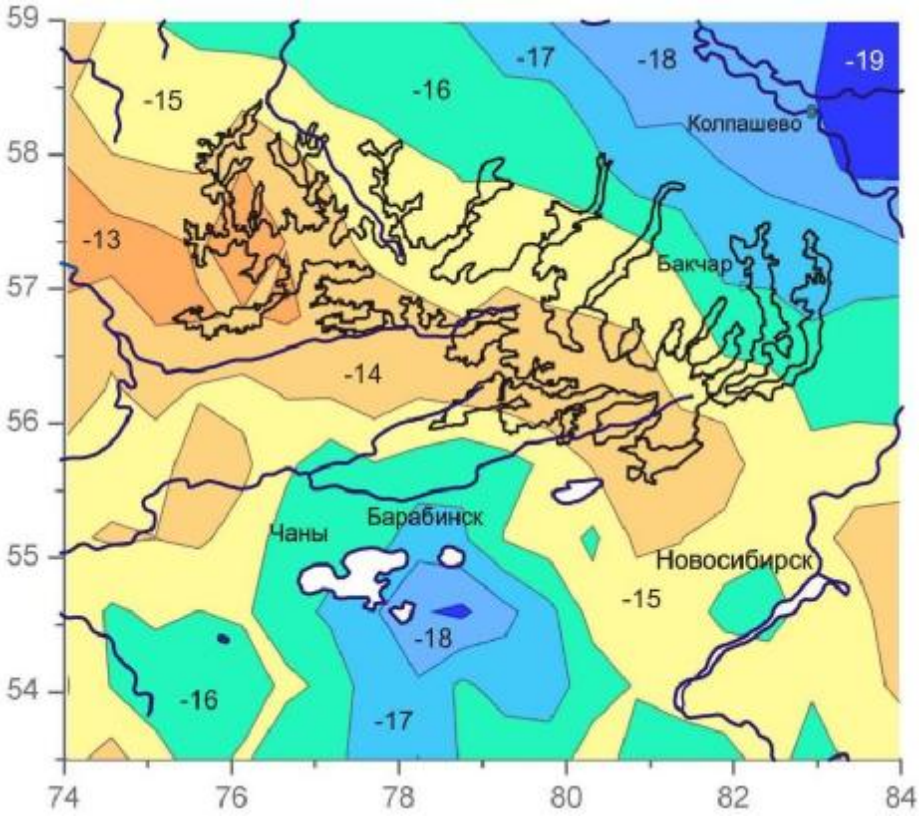
## *Vertical scales*

Maps of monthly mean temperatures show effect of Big Vasyugan Bog up to altitudes of 12 km (MODIS data).

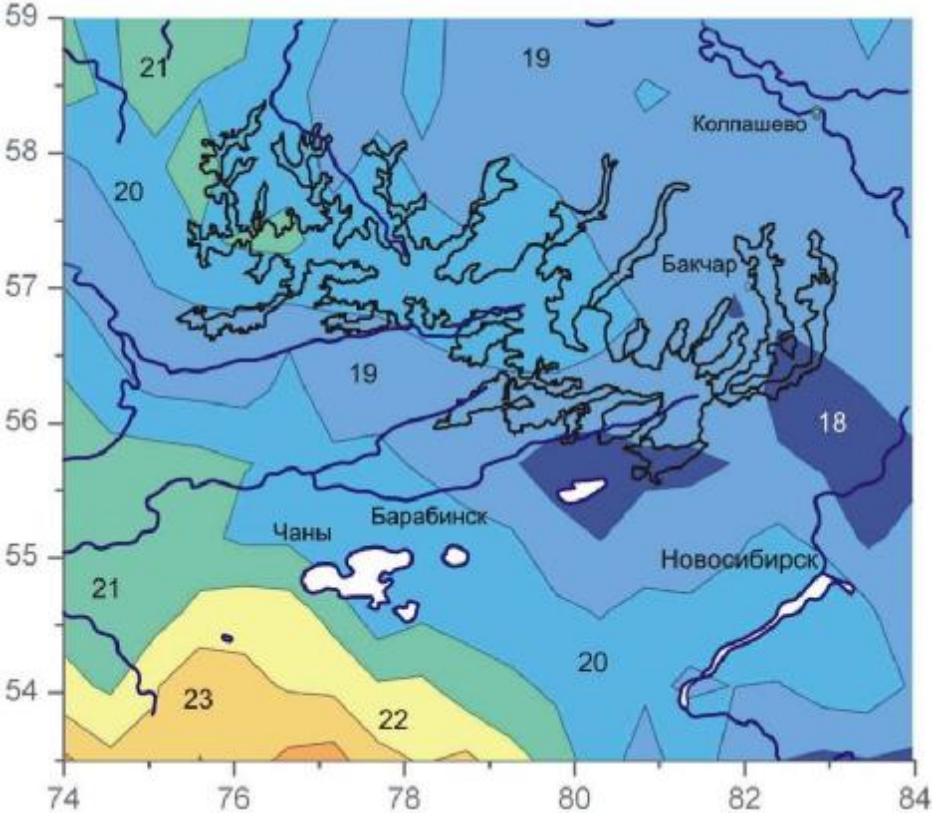



Map of linear trends of warming over the period from 1965 to 2000. Comparison with isolines for January (the upper line is for -28 °C, the lower one is for -20 °C) over the period from 1881 to 1935.

February of 2004

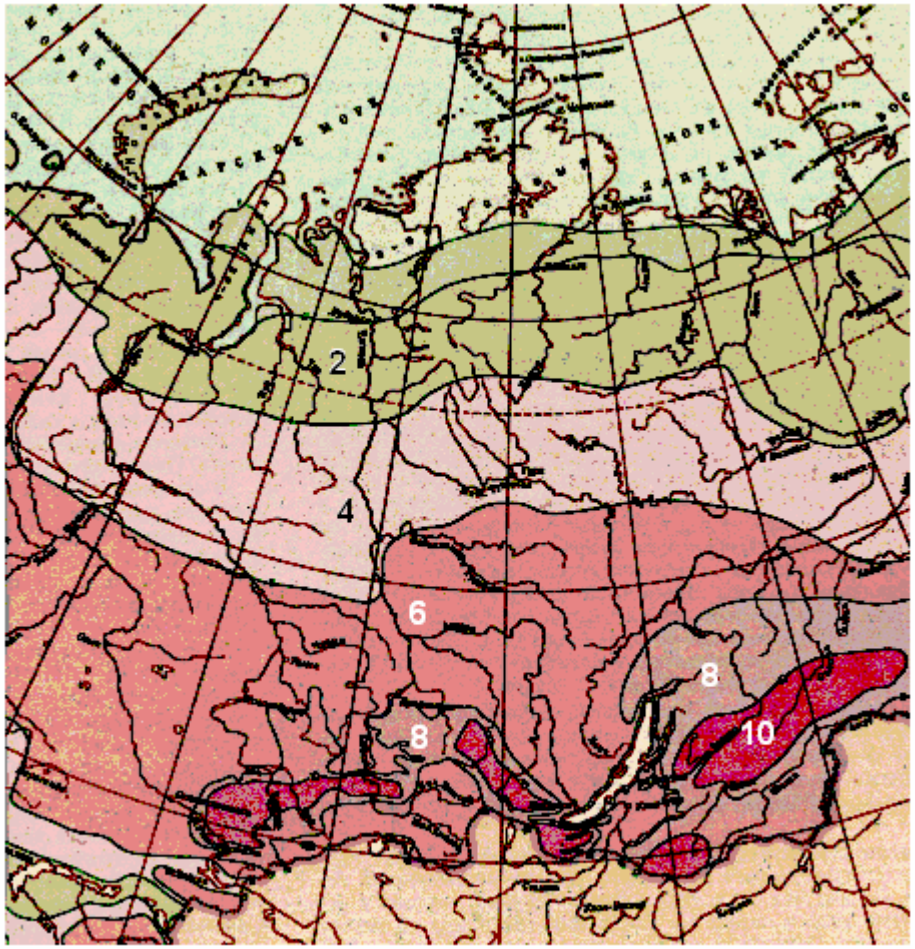



July of 2004

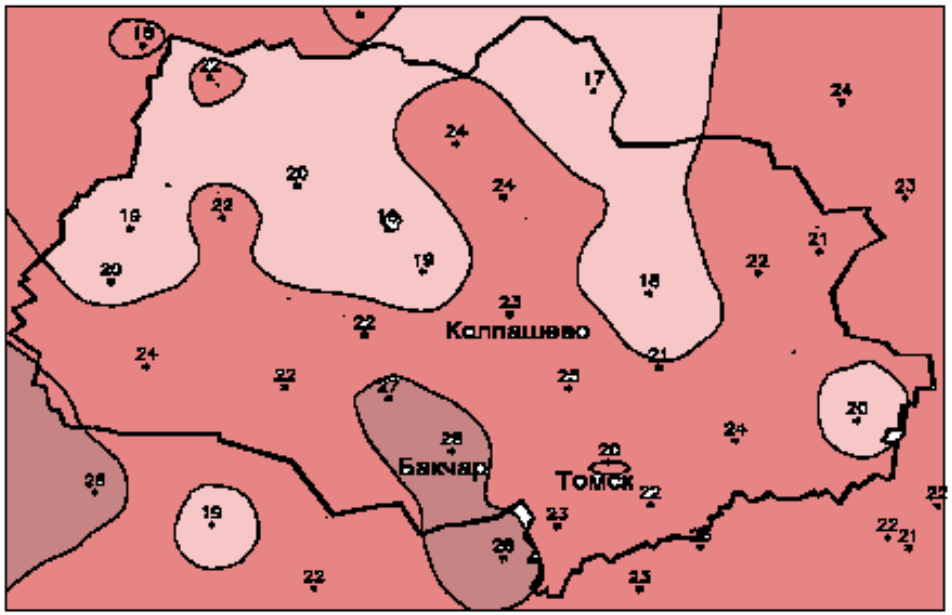



Map of surface temperature distribution at Big Vasyugan Bog and adjacent territories (MODIS data).

# Mean number of thunder days



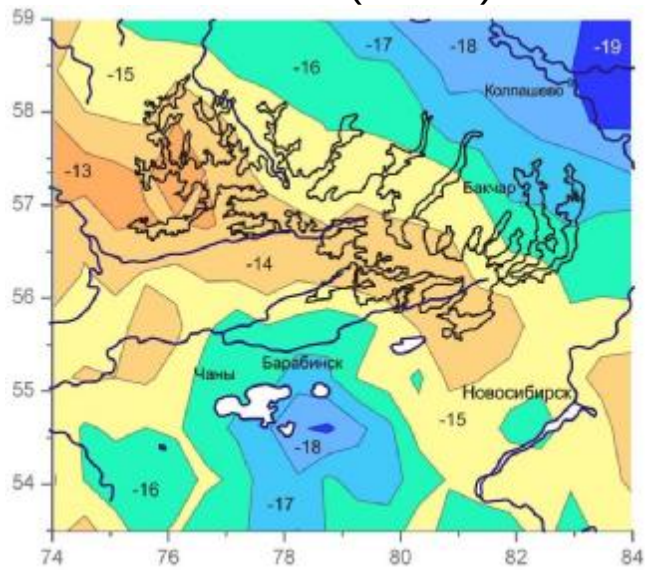

Siberia.
Monthly mean values (July)
over the period from 1891 to 1948



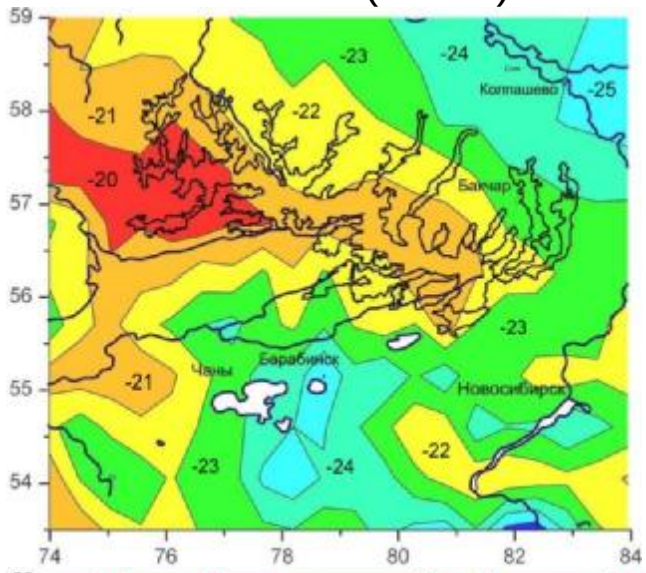

Tomsk oblast.
Annual mean values over the period
from 1966 to 1995

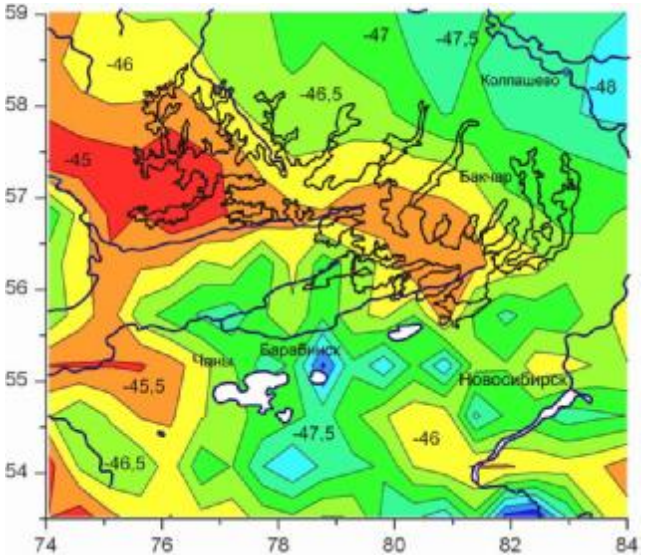
# Temperature distribution at different altitudes over Big Vasyugan Bog (MODIS data, February of 2004)

1000 mbar (~0 km)

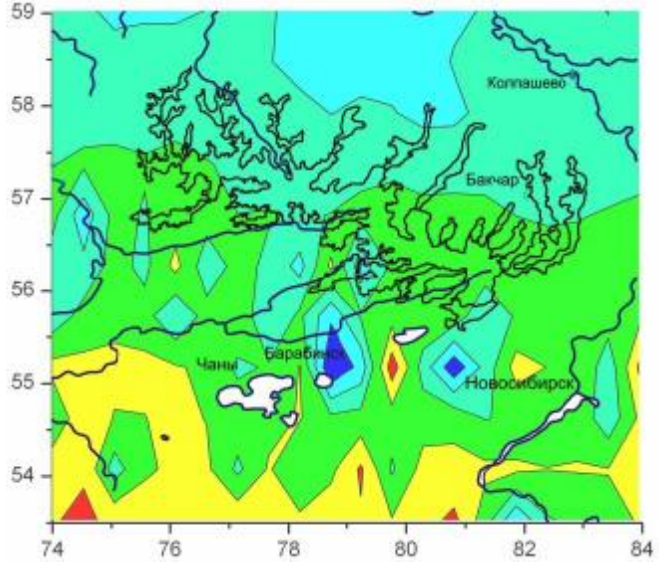



700 mbar (~3 km)

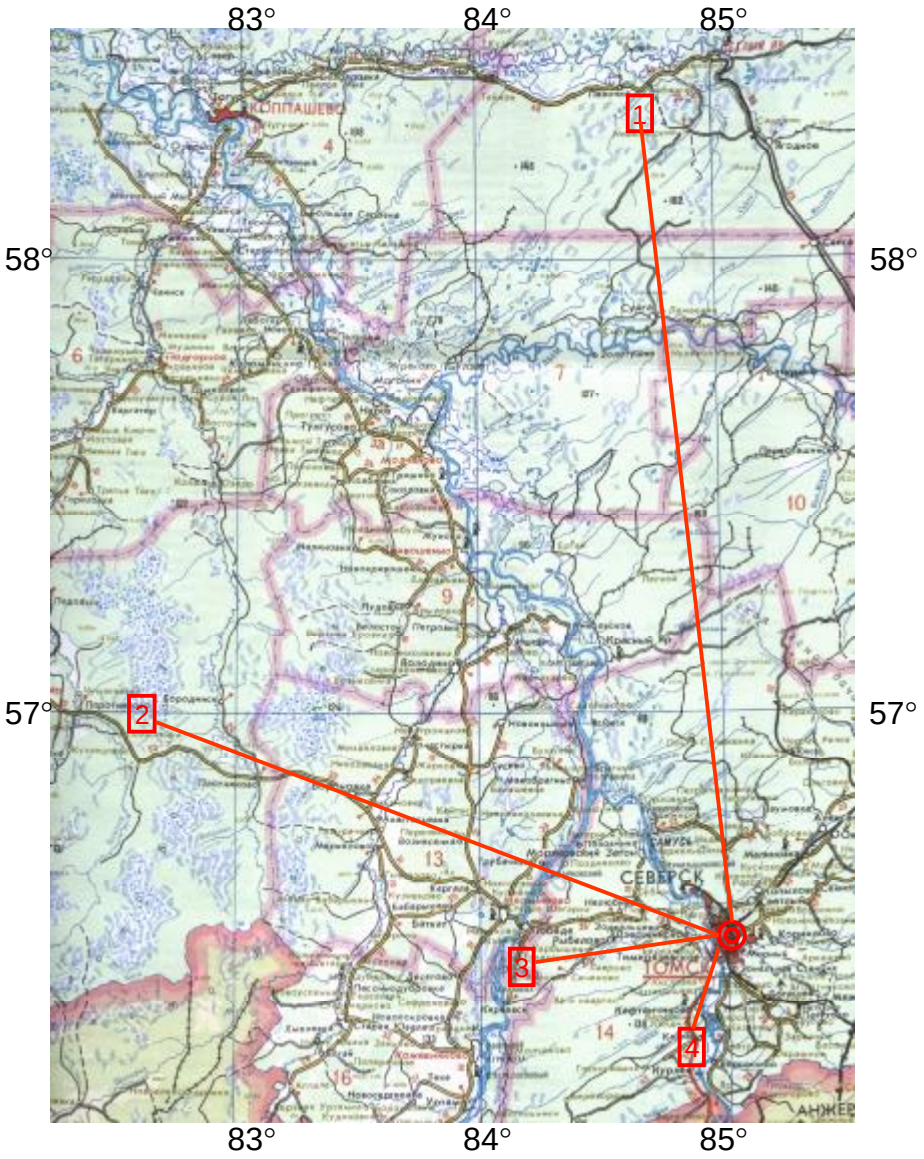



400 mbar (~7.5 km)




300 mbar (~ 9 km)




# Regional network of climate and ecological monitoring

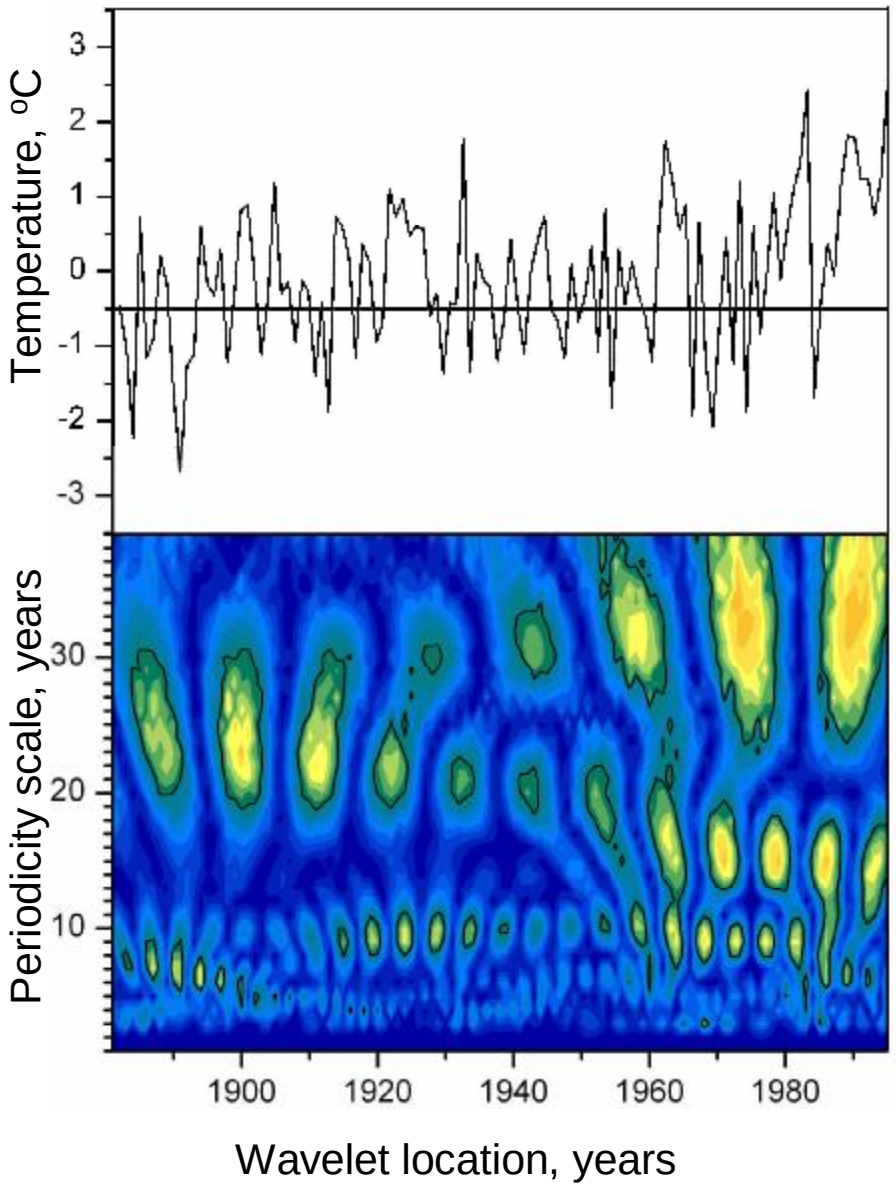
This network was created and developed based on revealed spatial scales for regional and subregional natural and climatic systems.

◎ Siberian Climate and Ecological Observatiry
1 Station «Taezhnyi»
2 Station «Vasyuganie»
3 Station «Kireevsk»
4 Station «Kedr»

# Dynamic parameters of regional natural and climatic systems

…In the absence of widely-used determination of a time scale separating **weather forming** and **climate forming processes,** not always we can manage to distinguish weather catastrophes from the climatic ones (M.I. Budyko, 1986).

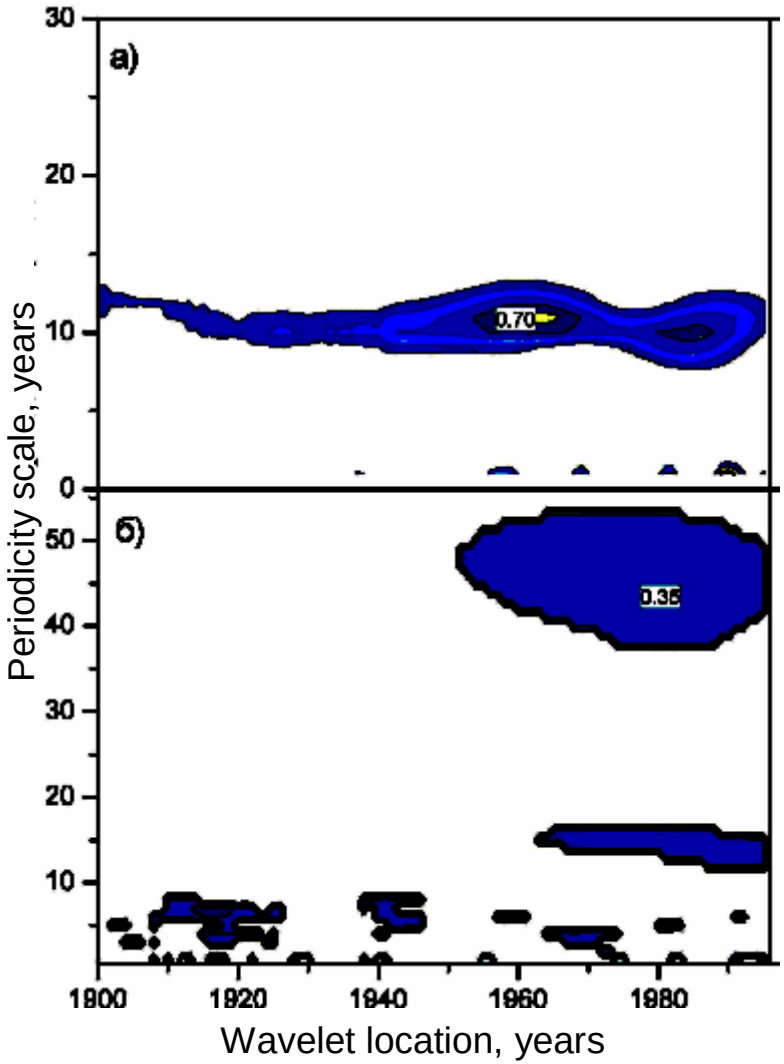
# Wavelet transform of time series of annual mean surface temperature




Dynamic parameters of surface temperature changes observed : **periodicities of different scales** and their present evolution.

Series of annual mean surface temperature (upper part) and its wavelet spectrum (lower part) for Tomsk city

# Correlation analysis of wavelet spectra for T, Wolf numbers and SOI



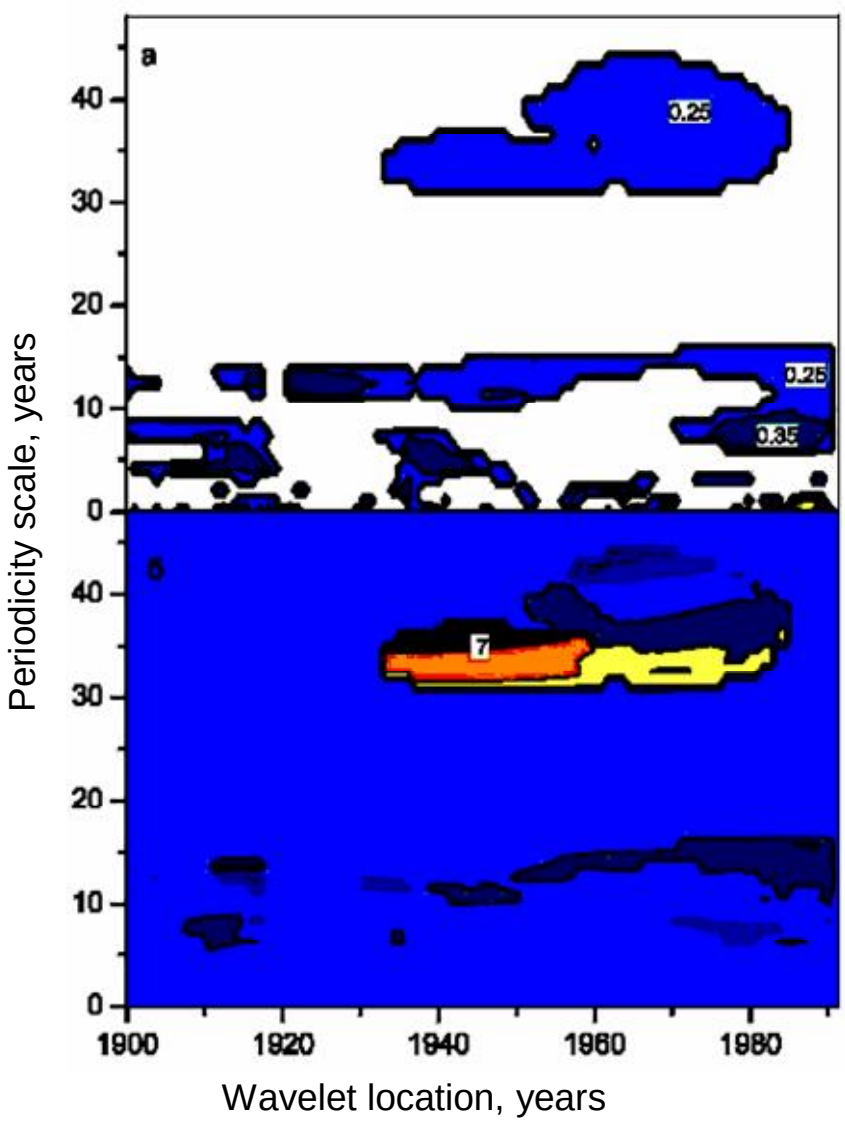

1. Significant correlation between temperature and Wolf numbers in the second half of 20$^{th}$ century for periodicities with the scales of 9 -14 years;

2. Insignificant correlation between temperature and SOI in 20 th century for the small-scale periodicities (<15 years);

3. Designated correlation between temperature and SOI in the second half of 20$^{th}$ century for periodicities of 30-year scale

Wavelet correlation between annual mean surface temperature T, Wolf numbers (a) and SOI (b)

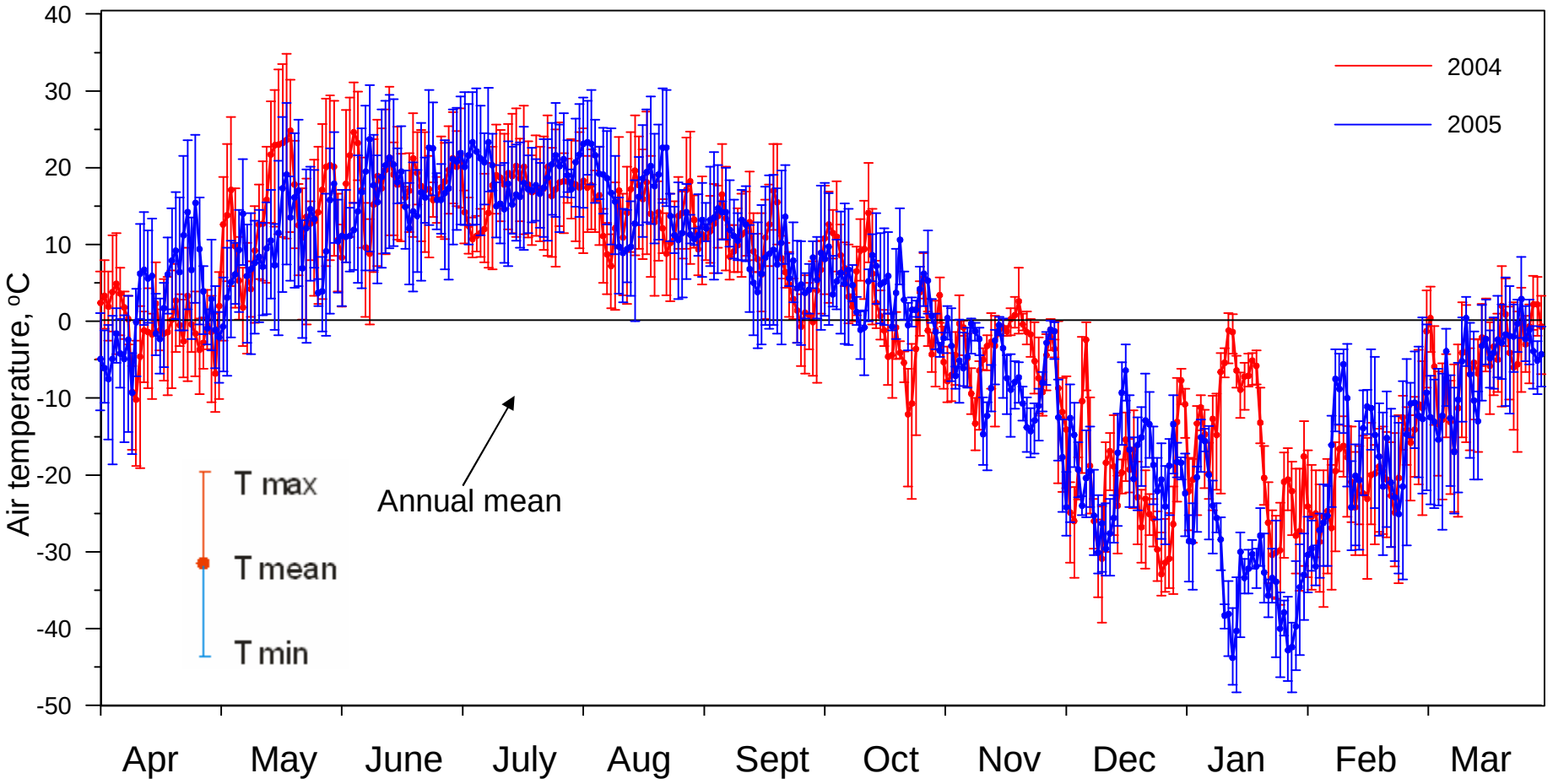
# Correlation analysis of wavelet spectra for T and NAO




1. Insignificant correlation for small-scale periodicities (<15 years);
2. Climatic phenomenon in the middle of 20$^{th}$ century: event of correlation for scale of 30-50 years;
3. Phase shift between wavelet spectra for T and NAO for climatic phenomenon

Wavelet correlation between annual mean surface temperature and North-Atlantic Oscillation (NAO)
(a) correlation coefficients (max. 0.5)
(b) Phase shifts (max. 7 years)

# Dynamics of annual variations of surface temperature (first and second moments)




Annual behavior of surface temperature (data of Bakchar weather station, 57˚05’ N, 81˚55’ E). Standard deviation of daily mean temperature is 15˚C.

## *Conclusion of section "Dynamic parameters…"*

**Weather processes are described by the functional**:

$$f(x,t) = \{f_1(x,t),\ f_2(x,t),\ldots f_k(x,t)\},$$

$f_1,\ f_2,\ldots f_k$ are functions of weather-forming processes,

$x$ are weather parameters

**Climatic processes, according to mathematical models, are described by the functional**:

$$g(x,t) = \{g_1(x,t), g_2(x,t),\ldots g_k(x,t)\},$$

$$g(x,t) = \overline{f(x,t)} \quad \text{over some period} \quad [t_1, t_2]$$

**Climatic processes, according to empirical data, are described by the functional** :

$$h(y,t) = \{h_1(y,t), h_2(y,t),\ldots h_k(y,t)\},$$

$$h(y,t) = g(\overline{x},t) \neq \overline{f(x,t)},$$

$y = \overline{x}$ is time averaged weather parameter $\tau \in [t_1, t_2]$.

**Ecosystem processes**, interactive associated with climatic ones, are now described as phenomenological (without matched dynamic parameters)

An advanced study of regional natural and climatic changes requires additional match of dynamic parameters for climatic and ecological systems.