UDC 551

Modern Climate Change and Mountain Skiing Tourism: the Alps and the Caucasus

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ABSTRACT. Relevance of the research of modern climate change is beyond all doubts at the moment. Climate is, first of all, a significant share of any country's resources. Losses due to global climate change can affect virtually all branches of economy and social aspects, including energy production, eco-systems, agriculture, forests, construction, transport, tourism etc.

Climate change imposes certain mode of economy, a strategy of economy's development years ahead. According to forecasts, for example the one of European environmental agency (EEA), one of the first "hostages" of climate change will be winter tourism and alpine skiing resorts. Climate change seriously influences incomes of countries and certain regions located in mountain areas and developing winter sports.

Yet, forecasts of climatologists on modern climate change trends are ambiguous and sometimes controversial. For this reason definite scientific and practical interest is raised by research in climate change trends in mountain areas based on mostly state network of meteorological stations.

Keywords: the modern climate change; tourist destinations; ski resorts; linear trends; statistical characteristics; adaptation; the impact of climate change on tourism and sustainable development of mountain tourism clusters; Winter Olympic Games.

1. INTRODUCTION. Europe as a whole is a recognized leader in world tourism. Particular place among the most well-known mountain climatic resorts and centers for winter sports is occupied by European resorts in the Alps. Today this region is an attraction for almost 15 % of the world's tourist flow of both recreational and excursion-learning features.

This region accounts for over 70 % of the world's tourist market and around 60 % of income. Almost 20 % stand for America, less than 10 % - for Asia, Africa and Australia. According to UNWTO forecasts (World Tourist Organization, http://www.unwto.org) in the nearest decades trends of tourism growth will remain stable, and by 2020 a number of international tourist arrivals should grow 2.2 times in comparison with 2000 (from 698 mln to 1,561 mln trips). Tourism is to generate income 4.2 times more: from 476 bln to 2 trln USD. As the dynamics of development of tourism depends on combination of various climatic, environmental, economic, political, institutional, social and technological processes going on in the world, research in regional climate change is an up-to-date issue for the development of world tourism as a whole and winter tourism in particular [1-11].

While the Alps are internationally recognized trend makers in winter sports and winter tourism, the western part of the Caucasus is quite young but rapidly developing region for winter sports, tourism and vacation [12, 13].

2. Influence of modern climate change on condition and development of winter sports and tourism

2.1. What is going on with mountain skiing tourism in the Alps?

To the opinion of climatologists of Oxford University which was sounded 10 years ago, the most popular alpine skiing destinations of Europe in the nearest decade might cease to exist. Global warming will lead to shrinking in a number of snowfall in the Alps and a tourist flow to this region can go down [14, 15]. A crisis of alpine skiing will first of all strike low-mountain regions of the Alps in Italy, Austria and Germany at elevations up to 1000 meters. In the course of time even more highland resorts of France will feel warmer climate and that will lead to deflux of tourists from the Alps to the North and to the East, for example to Norway or Slovakia. According to climatologists' forecasts, in 30 years time 50 of the resorts at elevations 1000-1300 meters will not see regular snowfall.

At first, such regional climate change can be struggled with by equipping mountain skiing resorts with snow-making facilities on the pastes. But that will only increase price of vacation in alpine resorts being one of the most expensive in Europe. It is possible that within 2-3 decades alpine resorts of Austria at elevations up to 1300 meters will have to be closed because of lack of snow. Climate change will seriously affect incomes of alpine countries generated by skiing tourism. Switzerland and Austria get 80% of their tourism-generated income during winter season. In comparison with Germany and Italy, which can compensate losses due to development of tourism in other regions, Switzerland and Austria might lose 7-10 bln USD of income by 2030.

French alpine skiing resorts also suffer from rise of temperature. Because of melting of snow winter sports will soon be unavailable in resorts located below 1200 meters. If the average yearly temperature rises by 2 degrees Centigrade, then out of 35 resorts in alpine region of Haute-Savoie there will be only 18 left.

Thus according to the forecast of leading climatologists which were sounded about 10 years ago, global climate change will significantly affect tourism development in Europe. These forecasts are likely to become true. Climate change is subject to influence financing of tourist markets. Investors re-assess companies, including touristic ones, activity of which is risky because of global climate change. Losses of European countries due to climate change are growing. Yet the most unpleasant things are ahead – adaptation to new weather and climatic conditions may require deep renovation of whole branches of the European economy [16-18].

Solid climatic information on vulnerable touristic destinations including alpine mountain resorts, mountain skiing and winter sports centers is vital for their sustainable development.

2.2 Adaptation measures for mitigation of negative effect of climate warming in Europe onto mountain skiing resorts.

One of the most well-known and generally accepted adaptation measure which is used in many mountain skiing resorts to solve the issue of changing snow covers is snow-making. This method requires balance from the standpoint of environmental effect as it consumes a large amount of water.

Extract of water from rivers and lakes for snow-making may decrease level of water during peak times and this can influence not only human demands in water but also fish and other water inhabitants. The forecasted climate warming in the future can lead to an increase in demand for snow-making, and in this connection mountain skiing destinations will be hard to earn their living.

One of activities allowing to increase sustainability of mountain skiing destinations is construction of special reservoirs which accumulate water in spring and in autumn to use it in winter.

Using climatic information, different climatic models and scenarios of global, regional and local climate change to increase sustainability of mountain skiing destinations is of extremely high practical significance.

For example, for successful XXII Olympic and XI Paralympic winter games "Sochi 2014" the mountain Olympic cluster (Krasnaya Polyana) accommodates several mountain reservoirs and has 45 snow-making facilities installed (www.olimpstroy.com).

2.3 Raising sustainability of touristic activities based on weather and climate information.

Reliable climatic information is essential for other adaptation technologies allowing for increase of sustainability of mountain skiing resorts and centers of winter sports in modern climate change environment.

Touristic sector interacts with climatic society, for example by means of UNWTO service (World Tourism Organization, www.unwto.org) for climate and tourism information exchange. A group of experts of the World Meteorological Organization (WMO) in climate in tourism examines effect of alterability and climate change onto tourism. It forges the development and usage of precise information on weather and climate to increase sustainability of tourism throughout the world.

A website of WMO "Serving world weather information" located and serviced in the Hong-Kong observatory (www.hko.gov.hk/content.html) offers to the global community and media an online access to the latest official weather forecasts and climatic information for more than 1200 cities in the world which is provided by meteo and hydrological services all over the globe. When possible, links to related official websites of meteorological services and touristic organizations are provided. Starting from 2008 this website was translated into 6 languages including English, Arabic, Spanish, Chinese, Portugal and French.

Another adaptation measure to preserve and develop mountain climatic touristic destinations is creation of new resort areas in the regions having less distinct trends of climate change than in the Alps or having opposite direction of these changes.

One of prerequisites for the development of existing and creation of new mountain climatic resorts are, of course, Olympic Winter Games. But it is important to mention that socio-political, economic, demographic environment in certain countries and regions can also be a factor adding to the development of alpine climatic resorts and mountain skiing centers.

XXII Olympic and XI Paralympic Winter Games "Sochi 2014" have become a catalyst for the development of Greater Sochi as the mountain climatic resort of a world class. In order to solve a range of socio-political, economic and demographic issues of the North-Caucasus Federal district a Federal Target Program (FTP) "Development of the North Caucasus resorts" was set up. The FTP envisages creation of 7 new mountain climatic resorts in the Russian territory of the Western Caucasus: **Lagonaki** (Krasnodar Krai and Adygeya republic); **Arkhyz** (Karacheavo-Cherkessian republic, Zelenchuk district); **Elbrus-Bezengi** (Kabardino-Balkar republic, Chegem and Elbrus districts); **Mamison** (North Ossetia-Alania republic, Alagir and Iraf districts); **Matlas** (Dagestan republic, Khunzakh district); **Armkhi** (Ingushetiya republic, Dzheyrakh district); **Tsori** (Ingushetiya republic, Dzheyrakh and Sunzha districts).

Making of such decisions is preceded by scientific research of not only modern environment but also of possible regional climate change.

3. Assessment of modern climate and inertial forecast of regional climate change trends for tourist *mountain s*kiing destinations

3.1 Meteo databases and research methods

It is widely known that full research of climate features includes assessment of various climatic factors (air temperature, precipitation, air pressure, clouds etc) and of their possible changes. But when exploring climate change (global, regional and local) the majority of authors restrict themselves with researches in average monthly air temperatures fluctuations only.

In order to provide comparative evaluation of climate of the main mountain climatic resorts of the Alps and the Caucasus we used special databases for average monthly temperatures (T^0C) which were created according to the data from 19 meteorological stations of the Alps and the Western Caucasus since the time of their foundation until 2008-2010 including cold months (November-March) as well. Ranges of meteo data from the following cities were used for comparative analysis: Georgia (Tbilisi), Peoples' Democratic Republic of Korea (Mokpo), the Korean republic (Incheon), Turkey (Sarykamysh, Erzurum) and Japan (Tokio and Sapporo) (Table 1).

When choosing meteorological stations data of which to use, the following factors were taken into consideration in the present survey:

- geographical coordinates at a latitude 43-47 degrees North (meteo-stations of the Alps and Russia's Western Caucasus);
- a period of registered meteorological exploration of not less than 50 years;

- location of a meteo-station in proximity (not exceeding 100 km) to mountain resorts and centers of winter sports (alpine skiing, slalom, snowboarding, biathlon etc).

№	Station name	Country	Geographical coordinates		Elevation,	Period of registered observations, years
			Latitude	Longitude		
1	Kislovodsk	Russia	43°55' N	42°43' E	840 m	1940-2010
2	Klukhorskyp erev	Russia	43°14' N	41°51' E	2781 m	1959-2010
3	Krasnaya Polyana	Russia	43°41' N	40°12' E	538 m	1961-2010
4	Sochi	Russia	43°35' N	39°43' E	14 m	1871-2010
5	Geneva	Switzerland	46°12' N	6°09' E	385 m	1753-2009
6	Lugano	Switzerland	46°00' N	8°57' E	372 m	1949-2009
7	Säntis	Switzerland	47°14' N	9°20' E	2502 m	1883-2009
8	Zurich	Switzerland	47°22' N	8°33' E	411 m	1864-2009
9	Innsbruck	Austria	47°16' N	11°23' E	574 m	1952-2009
10	Salzburg	Austria	47°48' N	13°02' E	424 m	1951-2009
11	Tarvisio	Italy	46°30' N	13°34' E	754 m	1951-1980*
12	Sarikamiş	Turkey	40°20' N	42°34' E	2074 m	1929-2009
13	Erzurum	Turkey	39°54' N	41°16' E	1939 m	1929-2009
14	Tbilisi	Georgia	41°43' N	44°47' E	415 m	1845-1991*
15	Tokyo	Japan	35°41' N	139°41' E	19 m	1776-2000
16	Sapporo	Japan	43°04' N	141°21' E	26 m	1889-2000
17	Mokpo	RepublicofKor	34°45' N	126°22' E	10 m	1905-2000
18	Incheon	RepublicofKor	37°29' N	126°38' E	8 m	1905-2000

*-closed

Table 1: List of meteorological stations information from which was used in the present study

8 meteorological stations (42%) have a range of observations of average monthly air temperature and average monthly precipitation for more than 100 years (Incheon, Mokpo, Santis, Tbilisi, Tokio, Sapporo, Sochi, Zurich). The longest range of registered observations is in Geneva, Switzerland – 257 years.

When creating a database of average monthly air temperature and average monthly precipitation according to meteorological stations next mountain climatic resorts (for registered observations) we used open information of domestic meteorological centers, of the World database center as well as well-known foreign meteorological centers. For example, data from Global historical climatological network (GHCN) database was obtained with the help of search engine of the Royal Meteorological Institute (the Netherlands) which is also open for public (http://kodac.knmi.nl/kodac/). The research used arrays of meteorological observations (stations) or their segments not shorter than 50 years and having a minimal number of gaps. The analysis included data for all 'cold' months (November-March) – a high season and the most favorable time for winter sports and vacation [19, 20].

First of all main statistic features of time arrays were calculated, diagrams of actual and theoretic distribution of meteorological indices were built, allowances for the main statistic features were envisaged. To find out a presence of positive or negative trend in yearly change in average monthly air temperature and precipitation sums, special linear trends were calculated (T) for stations with observations exceeding 50 years

$T = aX_i + b$ (1);

where X_i – year (i – from 1 to N, N - index of temporal array of meteorological figure);

where a и b – coefficients of regression equation.

As a result of study carried out, it was defined that according to the data of meteorological stations located in extreme proximity to alpine mountain resorts, significant climate changes do take place.

Thus, for example, a meteo-station "Geneva" (Switzerland) has registered observations from 1753. It is one of the most long-range meteorological stations in Europe. The main feature for all cold months (November-March) is a positive trend of movement in average monthly air temperatures (fig.1-5).

Correlation coefficients are, as a rule, positive and are subject to change depending on season within ∓ **|0,5|**. Student Criterion was used to assess reliability of acquired interdependencies. It turned out that reliable possibility of obtained interdependencies is at 90% and higher that evidences of relatively high sustainability of the explored trends.

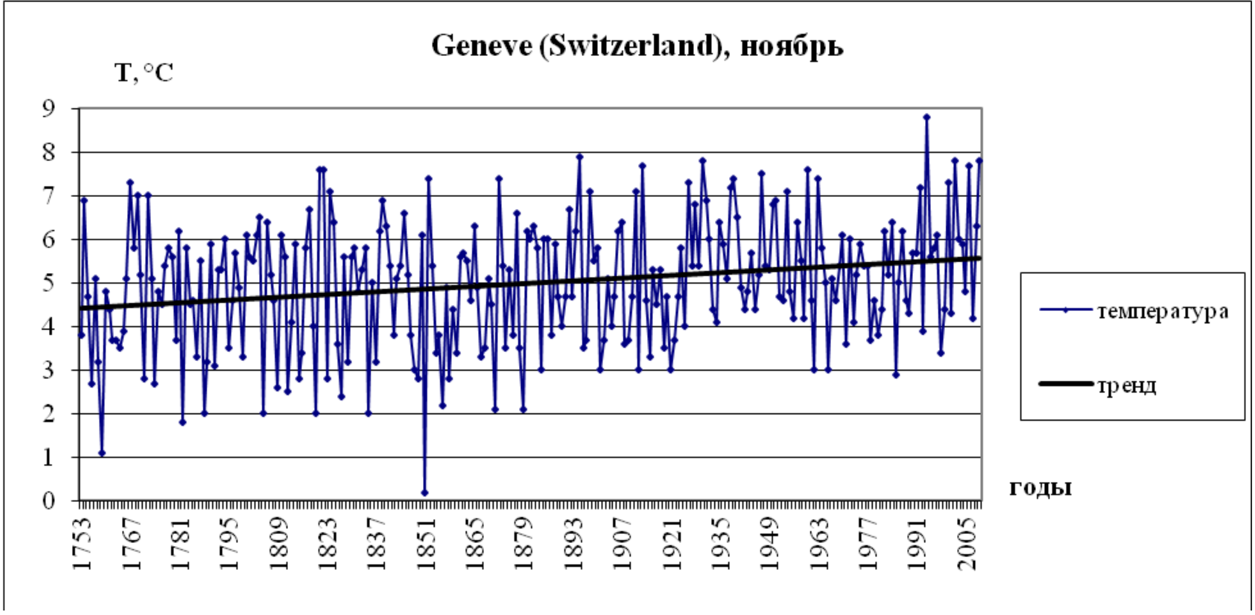


Fig. 1: Timely long-term fluctuations in average monthly air temperature and linear trend for November at meteorological station "Geneva". Student Criterion = 3,661

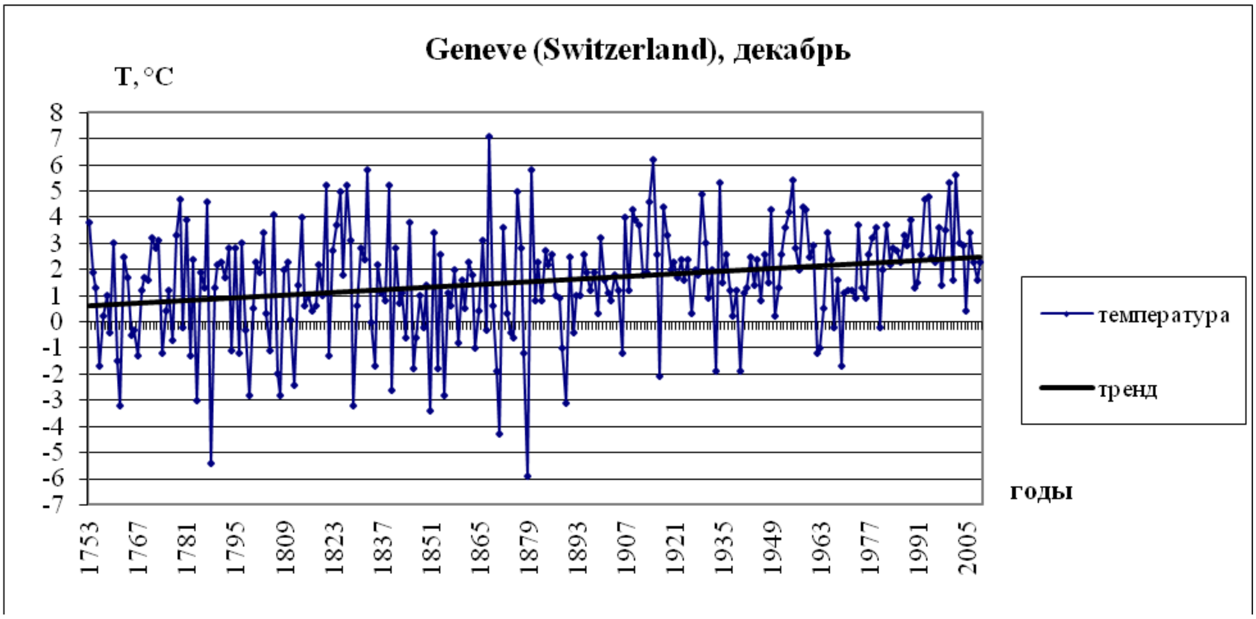


Fig. 2: Timely long-term fluctuations in average monthly air temperature and linear trend for December at meteorological station "Geneva". Student Criterion = 4,163

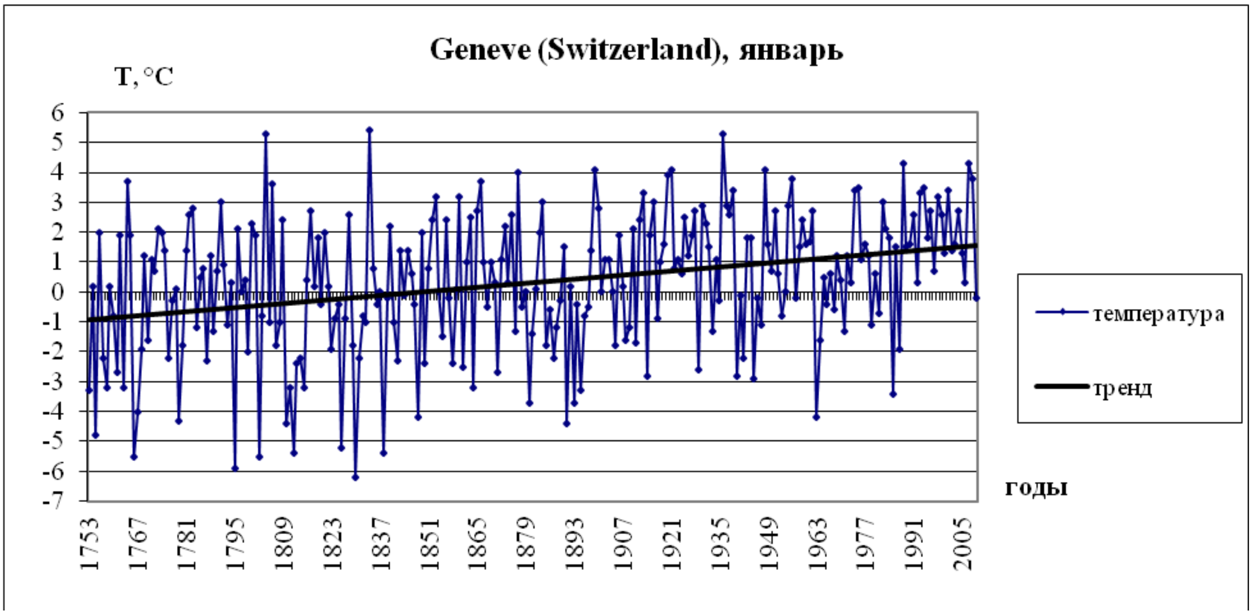


Fig. 3: Timely long-term fluctuations in average monthly air temperature and linear trend for January at meteorological station "Geneva". Student Criterion = 5,257

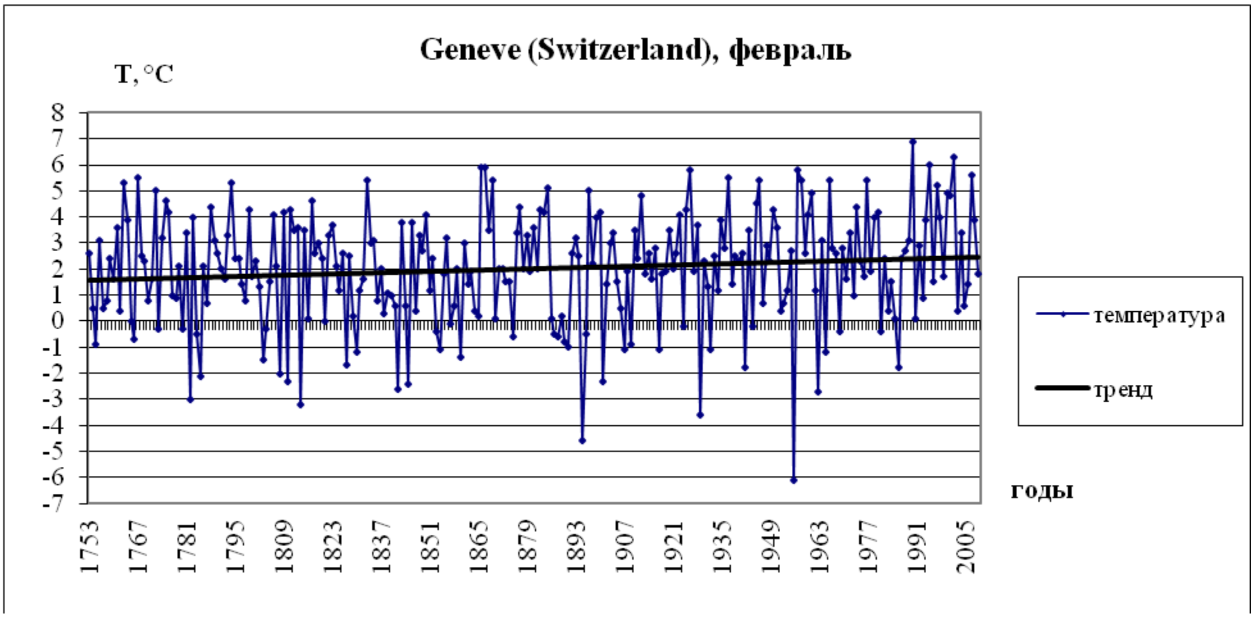


Fig. 4: Timely long-term fluctuations in average monthly air temperature and linear trend for February at meteorological station "Geneva". Student Criterion = 1,938

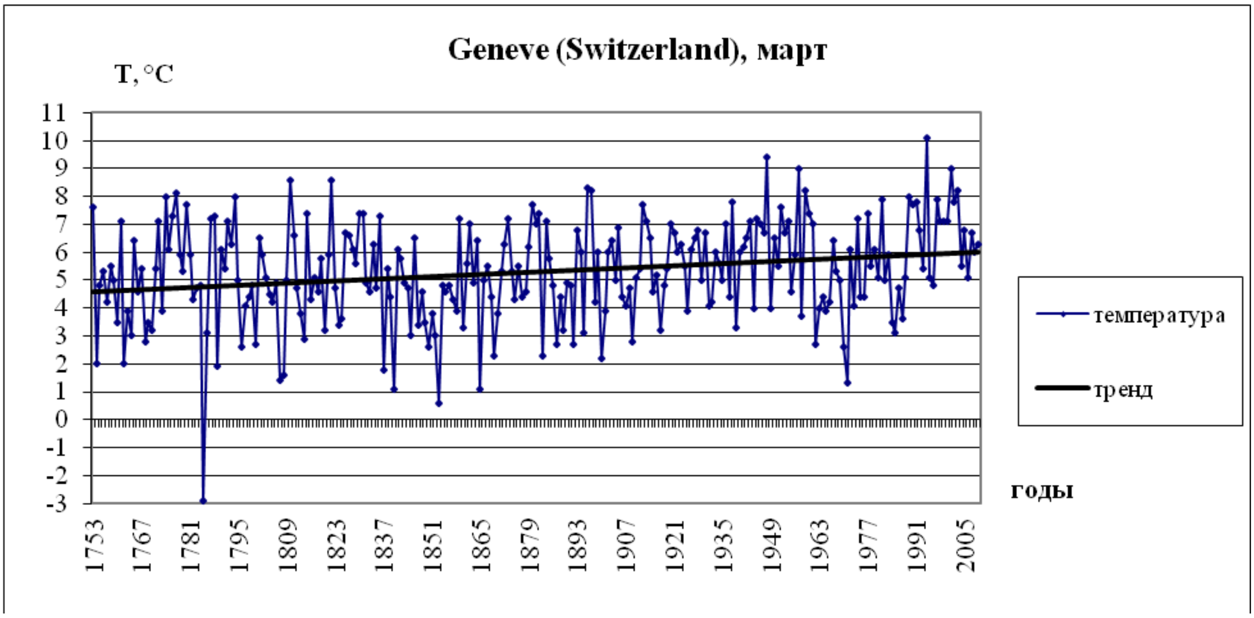


Fig. 5: Timely long-term fluctuations in average monthly air temperature and linear trend for March at meteorological station “Geneva”. Student Criterion = 3,809

Similar temporal step of average monthly air temperature within the reviewed months was also observed at a majority of meteorological stations (69%).

But alongside with the majority of meteorological stations which showed positive linear trend in yearly progress of average monthly air temperature there were also stations with a reverse progress of temporal step, correlation coefficients and Student criteria of 0. Negative linear trends in yearly progress of average monthly air temperature were noticed, for instance, in stations “Krasnaya Polyana”, “Klukhorskiy passage”, “Erzurum” in December (table 2), January (table 3) and February (table 4) except for “Krasnaya Polyana” in January. It is obvious that with almost equal conditions (coordinates, mountain relief) such a fact can be explained by such a climate-forming factor as atmosphere circulation and requires special research.

A peculiarity of data from meteorological stations is a presence of a negative coefficient of asymmetry (<0) at Klukhorskiy passage meteorological station and a positive one at Krasnaya Polyana, that shows, in the first case, a so-called “right deviation” of actual distribution and, in the second case, a “left deviation”. It is proved by charts in graph 6.

From a geographical point of view meteorological station “Klukhorskiy passage” (Russia) and “Erzurum” (Turkey) are 800 km from each other while the distance between Klukhorskiy passage” (Western Caucasus) and Krasnaya Polyana (Western Caucasus) does not exceed 350 km. Yet the former 2 stations have almost 100% coincidence in statistical characteristics of temporal arrays (table 2.4).

Statistics	Saentis, Switzerland	Salzburg, Austria	Krasnaya Polyana, Russia	Kluhorskiy Pereval, Russia	Erzurum, Turkey	Inchon, Korea	Sapporo, Japan
Sample size, years, N	126	57	50	50	78	84	102
Correlation coefficient (R)	0,2540	0,1074	-0,1042	-0,2784	-0,1058	0,3148	0,5772
Student's test	**2,9247**	0,8015	-0,7151	**-1,9871**	-0,9279	**3,0035**	**7,069**
The average long-term,(T℃)	-7,1	-0,2	2,2	-3,1	-5,49	-0,4	7,4
The mean square deviation	1,98	2,21	1,77	2,10	3,04	2,11	0,88
Dispersion (σ^2)	3,93	4,90	3,13	4,40	9,26	4,40	0,77
Coefficient of	0,50	0,45	0,57	0,48	0,33	-5,5	0,12

variation (C_v)							
Mode (M_o)	-0,37	0,31	-1,03	-0,71	-0,56	1,4	7,1
Median (Me)	0,02	-0,52	0,18	-0,15	-0,42	-0,5	7,4
Coefficient of skewness (Cs)	-7,9	1,8	0,3	-4,3	-7,40	0,01	-0,15
Coefficient of curtosis (C_ε)	-7,0	-0,1	2,1	-3,0	-5,15	-0,15	0,61
Maximum (T°C)	-2,2	4,2	5,6	1,0	-0,70	4,8	10,1
Minimum (T°C)	-12,3	-6,5	-1,2	-7,4	-12,90	-5	5
Amplitude	10,1	10,7	6,8	8,4	12,20	9,8	5,1

Table 2: The main statistical characteristics of time series of average monthly air temperature (T°C) at meteorological stations in well-known mountain ski resorts. Desember

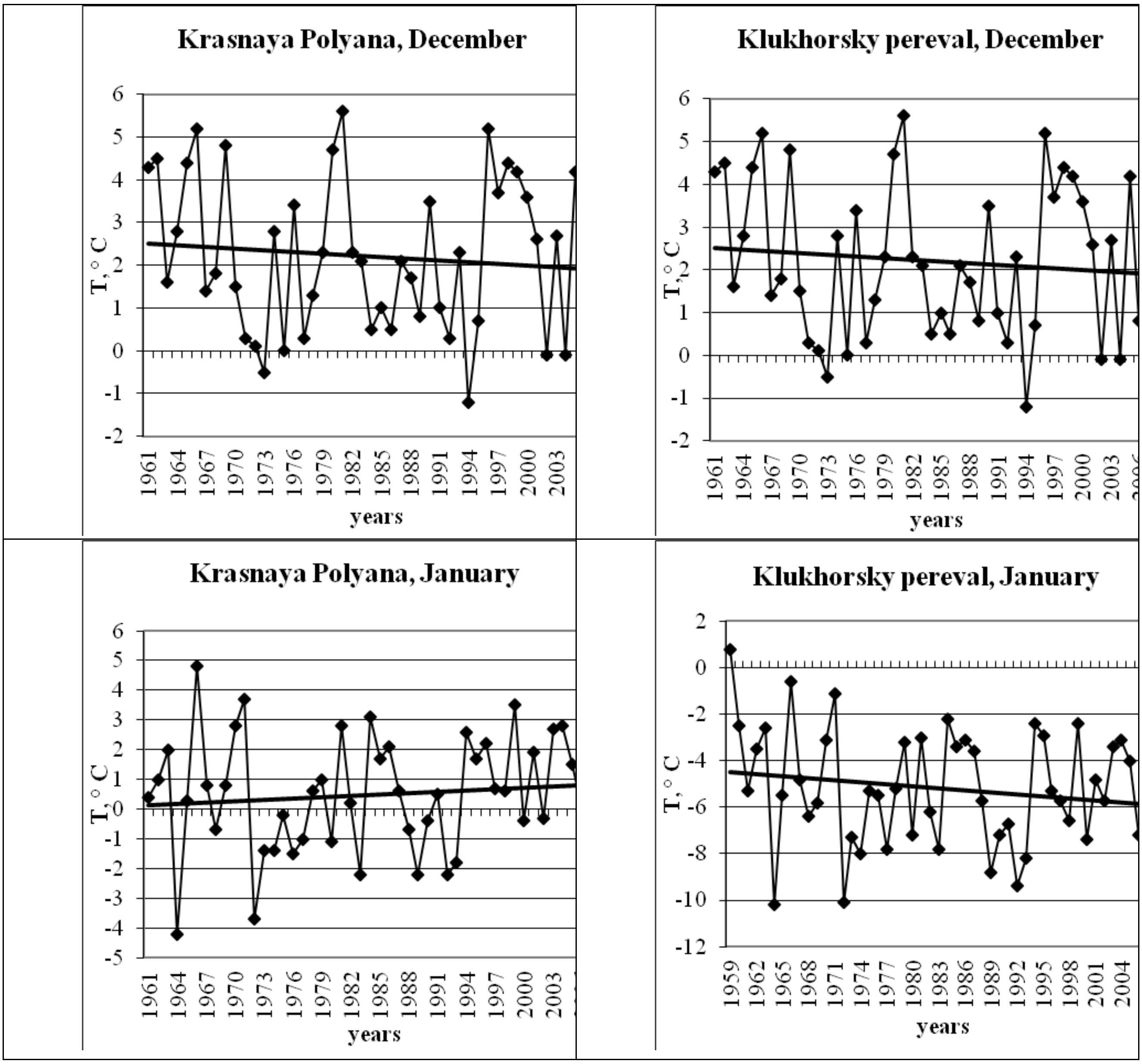
Statistics	Saentis, Switzerland	Salzburg, Austria	Krasnaya Polyana, Russia	Kluhorskiy Pereval, Russia	Erzurum, Turkey	Inchon, Korea	Sapporo, Japan
Sample size, years, N	127	58	50	50	78	84	102
Correlation coefficient (R)	0,269	0,212	0,111	-0,168	-0,214	0,053	0,450
Student's test	**3,1227**	**1,623**	0,762	-1,185	**-1,910**	0,481	**5,041**
The average long-term, (T°C)	-8,2	-1,4	0,5	-5,2	-9,08	-3,7	-5,6
The mean square deviation	2,32	2,49	1,94	2,56	3,38	2,13	1,72
Dispersion (σ^2)	5,39	6,20	3,75	6,53	11,44	4,48	2,94
Coefficient of variation (C_v)	0,43	0,40	0,52	0,39	0,30	-0,573	-0,31
Mode (M_o)	0,22	0,12	-0,14	-0,41	0,24	-3,8	-5,4
Median (Me)	-0,06	-0,13	-0,16	-0,06	0,05	-3,8	-5,5
Coefficient of skewness (Cs)	-7,9	-2,3	1	-5,3	-5,60	0,08	0,01
Coefficient of curtosis (C_ε)	-8,2	-1,4	0,6	-5,3	-8,80	0,15	-0,12
Maximum (T°C)	-1,8	4,3	4,8	0,8	0,00	1,1	-1,9
Minimum (T°C)	-14,3	-7,5	-4,2	-10,2	-16,90	-9	-10,2
Amplitude	12,5	11,8	9,0	11,0	16,90	10,1	8,3

Table 3: The main statistical characteristics of time series of average monthly air temperature (T °C) at meteorological stations in well-known mountain ski resorts. January

Statistics	Saentis, Switzerland	Salzburg, Austria	Krasnaya Polyana, Russia	Kluhorskiy Pereval, Russia	Erzurum, Turkey	Inchon, Korea	Sapporo, Japan
Sample size, years, N	127	59	48	49	78	80	102
Correlation coefficient (R)	0,155	0,244	-0,1708	-0,1686	-0,2158	0,237	0,413
Student's test	**1,761**	**1,897**	-1,175	-1,173	**-1,927**	**2,158**	**4,537**
The average long-term, (T°C)	-8,4	0,1	1,5	-4,9	-7,54	-1,7	-4,8
The mean square deviation	2,54	3,31	1,77	2,27	3,16	1,69	1,50

Dispersion (σ^2)	6,47	10,94	3,14	5,17	10,01	2,81	2,25
Coefficient of variation (C_v)	0,39	0,30	0,56	0,44	0,32	-0,99	-0,31
Mode (M_o)	0,45	1,30	-0,10	-0,49	-0,39	-3,0	-5,4
Median (Me)	-0,40	-0,69	-0,24	-0,19	-0,31	-1,9	-4,9
Coefficient of skewness (Cs)	-9,6	1,5	2,4	-4,4	-8,10	0,38	0,31
Coefficient of curtosis (C_ε)	-8,4	0,0	1,6	-4,5	-7,60	-0,82	-0,10
Maximum (T°C)	-2,3	5,9	5,1	-0,2	-0,80	2,2	-0,7
Minimum (T°C)	-17,2	-11,1	-2,9	-9,6	-15,10	-4,6	-7,9
Amplitude	14,9	17,0	8,0	9,4	14,30	6,8	7,2

Table 4: The main statistical characteristics of time series of average monthly air temperature (T °C) at meteorological stations in well-known mountain ski resorts. February



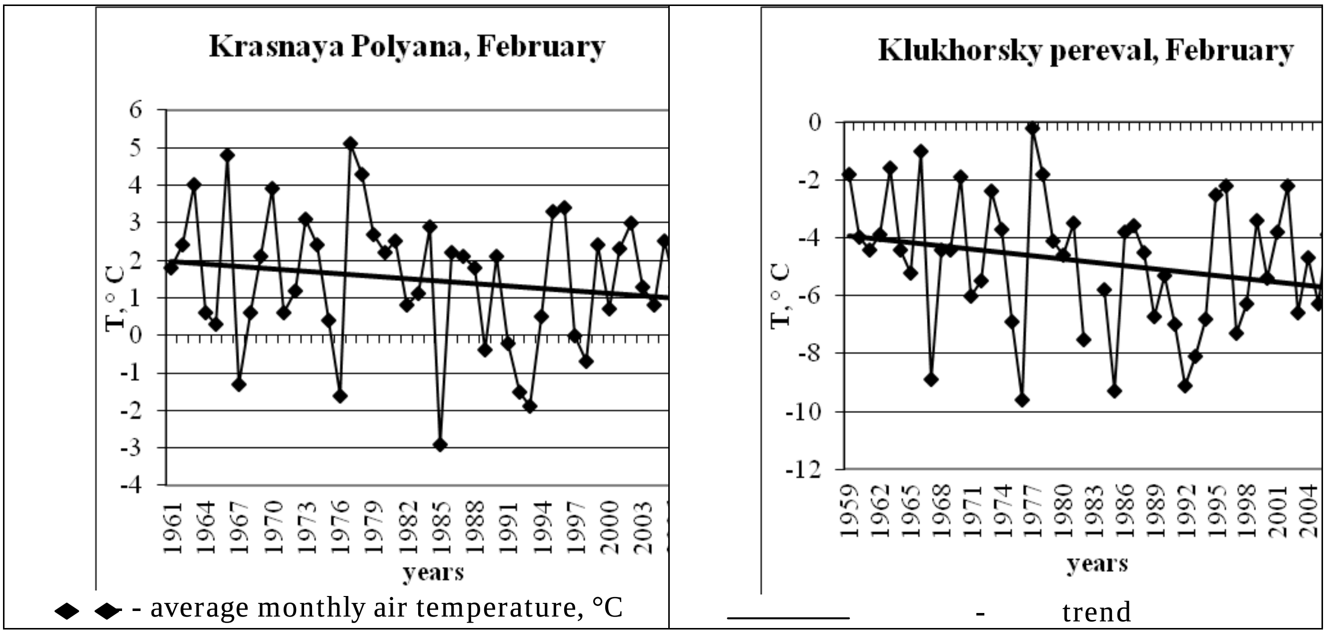


Fig. 5: Yearly progress of average monthly air temperature and linear trend for winter months (December-February) at meteorological stations Krasnaya Polyana and Klukhorskiy passage

Charts of distribution curves were built in order to compare selected actual distribution and theoretical normal distribution of meteorological figures for all stations and surveyed months (fig.6). The number of gradations was defined according to Sturgess rule:

$$K= 1+3,32\lg N \quad (2);$$

where N – size of sample, length of an array; K - number of gradations.

The largest correspondence of curves of selective actual and theoretical normal distribution was obtained according to samples from the longest in arrays station “Geneva” (257 years).

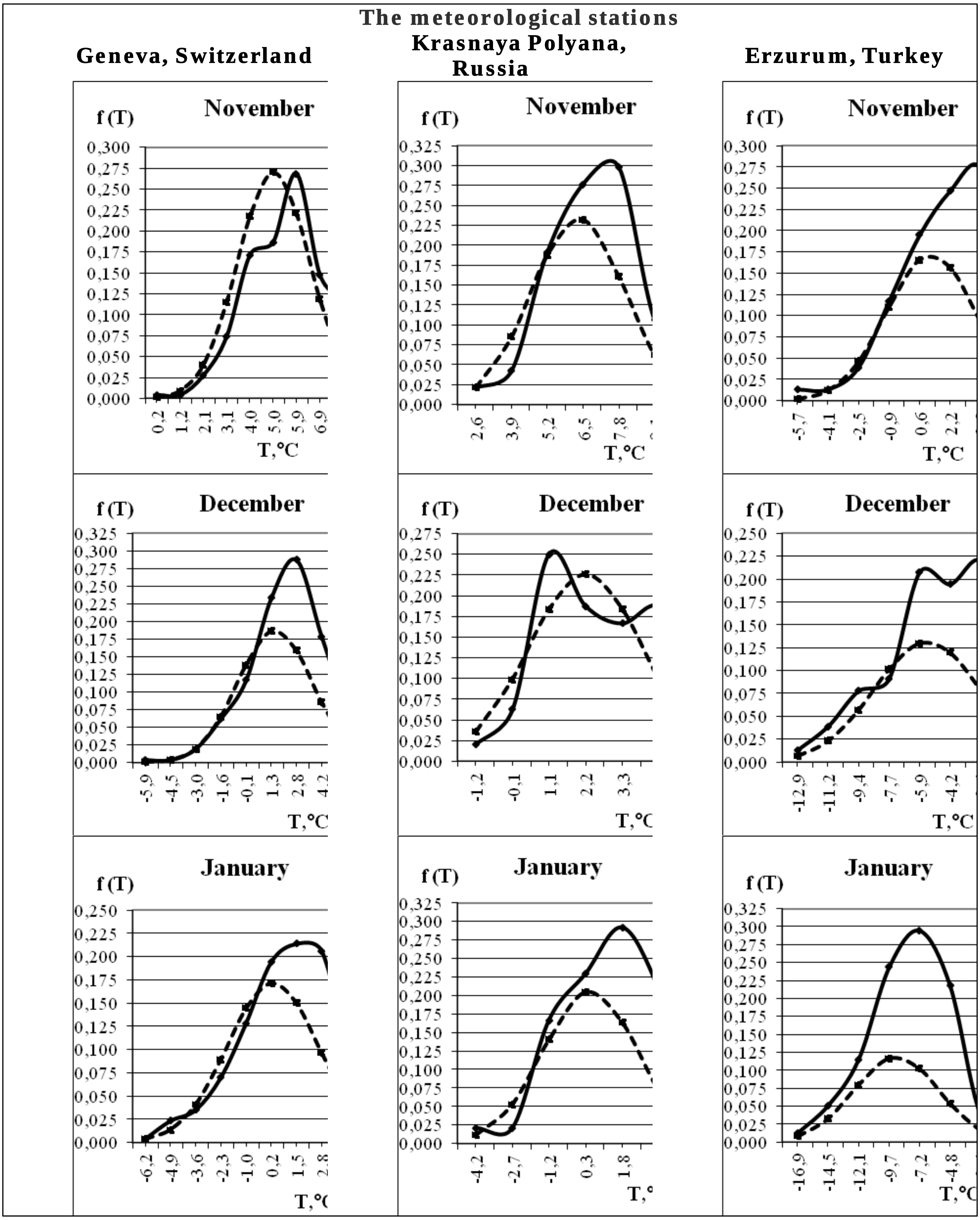
Main statistical characteristics of selective temporal array of an average monthly air temperature in December, for example, have the following values: average yearly for $(T^{\circ}C)$ = $1,5^{0}$C; Student criterion = 4,162; “**a”** coefficient in linear regression equation (1) = 0,252; mediana $=1,7^{0}$C (almost equal to a value of average yearly); asymmetry coefficient = -0,47 (deviated right-side distribution showing the prevalence of relatively significant (in absolute values) positive deviations from the trend); excess coefficient = 0,54 (showing an insignificant peak distribution of a sampling); amplitude is 13^{0}C. Thus it can rightly be said that a degree of coincidence of selected actual and theoretical normal distribution is quite high.

While “Krasnaya Polyana” (50 years) and “Erzurum” (78 years) show serious divergence and deviations of selected and theoretical distribution of the reviewed meteorological values

3.2. ***Comparison with other mountain skiing regions***

Comparison of results for main mountain skiing resorts of the Alps and Western Caucasus and other alpine skiing resorts located within 37 and 47 degrees of northern latitude is of particular interest. Namely – one of the main climate-forming factors – geographical latitude is conventionally permanent.

Meteorological station “Tbilisi” (Georgia) has had registered observations since 1844. Unfortunately this station was closed down in 1990. But it is still of high interest for exploration of climatic change trend of this region. As calculations have shown this region has witnessed stable temperature increase within the last 150 years. Average monthly air temperature in January during the period of registered observations has grown by 2 degrees, Student criterion made 3,567. Consequently, we can speak of stable and steady warming of regional climate.


The meteorological stations
Geneva, Switzerland
Krasnaya Polyana, Russia
Erzurum, Turkey
f (T)
November
0,300
0,275
0,250
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0,200
0,175
0,150
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T,°C
f (T)
December
0,275
0,250
0,225
0,200
0,175
0,150
0,125
0,100
0,075
0,050
0,025
0,000
-1,2
-0,1
1,1
2,2
3,3
T,°C
f (T)
December
0,250
0,225
0,200
0,175
0,150
0,125
0,100
0,075
0,050
0,025
0,000
-12,9
-11,2
-9,4
-7,7
-5,9
-4,2
T,°C
f (T)
January
0,250
0,225
0,200
0,175
0,150
0,125
0,100
0,075
0,050
0,025
0,000
-6,2
-4,9
-3,6
-2,3
-1,0
0,2
1,5
2,8
T,°C
f (T)
January
0,325
0,300
0,275
0,250
0,225
0,200
0,175
0,150
0,125
0,100
0,075
0,050
0,025
0,000
-4,2
-2,7
-1,2
0,3
1,8
T,°
f (T)
January
0,325
0,300
0,275
0,250
0,225
0,200
0,175
0,150
0,125
0,100
0,075
0,050
0,025
0,000
-16,9
-14,5
-12,1
-9,7
-7,2
-4,8
T,°C

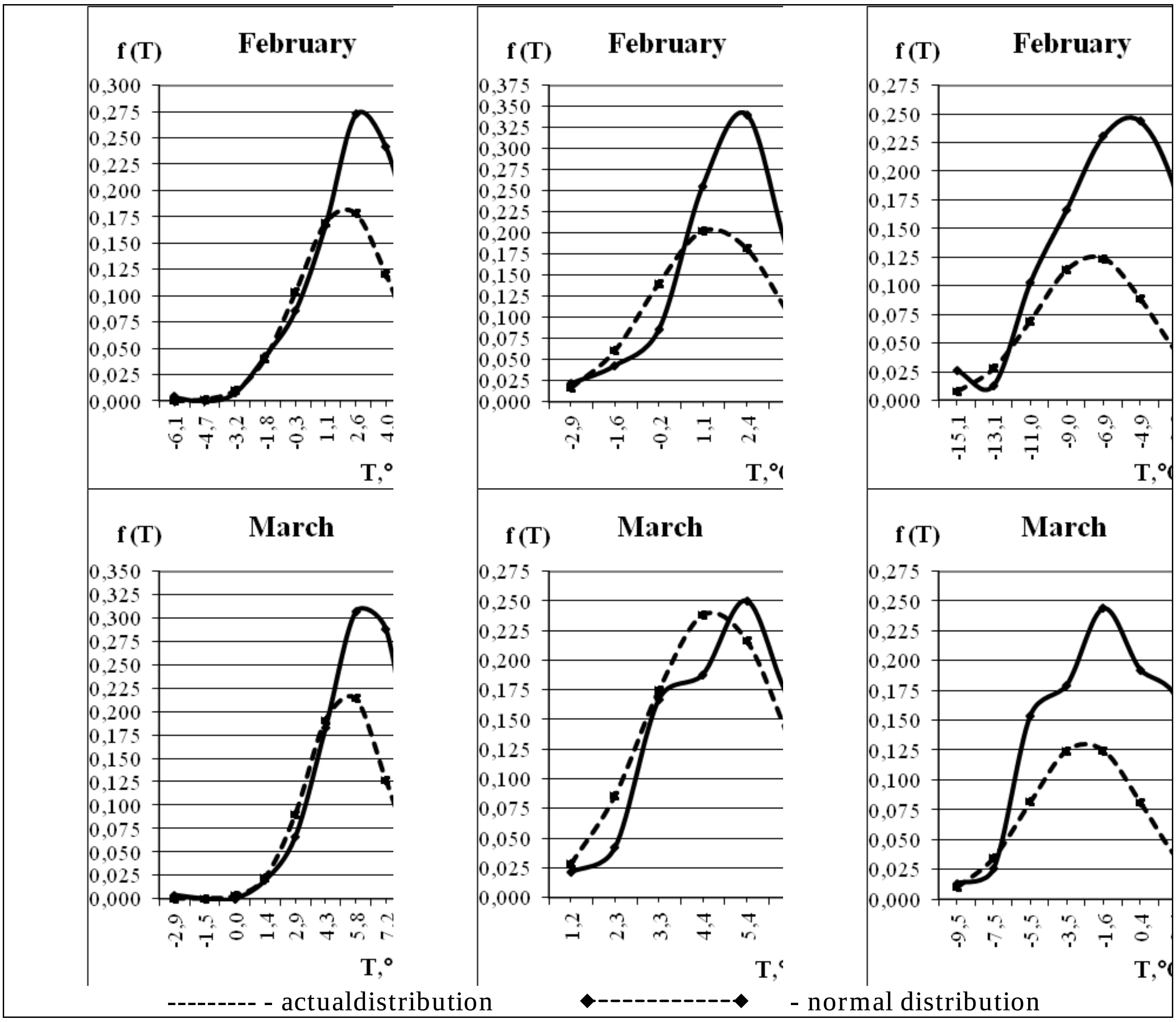

Fig. 6: Curves of selected actual and theoretical normal distribution of average monthly air temperature at the meteorological stations “Geneva”, “Krasnaya Polyana” and “Erzurum” for November-March

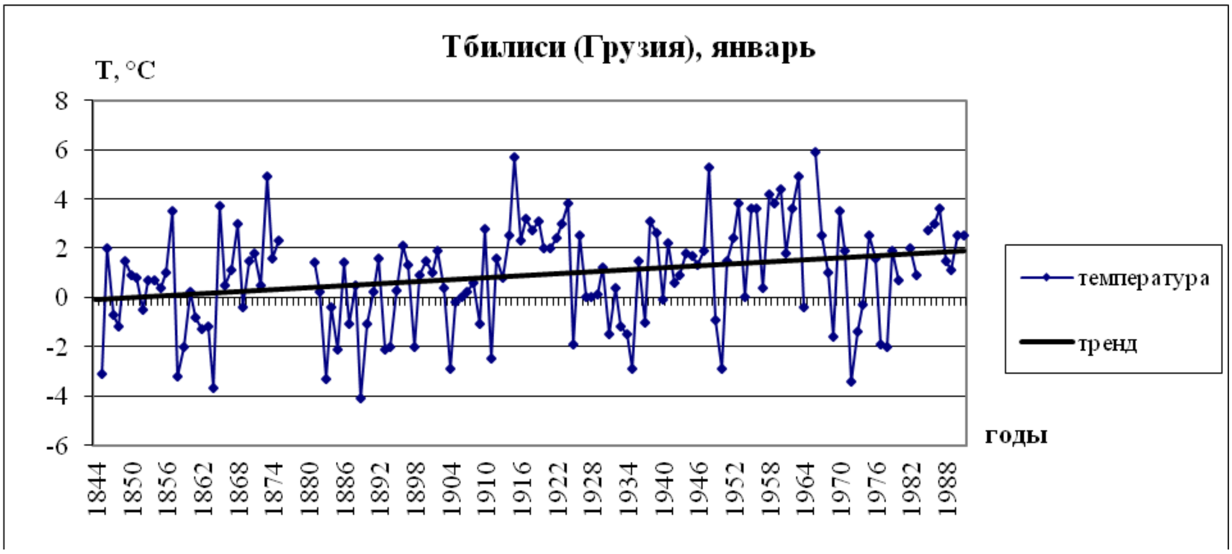

Fig. 7: Temporal yearly progress in average monthly air temperature and January linear trend for meteorological station “Tbilisi” (Georgia). Student criterion = 3,567

Mountain skiing resorts and winter sports are actively developing in Asian-Pacific Economic Cooperation (APEC) countries. The study is dedicated to an assessment of effect of modern climate change onto tourism [21].

Due to the future XXII Olympic and XI Paralympic Winter Games “Sochi 2014” a particular interest is raised by a comparative analysis of main climate change trends in the regions which have already hosted or are going to host Winter Olympics (Sapporo, Japan, 1972; Sochi, Russia, 2014; Incheon, Korea, 2022) (table 5).

Month	The meteorological stations					
	Sapporo		Krasnaya Polyana		Incheon	
	Average yearly (T^0C)	Student criterion	Average yearly (T^0C)	Student criterion	Average yearly (T^0C)	Student criterion
December	7,4	7,069	2,2	-0,715	-0,4	3,003
January	1,7	5,041	0,5	0,762	2,1	0,481
February	-4,8	4,537	1,5	-1,175	-1,7	2,158

Table 5: Main characteristics of climate change in Winter Olympics Host cities: Sapporo, Japan, 1972; Sochi, Russia, 2014; Incheon, Korea, 2022

As a rule, Winter Olympic Games take place in February. According to data from “Sapporo” and “Incheon” average yearly air temperature for this month is negative (-4.8 degrees C and -1.7 degrees C respectively), and for Krasnaya Polyana it is positive (1.5 degrees C). For Sapporo and Incheon positive stable linear trend (according to Student criterion) is characteristic, in other words climate warming is observed, at least in the places where weather stations are located. As for Krasnaya Polyana, December and January enjoy a decrease of average monthly air temperature (-0.715 and -1.175 degrees).

CONCLUSION.

Modern climate change seriously influences sustainable development and incomes of countries and certain regions having mountain climatic resorts and developing winter sports.

Main objective of the present research work is assessment of peculiarities of regional climate change in global climate change environment (destinations, clusters etc.) for regions with mountain climatic resorts, winter sports and tourism centres.

The work used data from meteorological stations for a maximum possible period of registered observations in November-March. We have calculated elementary statistic features of temporal arrays for average monthly air temperature, we have built curves of selective and theoretical normal values’ distribution as well as have defined a linear trend and assessed its reliable probability.

The carried out calculations have partly proved those previously made by other researchers that allow to conclude that the Alps (having main alpine skiing resorts of Europe) in 69 % of cases have stable positive trends of average monthly air temperature for cold months. Reliable probability of this event (according to the Student criterion) in 58 % of cases exceeds 90 %.

The results of the research prove the conclusions of well-known climatologists that by the year of 2100 average temperatures in Europe will grown another 2.0-6.3 degrees. While the number of precipitation goes down (by 20 %) in Southern and South-Eastern Europe for alpine skiing resorts, weather and climatic conditions will significantly worsen and, as a result, economic effect from winter sports and tourism might lead to a crisis in this branch of economy in the Alps.

Based upon a response rate of defined linear trends it can be said of preserving worsening climatic and environmental situation for sustainable development of winter skiing sports and alpine skiing resorts in the Alps.

Steady positive trend in climate change in the regions with the most well-known mountain skiing touristic destinations of the Eastern Asia (Japan, Korea, China) also sets a certain threat to the sustainable development of this branch of tourism.

But in the survey made by us is was defined that some of the regions of the Western Caucasus (Krasnaya Polyana, Klukhorskiy passage) as well as in the North-Eastern part of Turkey (Erzurum) during winter months enjoy controversial trends and linear tendencies are negative. Obviously, with other equal conditions (geographical coordinates, mountain relief) this fact can be explained by such climate-forming factor as atmosphere circulation and it requires special research.

If we take into account the fact that these regions of Russia and Turkey do not only have mountain skiing and winter sports resorts but are also planning to build new skiing destinations, then probably it is these regions that may become international centres of winter sports and tourism.

Due to forthcoming XXII Olympic and XI Paralympic Winter Games "Sochi 2014" a comparative analysis of main climate change trends of regions that have already hosted or are going to host Winter Olympics (Sapporo, Japan, 1972; Sochi, Russia, 2014; Seoul, Korea, 2022) is of particular interest. It turned out that in Japan and in Korea in the area where the Games have taken or are to take place a significant climate warming in winter months was noticed within a period of registered observations. At the same time the area of the mountain Olympic cluster (Krasnaya Polyana, Russia) enjoys slight (Student criterion varies from -0.715 to -1.175) decrease of average monthly air temperatures in winter.

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Изменение современного климата и горнолыжный туризм: Альпы и Кавказ

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Аннотация. Актуальность исследования современного изменения климата в наше время не вызывает сомнений. Климат – это, прежде всего, значительная доля ресурсов любой страны. Потери от глобального изменения климата могут затрагивать практически все секторы экономики и социальной сферы, включая энергетику, экосистемы, сельское хозяйство, лесное хозяйство, строительство, транспорт, туризм и др.

Изменение климата диктует определенный режим хозяйствования, стратегию развития экономики на долгие годы. Согласно прогнозам, например, Европейского агентства по окружающей среде (EEA), одним из первых заложников потепления климата станет зимний туризм и горнолыжные курорты. Изменение климата оказывает существенное влияние на доходы стран и отдельных регионов, имеющих высокогорные климатические курорты и развивающих зимние виды спорта.

Однако прогнозы ученых климатологов о тенденциях современного изменения климата не всегда однозначны, а иногда и противоположны. Поэтому определенный научный и практический интерес вызывают исследования тенденций изменения климата в горных районах на основе, прежде всего, государственной сети метеорологических станций.

Ключевые слова: современное изменение климата; туристские дестинации; горнолыжные курорты; линейные тренды; статистические характеристики; адаптация; влияние изменений климата на туризм; устойчивое развитие горных туристических кластеров; Зимние Олимпийские игры.