D.I. Maslennikov,

candidate of physical and mathematical sciences, an assistant professor Kharkiv National Agrarian University named after V.V. Dokuchayev

e-mail: d-masl@mail.ru

T.G. Tkachenko,

candidate of geographical sciences, an assistant professor Kharkiv National Agrarian University named after V.V. Dokuchayev

e-mail: ttg298@yandex.ua

MATHEMATICAL MODEL OF MICROCLIMATIC PECULIARITIES IN TEMPERATURE CONDITIONS

Abstract. The results of the changes of the air temperature at the meteorological stations of Kharkiv and Rogan (the experimental field of KhNAU) during the period 1968 – 2012 are given. It is determined that the air temperature in the city exceeds its changes in rural areas. During the research, the method of moving average, correlation and regression analysis, graphical methods were used. Space and time variability of the average annual air temperature was revealed with their help. Change of the microclimatic particularities of the regional climate leads to the global climate spatial change.

Keywords: air temperature, global warming, warm-up mode, change the climate, island of the heat, trend, oscillations.

Statement of the problem in general aspect and its connection with important scientific tasks. Climatic change is one of the most significant problems in the sphere of environment protection and balanced nature use. Climatic charge is concerned with increase of technogenic factors influence cause the breach of natural balance in the whole climatic system. Hence the changes of meteorological quantities and the increase of atmospheric phenomena recurrence take place. Owing to global

climatic changes an environment protection is examined both on the national and international levels. The results of instrumental meteorological observations testify to climatic change. These changes are followed by negative consequences both for economy and the whole mankind [1,2]. Natural fluctuations of climate, its changes under the influence of heat effect gain strength by anthropogenous activities of human. According to the estimates of Intergovernmental climate change experts group any climatic change is the result of natural changeableness and anthropogenous activities of human [3-5]. An absolute necessity to estimate climatic changes on the territory of Ukraine arouse. It is connected with the fact that the peculiarities of transformation in climatic field of air temperature near the soil surface during the last century are known [6]. Modern researches testify to the variety of characteristic fluctuation in climatic system which combines atmosphere, hydrosphere, cryosphere, biosphere. Complication of connections in climatic system, change of its components cause climatic change on the Earth. Heat condition of atmosphere is characterized by thermal conditions of active atmospheric layer and is expressed interacting with an ocean and waterless valley [1,4,5,7]. It has been ascertained that the global air temperature near the soil surface raised at 0,6±0,2ºC during the XX century. Rise in temperature was the most substantial during the last 1000 year, and the recent years were the warmest ones [1].

On the territory of Ukraine the heat distribution is stipulated by geographical position, radiation balance, atmospheric circulation in the close interaction with a covering surface. The influence of physical and geographical factors is not equivalent. It causes the variety of temperature contrasts. On the example of instrumental meteorological observations which were carried out at the meteorological stations (MS) in Kharkiv and Rogan (the experimental field of KhNAU) the peculiarities of the temperature conditions are considered under the conditions of global and regional climatic changes.

Analysis of the latest researches and publications. Many scientists study climatic problems [8-12]. M.I. Shcherban, O.V. Shakhnovich, A.O. Wilkinson began

microclimatic researches in the 50-s, [13,14]. G.P. Dubinskiy and A.D. Babich researched the microclimate of irrigated fields. The peculiarities of regional climatology and separate zones and areas in Ukraine were studied by Y.A. Burman, O.M. Rayevskiy, K.V. Golub, I.I. Kalinina, L.K. Smekalova, O.O. Vrublevskaya, I.K. Polovko, V.P. Popov, M.I. Shcherban, V.I. Romushkevich, P.I. Kolesnik, P.I. Kobzistyi, G.D. Protsenko and others studied some questions of climatic changes in separate regions [1].

The Climatic peculiarities of Kharkiv are formed in the result of microclimatic processes which arise in the natural and anthropologically changed landscapes. They interact with each other constantly. The differences of weather conditions in urban and rural areas are stipulated by the nature of covering surface and its heterogeneity chiefly. It gives an opportunity to show microclimatic heterogeneity of covering surface – relief, roughness of urban areas with the higher level of air pollution, forest, rivers, forest shelter – belts agricultural field, etc. Microclimatic peculiarities of meteorological quantities and urban building were examined in the works of scientists [15,16] anthropogenous influence of urban areas on microclimate formation is conditioned by industrial production work of transport, thermoelectric power stations. Quantitative active indices of meteorological quantities depend on gaseous and aerosol emissions into the atmosphere an urban area has an influence on microclimate by means of change in the covering surface and pollution of atmospheric layer near the soil surface. So, in the work [17] it was noted that the difference between an urban air temperature and rural one depended on the amount of population when the weather is quiet and cloudless. It is asserted that this aspect is typical for many European and American urban areas and even for small villages where the population is 1000 inhabitants. The diversity of covering surface is inevitable to cause the change of turbulence characteristics, direction and speed of wind. It means changes in water and thermal balance of an urban area. Roughness of covering surface, convection intensity, crystallization nuclei have an essential influence on cloudiness formation. Some specific conditions for solar radiation, temperature rate formation, air humidity, rainfall conditions come into existence in an

urban area. Studying climate of big urban areas the scientists prepared climatological characteristic of main Ukrainian urban areas during 80-90-s. So, in the work [18] the microclimate of Kharkiv was researched. It should be noted that he present territory experienced an anthropogenous load. Positive and negative consequences of «a heat island» were described in works [15,16]. Under the conditions of the present climate the dates concerning steady change of air temperature through 0, 5, 10, 15 ºC in spring and autumn, dates of climatic seasons change their duration, heating seasons period etc. [19,20] have changed considerably.

The aim of the given research is the analysis of changes in the average annual air temperature at MS Kharkiv and Rogan (the experimental field of KhNAU) during the observation period from 1968 to 2012. During the research, the method of moving average, correlation and regression analysis, graphical and mapping methods were used. Space and time variability of the average annual air temperature was revealed with their help.

The results of the research. The time rows of the air temperatures for the period from 1968 to 2012 were analyzed to establish the dynamics of the average annual air temperature at MS Kharkiv and Rogan (the experimental field of KhNAU). The average annual air temperature at MS Kharkiv and Rogan (the experimental field of KhNAU) are given in Table 1.

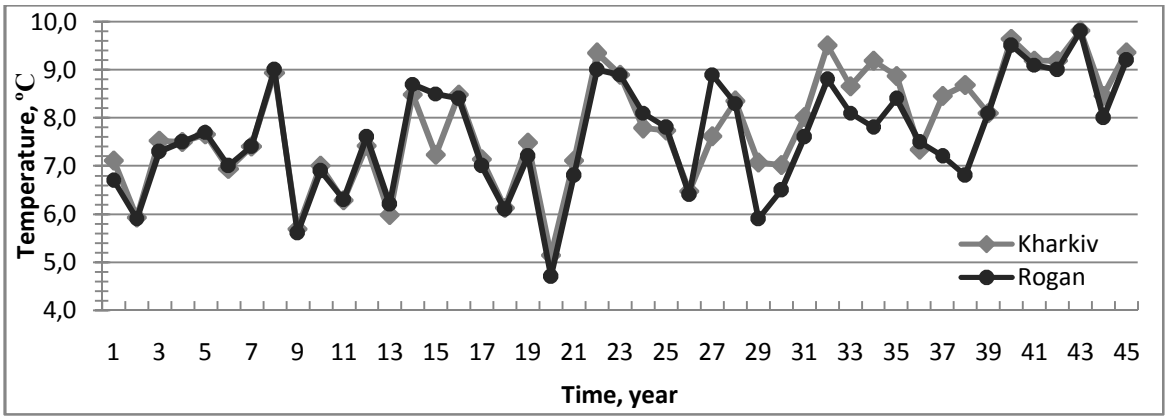
Table 1

Average Annual Air Temperature, ^{0}C MS Kharkiv and MS Rogan

Year	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**
T, ºC, Kharkiv	7,1	5,9	7,5	7,5	7,7	6,9	7,4	8,9	5,7
T, ºC, Rogan	6,7	5,9	7,3	7,5	7,7	7,0	7,4	9,0	5,6
Year	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**
T, ºC, Kharkiv	7,0	6,3	7,4	6,0	8,5	7,2	8,5	7,1	6,5
T, ºC, Rogan	6,9	6,3	7,6	6,2	8,7	8,5	8,4	7,0	6,1
Year	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**

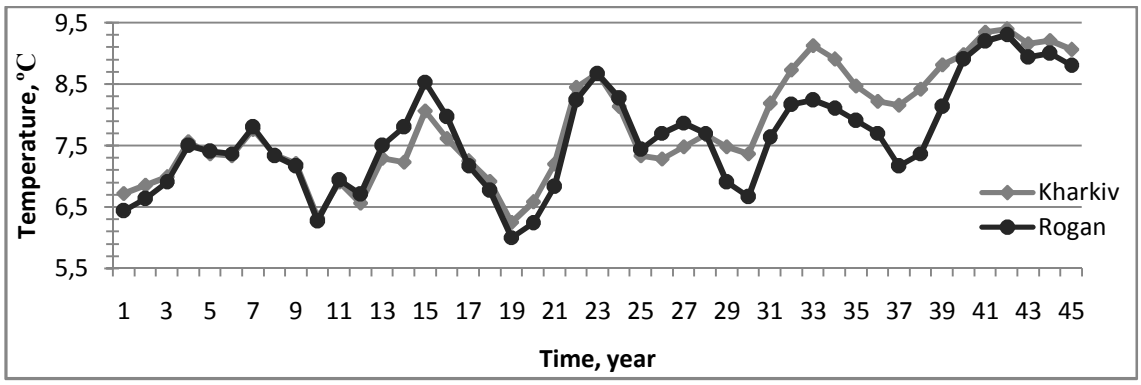
T, ºC, Kharkiv	7,5	5,1	7,1	9,3	8,9	7,8	7,7	6,5	7,6
T, ºC, Rogan	7,2	4,7	6,8	9,0	8,9	8,1	7,8	6,4	8,9
Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
T, ºC, Kharkiv	8,3	7,1	7,0	8,0	9,5	8,7	9,2	8,9	7,3
T, ºC, Rogan	8,3	5,9	6,5	7,6	8,8	8,1	7,8	8,4	7,5
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
T, ºC, Kharkiv	8,5	8,7	8,1	9,6	9,2	9,2	9,8	8,5	9,4
T, ºC, Rogan	7,2	6,8	8,1	9,5	9,1	9,0	9,8	8,0	9,2

The distribution of the average annual air temperature at MS Kharkiv and MS Rogan (the experimental field of KhNAU) is given in Picture 1 where the year 1968 is considered to be the first.



Pic. 1. Dynamics of Average Annual Air Temperature at MS Kharkiv and Rogan (the experimental field of KhNAU).

The equalization of the results by the method of moving average was made to simplify the further calculations that allowed to get rid of random fluctuations. The changes of the average annual air temperature for the period from 1968 to 2012 were revealed. The average annual air temperature after equalization is given in Pic. 2.



Pic. 2. Dynamics of Average Annual Air Temperature after equalization at MS Kharkiv and Rogan (the experimental field of KhNAU).

The tendency of the average annual air temperature increase at meteorological stations Kharkiv and Rogan (the experimental field of KhNAU) is obvious in Pic. 2. The further assessment of the climate trends was carried out by the methods of correlation and regression analyzes. The correlation coefficients for the average annual temperatures after equalization were found. So, for Kharkiv the correlation coefficients are

$$r_{Kh} = 0{,}786, \tag{1}$$

and for Rogan (the experimental field of KhNAU) correspondently

$$r_R = 0{,}617. \tag{2}$$

Testing the significance of the correlation coefficients was carried out using t – the criteria of Student. Assuming that the null hypothesis H_0 equality to zero of correlation coefficient r = 0, and the alternative H_1- inequality to zero r≠0, the criterion value for Kharkiv City was received t_{Kh}=8,34, for Rogan (the experimental field of KhNAU) t_R= 5,14. By the significance level α=0,95 the critical value of the criterion is t_{cr}= 2,014. Thus, in both cases, there is reason to reject the null hypothesis and accept the alternative one. The presence of the average annual temperature dependence by the time is proved. The equation of a straight regression line was recorded to find the analytical expression. So for MS Kharkiv it takes the following form:

$$x = 0{,}053t + 6{,}590, \quad (3)$$

for MS Rogan correspondently (the experimental field of KhNAU):

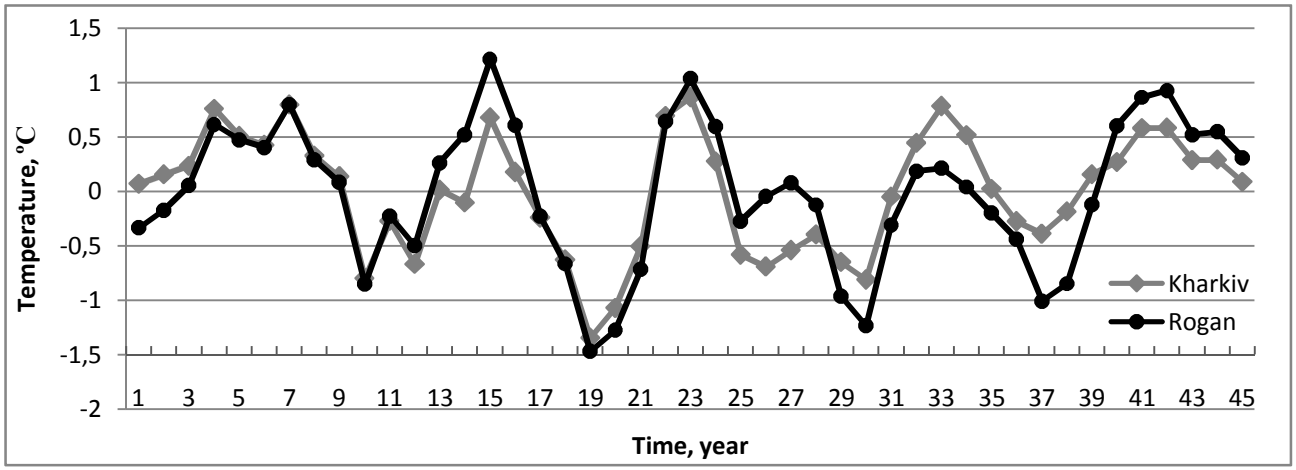
$$x = 0{,}039t + 6{,}726, \quad (4)$$

where – the appropriate average annual temperature, ^{0}C; t– time, year.

In formulas (3) and (4) the coefficients show that on average per year during 45 years of observations, the average annual temperature increased in Kharkiv City on 0,053^{0}C, and in suburban area Rogan (the experimental field of KhNAU) on 0,039^{0}C. Overall, during the period of the instrumental observations from 1968 to 2012 the average annual temperature increased on 2,39^{0}C for Kharkiv City and on 1,78^{0}C for Rogan (the experimental field of KhNAU).

The calculations indicate the existence of a "heat island", in which there is an increase of the temperature background in the city compared to the suburban area. So the city warms more and cools more slowly, giving heat. Great heat capacity of the building materials, the dark asphalt of the city significantly influence the surface albedo, change thermal storage. Changing of the temperature in Kharkiv City corresponds to the general laws inherent for a temperate climate.

The deviation values calculated from the regression equation from the measured average annual temperatures were analyzed during the research. The dynamics of the given deviations on MS Kharkiv and MS Rogan (the experimental field of KhNAU) are shown in Pic. 3.



Pic. 3. Dynamics of Deviations of Average Annual Air Temperature from Straight Line of Regression at MS Kharkiv and MS Rogan (the experimental field of KhNAU).

The dynamics of changes in the annual air temperature repeats periodic fluctuations. Therefore the approximation of the above mentioned deviations by the method of the least squares was carried out. The trigonometric function was chosen as the unknown quantity

$$\Delta x = asin\omega t + bcos\omega t, \quad (5)$$

where Δx– the deviations of the average annual air temperature from the straight line of regression, – the cyclic frequency, T – the period of fluctuations, a and b – the constant coefficients, t – time in years, where the year 1968 is considered to be the first.

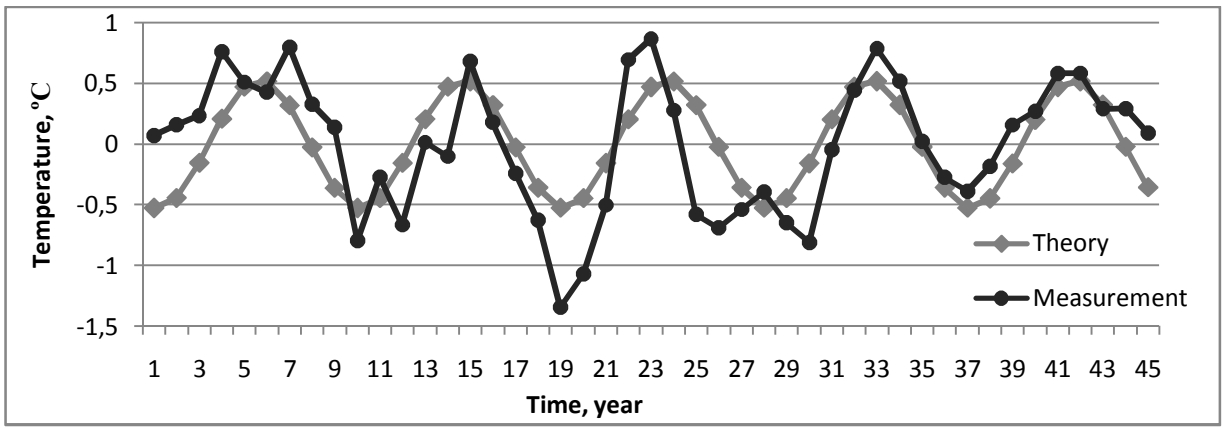
The studies show that the deviation of the average annual temperature from the straight regression line describes the fluctuations with a period T = 9 years to the best advantage, and the coefficients of the function (5) in this case are as follows: for Kharkiv

$$\Delta x = -0{,}388sin0{,}698t - 0{,}363cos0{,}698t, \quad (6)$$

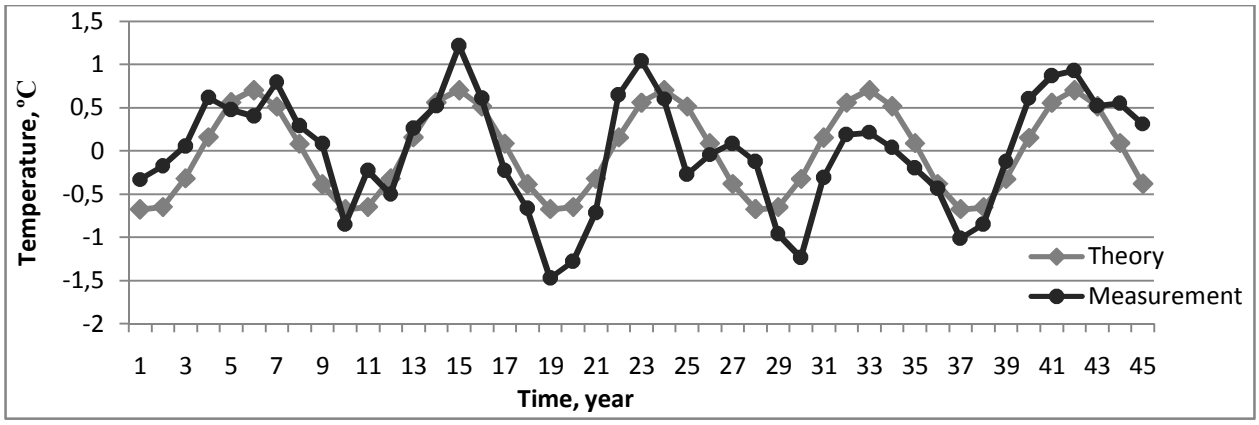
for Rogan (KhNAU experimental field)

$$\Delta x = -0{,}589sin0{,}698t - 0{,}387cos0{,}698t. \quad (7)$$

The diagrams for theoretical meanings of the deflections of an average annual air temperature from the measured and calculated ones with the help of the formulae (6) for MS Kharkiv (7), for MS Rogan (KhNAU experimental field) are given in picture 4 and 5.



Pic.4 The dynamics of the deflections of an average annual air temperature from the regression straight line for MS Kharkiv.



Pic.5.The dynamics of the deflections of an average annual air temperature from the regression straight line for MS Rogan (KhNAU experimental field).

Combining the formulae (3) and (6) as well as (4) and (7) we get accordingly

for MS Kharkiv

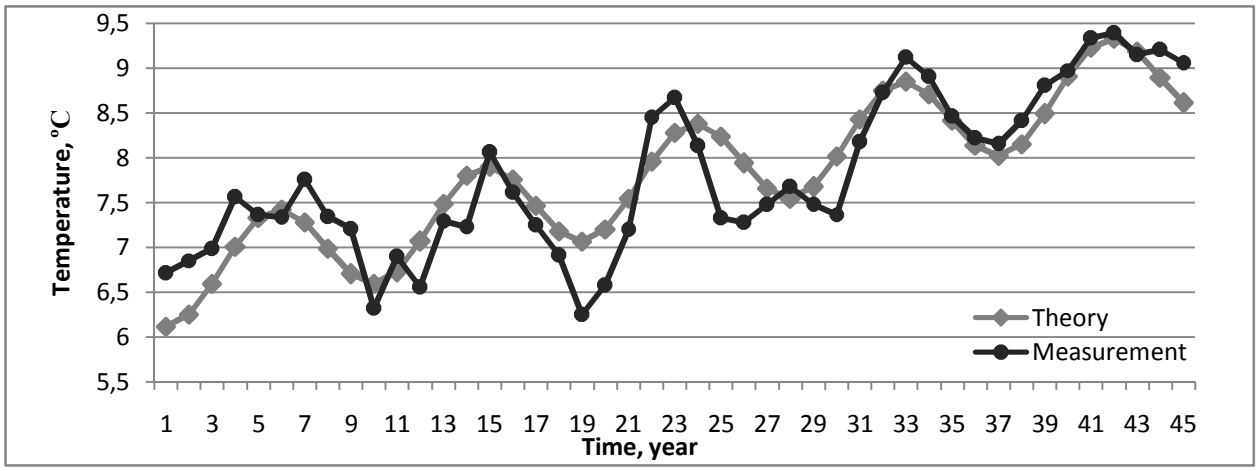
$$x = 0{,}053t + 6{,}590 - 0{,}388sin0{,}698t - 0{,}363cos0{,}698t, \quad (8)$$

for MS Rogan (KhNAU experimental field)

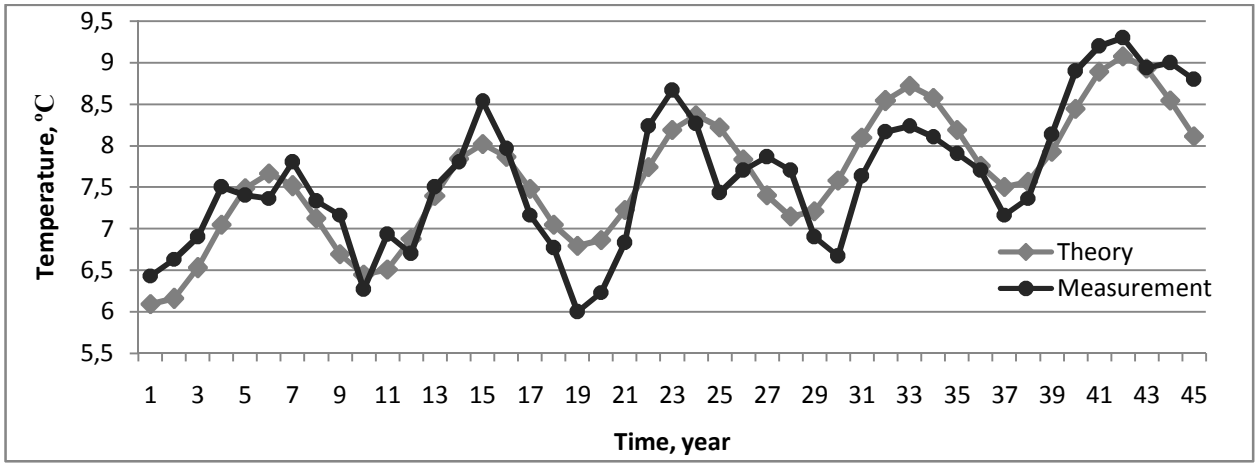
$$x = 0{,}039t + 6{,}726 - 0{,}589sin0{,}698t - 0{,}387cos0{,}698t. \quad (9)$$

It should be noted that the oscillation amplitude for Kharkiv is 0.531 ^{o}C and for Rogan it's 0.705 ^{o}C. We can observe faster rise of the air temperature in the city than in the country but it fluctuates less from the average meaning. In the Picture 6 and 7 the comparative meanings of the theoretical average annual air temperature are presented which are calculated according to the formula (8) and (9) and measured for MS Kharkiv and Rogan (KhNAU experimental field). In most cases i.e. in the winter,

spring and at the beginning of summer the temperature rise is observed in some regions of Kharkiv in comparison with Rogan countryside territory.



Pic.6.The comparison of the theoretical average annual air temperature with the measured one for MS Kharkiv.



Pic.7. The comparison of the theoretical average annual air temperature with the measured one for MS Rogan (KhNAU experimental field).

The calculating of the active temperature sum in the region proves the tendency of the air temperature rise. The sum of temperatures tells about the providing the territory with warmth and has biological and physical sense. Besides the sums of temperatures is used to express the need of agricultural crops for warmth. It is also used for the forecast of plant diseases and pests. Thus the meanings of the sum of the air temperature have risen up to 3000^{o}C and higher and this hastens the behavior of the plant phonological phases.

Conclusions. The thermal state of the atmosphere is one of the climatic system components which is characterized by the temperature rate. So at the meteorological stations of Kharkiv and Rogan (KhNAU experimental field) the rise of average annual air temperature is observed. The most significant air temperature changes

happen in winter and spring seasons and one should take it into consideration while doing any kind of agricultural or agro-technical work.

The rise of average annual air temperature in the city of Kharkiv is connected with the tendency of the rise of anthropogenic effect on the natural environment. The effect of the city on the formation of the temperature rate is conditioned by the change of the underlying surface. The additional discharge of heat from transport and industry should be also taken into consideration. The size of the "heat island" may change under the influence of weather conditions. The largest effect is revealed in the conditions of anticyclone type of weather. The local conditions (relief, the type of underlying surface) influence considerably the specific features of air temperature formation over the city. Microclimatic features of the city and industrial regions should be taken into account to use the nature rationally. It is determined that the average annual temperature in the city of Kharkiv has gone up 0.053^{o}C for the last 45 years and in the country, on the territory of Rogan (KhNAU experimental field), it has gone up 0.039^{o}C.On the whole for the period of the tool observation from 1968 till 2012 the average air temperature in the city of Kharkiv has gone up 2.39^{o} C and 1.78^{o}C in Rogan (KhNAU experimental field).

The researches held prove the existence of the "heat island" where the rise of the temperature background in the city is observed in comparison with the country side territory. The consistent air temperature rise, long lack of rains, low air humidity, dry winds, atmospheric and soil drought induce scientists and specialists in agriculture to develop the system of agro-technical and land improvement measures directed to the crop and varieties choice, explanation of agro- and phyto- technologies and introducing irrigated farming.

References

1.Budyko M.I. A climate in the past and future / M.I. Budyko. – Leningrad. : Gidrometeoizdat, 1980. – 351p.

2. Budyko M.I. A climate and a life. / M.I. Budyko. - Leningrad. : Gidrometeoizdat, 1971. - 472 p.

3. Lipinsky V.M., A climate of the Ukraine /V. M. Lipinsky, V.A.Djachuk, V.M. Babichenko – Kyiv: Raevsry publishing house, 2003. – 343 p.

4. Loginov V. F. Global and regional climate changes and their demonstrative base / V.F. Loginov//Global and regional changes. – Kyiv, 2011. - P. 23-37.

5. Loginov V. F. Radiating factors and demonstrative base of modern changes of a climate. - Minsk, 2012. - 266 p.
6. Voloshchuk V. M, Boychenko S.G. Reaction of a seasonal course of ground temperature of Ukraine to global warming of a climate // The reports of National Academy of Sciences of Ukraine. –K.: 1997. - №9. - P. 113- 118.
7. Silver J. Global warming / J. Silver. - Moscow, 2009. – 365p.
8. Peng Li. Climate warming due to increasing atmospheric CO2: simulations with a multilayer coupled atmosphere-ocean seasonal energy balance model/Li Peng, Ming-Dah - Chou, A. Arking//J. Geophys. Res. - 1987. - Vol. 92. - P. 5505-5521.
9. Ramage C.S. Secular change in reported surface wind speed over the Ocean/C. S. Ramage//J. Clim. Appl. Meteorol. - 1987. - V. 26. - P. 525-528.
10. Roemmich D. 135 years of global ocean warming between the Challenger Expedition and the Argo Programme/Dean, Roemmich, W. John, Gould, John, Gilson//Nature Climate Change, 2, 425-428. - 2012.(Doi: 10.1038 / nclimate1461).
11. Tollefson J. The case of the missing heat [Text] / J. Tollefson//Nature. 2014.- Vol. 505. - P. 276-278.
12. Wigley T. Analytical solution for the effect of increasing CO2 on global mean temperature [Text] / T. M. L. Wigley, M.E. Schlesinger//Nature.1985. - Vol. 315. - P. 649-652.
13. Shcherban M. Microclimatelogy.-Kyiv: Vyscha shkola, 1985.-222p.
14. Shahnovich A.V. Microclimatic territory estimation at some types the weather//Works of Ukraine scientific and research gidrometeorological institute. - 1964.-V.45. - p.83-96.
15. Ivanov S.V Albedo role in formation of city heat island / S.V. Ivanov, O.R. Dranicher// The bulletin of Odessa state ecology university. –O: 2013.-V. 15 - P. 79-88.
16. Shevchenko O.G. Temperature anomalies of great city. O.G. Shevchenko, S.I. Snigko, E.V. Samchuk//Ukraine gidrometeorology magazine - 2011. - №8 - p.67 - 73.
17. Oke T.R. Climate of an interface. – Leningrad: Gidrometeoizdat, 1982. - 358 p.

18. Babichenko V.M. Climate of Kharkov / V.M. Babichenko. - Leningrad. : Gidrometeoizdat, 1983. - 216 p.
19. Babichenko V.M. Springtime coming (transition of mean daily air temperature values over 0°C) in Ukraine under conditions of modern climate/V. Babichenko, N. Nikolaeva, S. Rudishina, L. Guschina//Ukraine geographic magazine - 2009. - №9. - p. 25 - 35.
20. Zatula V. Zatula D. Newnot interpolation polynomials application for calculation of average dates of air temperature transition through determined levels in Ukraine/ V.I. Zatula, D.V.Zatula// Ukraine gidrometeorology magazine. - 2011. - №8. - P. 60-66.
21. Reshetchenko S.I. Change of a temperature mode in territory of the Kharkov region / S.I. Reshetchenko, T.G. Tkachenko, O.G. Lisenko// V. N. Karazin Kharkiv National University bulletin, V. 43, Geology, Geography, Economic - 2015. - p. 153 - 159.