Current dynamics of air temperature in Saint Petersburg and suburbs

Vladimir I. Sturman*, *Alyona N.* Loginovskaya

The Bonch-Bruevich Saint-Petersburg State University of Telecommunications, 22 Prospekt Bolshevikov, St. Petersburg, 193232 Russia

Abstract. The dynamics of mean annual, seasonal and monthly temperatures at meteorological stations of Saint Petersburg and its suburbs in 1960-2023 was studied. It was found that actual growth of temperatures is revealed for annual and seasonal averages, but not for monthly values - in half of the cases only. This trends reflects only global processes, as the difference between the city and suburbs has not changed significantly over the period under consideration. The increase is mainly due to winter temperatures, while summer temperatures increased minimally.

1 Introduction

The current dynamics of climatic conditions attracts exceptional public attention [1]. Additional relevance of the study is given by periodically appearing reports on the suspension of temperature growth processes on a global scale (the period after 2000 on the graph of global temperature anomalies [2]), or within certain territories (Yakutia after 2005 [3]). Saint Petersburg is part of the region adjacent to the Baltic Sea with increased temperature growth rates [2]. Along with global models, studies covering limited areas of the territory, within these the details of ongoing climatic changes related to the peculiarities of interaction between components of the natural environment can be revealed, can be of certain importance [4]. The specific features of Saint Petersburg include the urban microclimate and land interaction with two large water bodies between which the city is located - the Gulf of Finland and Lake Ladoga.

2 Materials and Methods

The study utilizes available climate databases (http://www.pogodaiklimat.ru/history.php?id=ru) and methods of statistical processing. Since the study is aimed at geo-ecological rather than climatological tasks, the time interval 1960-2023 was chosen, which is in current people's memory and at the same time twice exceeds the minimum period of climatic generalizations. From the point of view of assessing the significance and possible prospects of modern climatic changes, it is important not only to state the general trend, but also to identify the nature of its temporal

* Corresponding author: st@izh.com

variability and the distribution of changes by seasons and months. For this purpose, graphs of changes in mean annual, mean monthly and average temperatures for seasons were plotted and analyzed. It was determined experimentally that the most informative for the specified time interval is the polynomial trend line of the 3rd degree. The lines of the 5th and 6th etc. degrees reveal a greater dependence on cyclic processes. The linear trend shows only the presence or absence of warming, leaving out of consideration its variability over time.

3 Results and Discussion

It is known [5, 6] that a large city forms an area of warmed air ("thermal island") and thus has a significant impact on the urban microclimate. In case of Saint Petersburg, as the largest megacity, this influence is very large and can be illustrated by the following facts. According to http://www.pogodaiklimat.ru/history.php?id=ru, the average annual temperature for the period 1960-2023 is 5.68°C, which is 1-1.4°C higher than the values for the same period for the nearest suburban meteorological stations: Belogorka (70 km to the south) - 4.38°C, Sosnovo (64 km to the north) - 4.27°C, Shlisselburg (40 km to the east) - 4.65°C. The location of the meteorological stations is shown in Fig. 1.

The longer the averaging period, the more inertial the obtained values are. When averaging over shorter periods, the dynamics of moving averages is much more pronounced. Thus, the last 10-year average (2014-2023) for Saint Petersburg is 7.07°C. As can be seen from Fig. 2, the growth of moving averages in Saint Petersburg and the nearest suburban areas was almost identical. At the same time, the minimum difference with the weather station of Shlisselburg is 1.02°C. This value is 1°C at the level of annual average temperatures and can be taken as a contribution of the urban microclimate to the indicators of Saint Petersburg.

Fig. 1. Location of meteorological stations in Saint Petersburg and adjacent territories

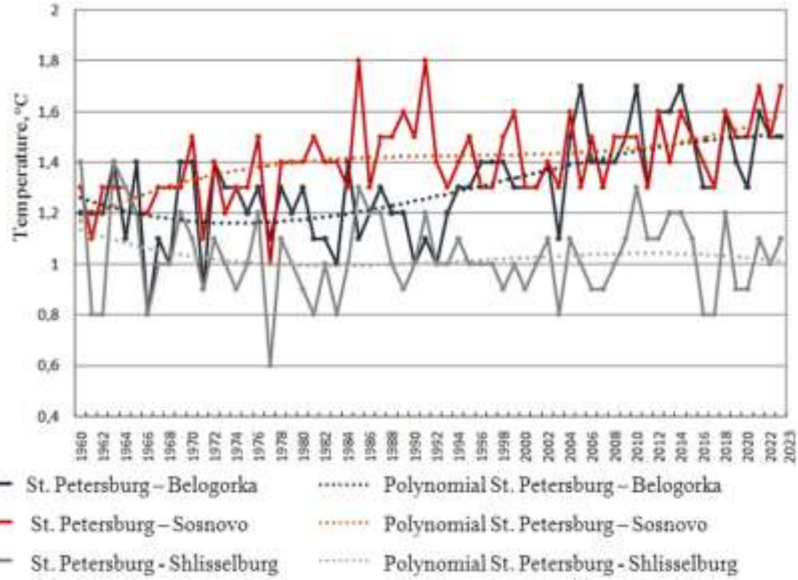

Fig. 2. Dynamics of 10-year moving average temperatures for Saint Petersburg and the nearest suburban meteorological stations

The dynamics of the difference in mean annual temperature differences between Saint Petersburg and the surrounding meteorological stations, as can be seen from Fig. 3, is expressed weakly and unequally for the three compared pairs. The difference with Belogorka and Sosnovo increased over the period under consideration, whereas with Shlisselburg it remained stable. In addition, the lower temperatures at Sosnovo weather station reflect its more northerly and hypsometrically elevated position.

Thus, the assumption [1] about a more intensive change in the temperature regime of large cities in comparison with neighboring territories due to the superposition of the "thermal island" effect is not confirmed on the example of Saint Petersburg.

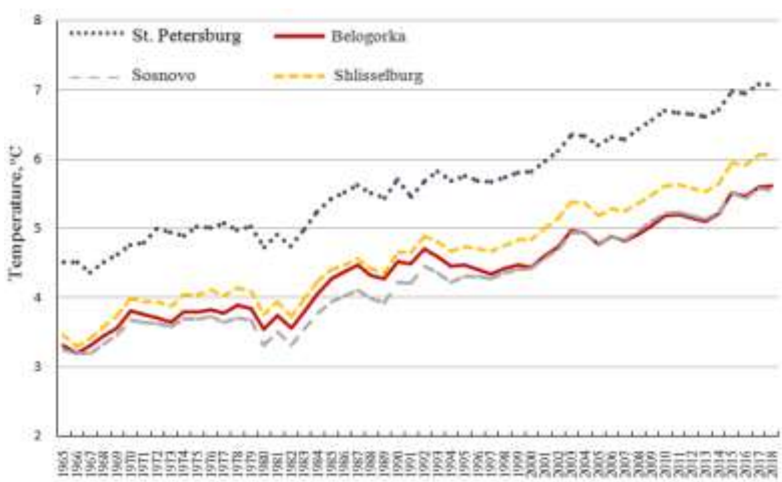

Fig. 3. Dynamics of the difference in mean annual temperature between Saint Petersburg and the surrounding meteorological stations

With Shlisselburg for 1877-1908, the difference averaged 0.45°C; for 1944-1959, 0.88°C; for 1960-2023 - 1.03°C. For Belogorka weather station the difference was 1.01°C in 1927-1940; 0.94°C in 1945-1959 and 1.3°C in 1960-2023. At the Sosnovka weather station, the temperature difference has not changed significantly for 100 years: 1.39°C in 1927-1940; 1.1°C in 1945-1959 and 1.41°C in 1960-2023. Thus, the "thermal island" was formed here in the XIX - early XX centuries, the last decades have strengthened it insignificantly, and the current trends are caused by global processes.

The temperature dynamics of the last decades is presented in Fig. 4. A similar character of dynamics is traced for all meteorological stations of the Leningrad region. Within the time interval under consideration, there is a period of cooling that ended in the late 1960s - early 1970s and a warming period that followed. Since 2010, a slowdown in the warming process has been observed at all meteorological stations under consideration, and in some cases the opposite trend has been observed.

Seasonal temperature graphs for Saint Petersburg are presented in Fig. 5. The general course of temperatures is similar, differing in details. The coefficients of variation are presented in Table 1. The growth rates were determined taking into account the actual duration of growth periods.

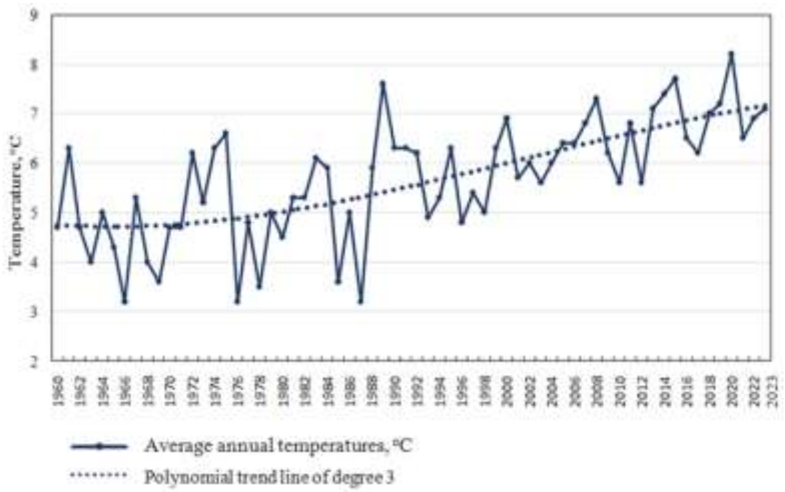

Fig. 4. Mean annual temperatures at the meteorological station Saint Petersburg

As can be seen from Fig. 5 and Table 1, the winter period is characterized by the greatest interannual variability. At the same time, the general warming trend is overlaid by cooling-warming cycles of about 5-10 years each. The growth rates are the highest.

The spring period is similar to the winter period by the character of dynamics. The difference is in shorter duration of cooling-warming cycles, usually up to 5 years each.

Summer temperatures are the most stable. Cyclicity is not traceable. Growth rates are minimal.

Table 1. Season indicators of variability of temperatures in 1960-2023 on a meteorological station Saint Petersburg

Indicators	Winter	Spring	Summer	Autumn
Average seasonal	-5.2	4.8	17.1	6.0
Variation ratio, %%	54.5	28.0	7.8	26.3
Growth rates, ºC/10 years	0.62	0.44	0.39	0.46

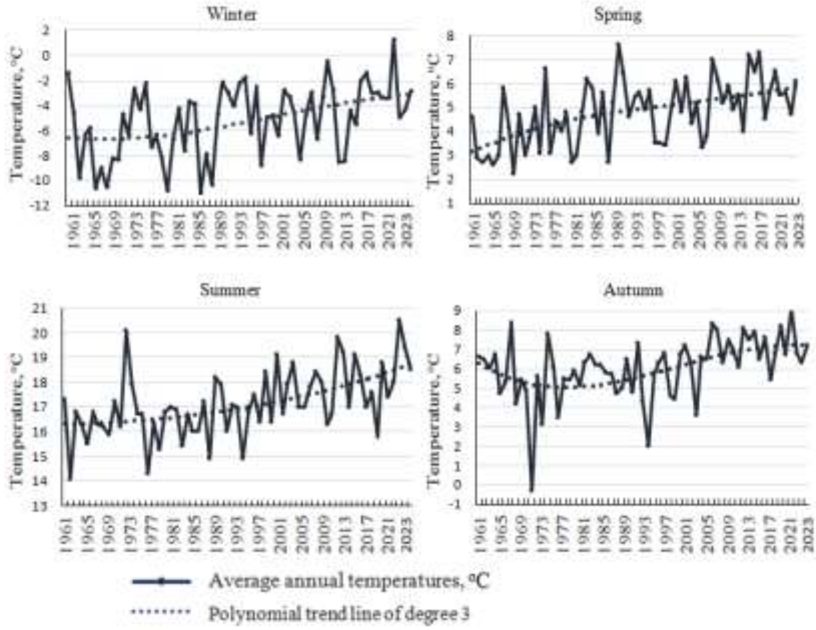

Fig. 5. Mean seasonal temperatures at the Saint Petersburg weather station

The graphs for the year as a whole, as well as winter and spring, show a sharp break to warming in 1987-1989. After this break, both maximum and minimum values were invariably higher than the maximums and minimums of the subsequent period.

Further increases in mean monthly temperatures are now detected in February, March, June, August, September, and October. In other months, stabilization or even a downward trend has occurred. For examples, see Fig. 6.

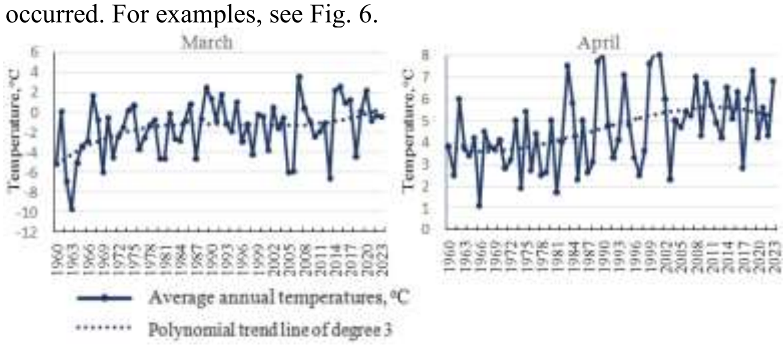

Fig. 6. Examples of graphs of average monthly temperatures at the Saint Petersburg weather station

4 Conclusions

On the example of Saint Petersburg and its suburbs it was revealed that the growth of temperatures caused by global processes continues at the present time at the level of both average annual and all average seasonal values. The degree of expression of the "thermal island" in Saint Petersburg has grown insignificantly over the last decades. The assumption of accelerated temperature growth in the largest cities is not confirmed in Saint Petersburg. The most pronounced temperature growth takes place in winter. The growth of summer temperatures, which could pose the greatest threat to the environment and socio-economic conditions, is characterized by minimal rates. At the level of monthly values, the tendency for further temperature growth after 2010 is maintained only in half of cases, while earlier such growth was observed in all months.

The submitted data are limited on the volume and the territory and are insufficient for conclusions of global character, however they point to the decrease in rates of increase in temperatures which began after extreme summer of 2010. It, in turn, can be considered as the evidence of natural nature of the fluctuations of climate happening in the last decades.

References

1. Third Assessment Report on Climate Change and its Impacts on the Territory of the Russian Federation. General summary. Saint Petersburg: Science-intensive technologies, 2022. 124 p. [In Russian].
2. Sherstyukov B.G. *Changes, Variability and Climate Fluctuations* (: FSBI "VNIIGMI-MCD", Obninsk, 2011). [In Russian].
3. Shats M.M. *Modern Climate Change in the North of the Russian Federation. Trends and Consequences* https://geoinfo.ru/product/shac-mark-mihajlovich/sovremennoe-izmenenie-klimata-severa-rf-tendencii-i-posledstviya-35141.shtml (accessed on 06.02.24). [In Russian].
4. Perevedentsev Yu.P. Izv. Russian Academy of Sciences. Issue. Geogr. **6**, 5-17 (2005) [In Russian].
5. Kratzer A., *The Climate of Cities (Das Stadtklima)* (Air Force Cambridge Research Laboratories. L. G. Hanscom Field Bedford, Massachusetts, 1956)
6. Landsberg H.E. *The Urban Climate. International Geophysics Series*, **28**, 275 (Academic Press, New York, 1981)