AGU FALL MEETING 2011
SAN FRANCISCO, CALIFORNIA, USA
5-9 DECEMBER 2011

CLIMATE CHANGE IN THE RUSSIAN ALTAI MOUNTAINS AND ITS INFLUENCE ON TREE LINE AND GLACIER DYNAMICS

Margarita Syromyatina, Igor Moskalenko, Dmitry Ganushkin, Kirill Chistyakov
Saint-Petersburg State University, St.Petersburg, Russia
Margarita_soi@rambler.ru ganushkinspbgu@mail.ru

Saint-Petersburg State University

1. INTRODUCTION

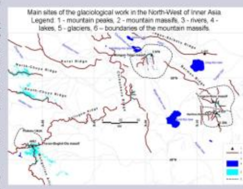
The Russian Altai Mountains are located in the Inner Asia on the border of Russia, Kazakhstan, China and Mongolia. The uniqueness of the Altai landscapes lies in their great variety as these mountains are higher than 4 km and are located on the zonal border between steppes and semi-deserts and between continental and sharply continental climates. **The main purpose** of the research was to reveal space-time features of regional climate changes and the reaction of different altitudinal zonation elements since the end of the Little Ice Age (LIA).

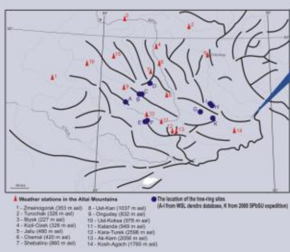
The regional climate changes are presented against the background of global climate change including the atmospheric circulation epochs. The analysis of climate change spatial patterns in the region was made. The dendrochronological analysis was employed to range the tendency of climate changes over the pre-instrumental period.

The sensivity of the Alpine landscapes to climate changes makes this research of extra relevance. It is also focuses on the climatic conditionality of the altitudinal belt spatial distribution and treeline and glacier dynamics since the end of the Little Ice Age.

2. DATA AND METHODS

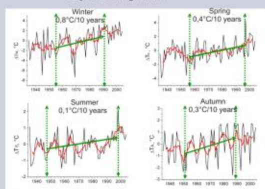
1. The 1935-2004 time series of the seasonal air temperature and precipitation from the 14 weather stations (Federal Service for Hydrometeorology and Environmental Monitoring, All Russian Research Institute of Hydrometeorological Information - World Data Center) from 300 to 2600 m a.s.l. were statistically analyzed applying regression, correlation, spectral and cluster analyses.
2. To compare regional climate change with the global changes were used:
- the air temperature time series from 1881 to 2005 (relative to a reference period 1951-1975) spatially-averaged over the 30-degree latitudinal belts of the globe (Lugina et al., 2006).
- types of the atmospheric circulation patterns (zonal and meridional) (Catalogue..., 1964).
3. To extend the time series over the past 350-400 years, mean summer temperature and precipitation were reconstructed applying dendroclimatological methods (Cook, 1985; Methods of dendrochronology, 1990) and using the WSL Dendro data base (www.wsl.ch/dendro) including tree-ring width and maximum tree-ring density.
4. Core samples and tree line position estimates received during the field expeditions.
5. Glaciation reconstruction by mapping, aerial photo and satellite imagery interpretation and also using moraine complexes locations.





3. CLIMATE CHANGE

I Anomalies of the seasonal year temperature (w.r.t. 1940-2004)



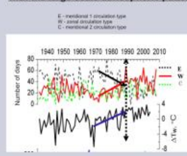
Comparing to the Northern Hemisphere the tendency of air temperature increase in the second half of the 20th century over the Altai Mountains has been observed generally earlier, since 1950s. Maximum warming rate in the last quarter of the 20th century is typical to winter in the Altai as well as in the entire Northern Hemisphere. **At the turn of the XX-XXI centuries warming rates slow down in the Altai region while the temperature level is still high.**

II Correlation analysis between seasonal air temperature variability in the Altai and in the temperate and polar latitudes and the whole Northern Hemisphere.

Latitudinal zones, °N	Season	Correlation Coefficients	
30 - 60	Winter	1955-1974	0,57
		1975-2004	0,75
	Spring	1955-1974	0,82
		1975-2004	0,69
	Summer	1955-1974	-0,19
		1975-2004	0,62
	Autumn	1955-1974	0,24
		1975-2004	0,66
60 - 90	Winter	1955-1974	0,16
		1975-2004	-0,02
	Spring	1955-1974	0,38
		1975-2004	0,42
	Summer	1955-1974	-0,24
		1975-2004	0,47
	Autumn	1955-1974	-0,07
		1975-2004	0,12
0 - 90	Winter	1955-1974	0,42
		1975-2004	0,86
	Spring	1955-1974	0,37
		1975-2004	0,57
	Summer	1955-1974	-0,29
		1975-2004	0,66
	Autumn	1955-1974	0,06
		1975-2004	0,62

There are periods of synchronous and asynchronous temperature changes in the Altai region against the background of global climate changes. **Synchronous changes in the Altai and entire Northern Hemisphere are observed in all seasons only from 1975 to 2004 years**, in the Altai and polar latitudes in spring and summer at the same period.

III Compare mean winter temperature in the Altai with the large scale atmospheric patterns

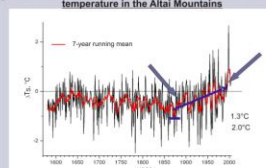


Regional climate changes are partly associated with the circulation epochs, especially in winter. For example, winter temperature intensive increase stopped in the early 1990s along with the beginning of new circulation epoch.

IV

The analysis of climate change spatial patterns showed that the most intense temperature increase during the last 20-30 years is specific to the most arid part of the region - South-Eastern Altai.

V Dendrochronological reconstruction of the mean summer temperature in the Altai Mountains



The dendrochronological analysis was employed to range the tendency of climate changes over the pre-instrumental period. According to the dendrochronological reconstruction mean summer temperature increased from the end of the Little Ice Age (LIA) to its maximum in the 1990s by approximately **2°C,** to the average for the period 1986-2004 years about **1,3°C**.
Recent fast warming especially from the mid-1980s in the Altai Mountains is non-exclusive. The similar abrupt increase of mean summer temperature was observed, for example, in the second half of the 19th century.

4. ALPINE LANDSCAPE RESPONSE

VI Altitudinal hydrothermal gradients and climatic area of the altitudinal vegetation belts

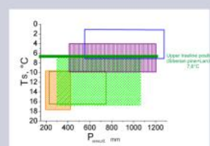
Mean summer temperature vertical gradients:
Central Altai 0,5 - 0,6°C/100 m
North Altai 0,6°C/100 m
South-Eastern Altai 0,80-0,82°C/100 m

Annual precipitation vertical gradients:
from 20-40 mm/100 m to 150-200 mm/100 m in the different localities of the Altai Mountains

Vertical hydrothermal gradients were employed to characterize each altitudinal belt in different geobotanical provinces of the Altai Mountains (Central Altai, North-Eastern Altai, North-Western Altai, North Altai and South-Eastern Altai) by the climatic area of distribution.

Altitudinal vegetation belts in the Altai Mountains

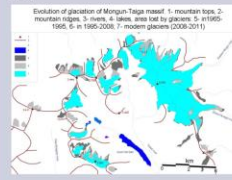
The example of the climatic area of the altitudinal belt distribution (Central Altai). Each belt is characterized by the range of mean summer temperature and annual precipitation.



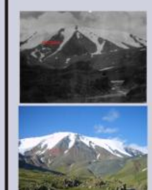
VII Upper treeline dynamics

As treeline against the other belt borders strongly limited by summer temperature (7,5-9,0°C), its eventual dynamics since the end of the Little Ice Age over the Altai Mountains were estimated using the altitudinal temperature gradients, weather station data and dendrochronological mean summer temperature reconstruction.
Theoretical evaluation shows that mean summer temperature increase of 1.3°C from the end of the LIA (1860-1880 yrs) to the period of 1986-2004 yrs causes **treeline to rise maximum by 180-280 m** in different localities of the Altai Mountains. Received estimations on the whole are confirmed by the field data.

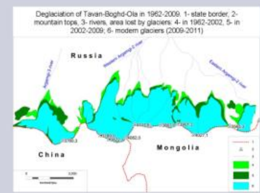
VIII Glacier dynamics



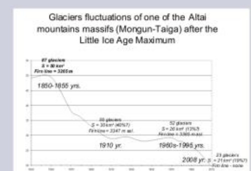
North-West Inner Asia is a mountainous area at the intersection of Altai, Sayan, Mongolian Altai and Tannu-Ola mountain ridges. Glacial complexes of mountain massifs Mongun-Taiga (20.3 km^2), Tavan-Boghd-Ola (21.2 km^2), Turgeni-Nuru (42.8 km^2) and Harhira-Nuru (33.1 km^2) are represented by small glaciers mostly on northern and eastern leeward slopes. Being situated in region with dry climatic conditions (annual precipitation in the alpine zone is 250-400 mm) glaciers survive only in negative forms of relief with high concentration of snow. Accumulation coefficient is mainly from 2 to 3, and on cirque glaciers is from 6 to 8. Now glaciers retreat rapidly (17% of area loss for the period of 1995-2010 for Mongun-Taiga, 12% in 2002-2009 for Tavan-Boghd-Ola), especially valley glaciers (2-10 m/year), the number of glaciers increase due to disintegration of larger glaciers. Small forms of glaciation disappear or transform into snow patches and rock glaciers. The cause of changes is not only warming, but also increasing dryness.



Degradation of small glaciers of the north-eastern slope of Mongun-Taiga massif in the period from 1994 (top photo) till 2011 (bottom photo). Red arrow shoes part of the glacier which separated from the main body and became debris-covered.



Left Mugur valley glacier (Mongun Taiga massif in 1974 (above) and 2011. Arrows show the same point in 1994 and 2011.



Using location of the moraine complexes, air photo interpretation the glaciation area dynamics of the massif after the Little Ice Age maximum (LIAM) were reconstructed. At LIAM there were 87 glaciers in area of appr. 50 km2. Deglaciation after the LIAM consists of several stages. Very fast glacier reduction during the period from 1850 yrs to the 1910-1925 yrs. To this time the total amount of glaciers decreased to 55 with area of 30 km2. At this stage glaciation degradation appeared in the breakdown of valley glaciers and disappearance of small corrie and corrie-hanging glaciers.
The period from the end of 1920s to the end of 1960s is marked by relative stability of glaciers. The next degradation stage was at the end of 1960s – 1995 when the total glaciers area dropped by 13%, generally due to the reduction of slope glaciers and also corrie-valley glaciers generally through the breakdown on the glaciers of other morphological type.
The last stage of deglaciation from 1995 to 2008 is characterized by very fast degradation, the area just in 13 years decrease by 19%, moreover as against the earlier stages considerably reduced valley glaciers, that appeared in their breakdown. The remarkable fact is almost complete disappearance of the neve line during the last 3 years due to the low winter precipitation.