Acta Agrophysica, 2000, 26, 255-274

REASONS AND CONSEQUENCES OF CLIMATE CHANGES IN BELARUS

V.F. Loginov

Institute for Problems of Natural Resources Use and Ecology, Academy of Sciences of Belarus,
Staroborisovsky Trakt 10, 220114 Minsk, Belarus

A b s t r a c t. Analysis of temperature measurements in the Polesye and the republic in general revealed the presence of two warmings during the period of observations (~120 years). The warming of the 1930's is of radiation origin and relates to the atmospheric purification from volcanic powder. The heating took place in summer. Modern warming is that of winter type. Its origin is related to the increase of greenhouse gases content in the atmosphere.

Changes in precipitation taking place for of many years are of great complexity. In the south part of the republic during the postwar period the amount of precipitation decreased by about 100 mm when compared to the preceding half-century. In the north Belarus a rise of precipitation for the past two decades is observed.

The amelioration of southern areas of Belarus and the adjacent territories resulted in temperature variation in southern part of our state by 0.3-0.4 °C, precipitation by 10-35 mm in summer. Temperature and precipitation variation patterns differ in the first and second part of summer.

Analysis of the range of daily temperature course, as well as temperature maxima and minima for big towns revealed anthropogenic "signal" that must stressed be while assessing variations in daily course ranges. Interpretation of the features of temperature variability in space and time in towns and suburbs was presented.

K e y w o r d s: climatic change, amelioration, range of daily temperature course, regional climate, assessment of anthropogenic "signal", linear trends, albedo, period of instrumental observation, greenhouse gases.

INTRODUCTION

Assessment of contribution of various anthropogenic factors in climatic changes are rather contradictory. A more comprehensive assessment of the impact of anthropogenic activities on town climate has been carried out. A well-known physical notion of natural cycles of heat and moisture disturbances in anthropogenically damaged territories are proved by test data. Assessments of the role of temperature rise in towns as a result of anthropogenic activity in global climate warming fluctuates from 10 to 30% [3,5].

Investigations of peculiarities of town climate show that a town influences practically all climatic parameters: formation of heat islands in towns, reduction of solar radiation inflow, variation in the precipitation amount, number of foggy days, reduction of wind rate and especially frequency of strong wind velocity levels. The greatest differences in air temperature are observed at night in cloudless, windless weather. Average annual temperature in big towns is higher than in suburbs by several tenths of ^{o}C and in the case of very big towns temperature difference far exceeds 1 ^{o}C. Temperature difference between "town and suburb" at night is especially high.

Presence of the so-called "heat islands" in towns stipulates a significantly higher difference of "town – suburb" temperature.

The summer daily course of temperature difference "town - suburb" shows that temperature in suburb in the afternoon hours appears to be even higher, than at night and vice versa, temperature in town exceeds the temperature in a suburb.

In winter, daily temperature in town is higher all day long when compared to the suburb. In most cases, mean intensity of "heat islands" in winter is less than in summer due to great cloudiness and higher speed of wind rate that prevents formation of heat islands in towns.

The issue of the influence of amelioration on climate was discussed in numerous articles. So, microclimatic variations due to the amelioration of mires in Belarus were evident [9], but theoretical and experimental study of the issue carried out more actively in the period 1960-1980 was not properly continued. Evaluation of the influence of amelioration on the regional climatic changes, and as a result, exclusion of the role of amelioration role from the current climatic changes is of special interest.

In the assessment of the contribution of greenhouse gases and aerosols of natural and anthropogenic origin in modern climatic change there is, however, some uncertainty.

One of the statistic proofs of greenhouse effect is presented in a number of works on various values of trends of extreme temperatures in various parts of the Globe [2,4]. While Karl *et al.* [4] stated that minimum temperatures increase three times quicker than maximum ones in over 37% of land (0.084 and 0.024 ^{o}C within a decade in the period from 1951 to 1990). A more detailed study of seasonal maximum and minimum temperatures in Czech stations and in other European countries did not fully confirm this intriguing conclusion of Karl *et al.* [4].

A substantial interest in assessing climatic changes is represented by the notion of daily temperature course as the range of its daily courses. This complex characteristics reflects day and night temperature modes. This way the anthropogenic "signal" is revealed as stresses stronger.

Warming of the climate found and calls for a research on the possible results of climatic changes. Possible scenarios of the development of man's activities in the conditions of varying climate should be worked out.

RESULTS AND DISCUSSION

Change of the Polesye climate

Characteristics of territorial climatic conditions is made up from several indices such as: solar radiation, temperature and moisture modes, air pressure and wind velocity. Annual sums of total radiation vary in the Polesye within the limits of 3900-4050 MJ m^{-2}. The values of direct radiation levels comprise 1850-2000 MJ m^{-2}, and that of dispersed – 2050 – 2130 MJ m^{-2}[3]. Cloudiness reduces annual sums of direct solar radiation 2.5-3 times. Total annual radiation sums decrease by about 40% compared to the values with clear sky. At the same time, the sum of diffused radiation at the mean cloudiness are about by 40% higher, than when the sky is clear. All months long, except in June and July, the diffused radiation makes up more than a half of the total, and in June and July - 47-49%.

Annual sums of radiation balance ranged from 1650 to 1750 MJ m^{-2}. Annual sums of short-wave balance and effective radiation are about 2900-3000 and 1150-1300 MJ m^{-2}, respectively.

The intensity of efficiently used PAR (Photosynthetic Active Radiation) (0.38-0.1 μm km) per year is about 2150 MJ m^{-2}, three summer months require more than 45% of the annual sum. During the year the diffused PAR comprises the greater part of the sum. Duration of solar radiation is 1800-1850 h.

The albedo of natural cover area within a year increases from 20% in summer till 60% in January–February.

The mean values stated above are subject to considerable seasonable and long term annual variation under the influence of natural and anthropogenic factors. Thus our assessments of direct and total radiation for the first three decades prove that direct radiation under the influence of anthropogenic aerosol was reduced by 7-10%, and the total radiation by 1-2%. In towns, reduction of direct and total radiation is high. After big volcanic eruptions direct solar radiation in several months' up to 1.5 years decreases by 5-25%, and the total sum by several percents [5]. This radiation factor should be considered while studying climatic changes. Other reasons for climatic changes are discussed in details in [6-8].

The Polesye climate has been considerably changing for the past century. Most continuous and homogeneous series of observations are available for temperature, precipitation and wind rate. Let us consider these characteristic variations in the period of instrumental observations. Figure 1 provides temperature variations in the Polesye in the period of instrumental observations in various seasons. It shows that temperature rises occur in winter and spring seasons for the last 10-15 years. In autumn temperature does not vary or even decreases. Therefore, nowadays' warming is of winter character, while the warming of the 1930's was that of summer type and originated from radiation [3,5,7].

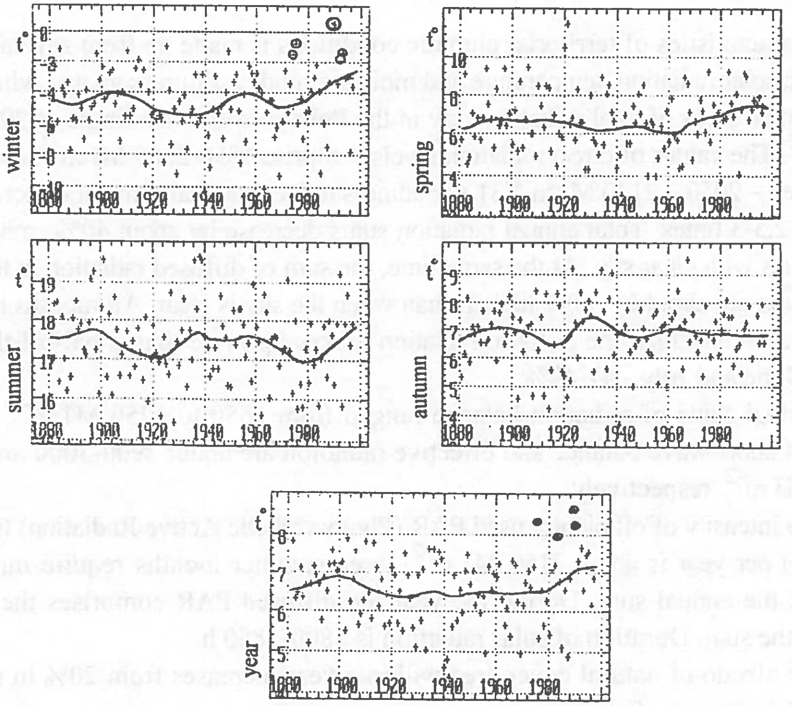

Fig. 1. Changes in temperature in the southern part of Belarus in various seasons and annually.

Variability in precipitation is specific with even greater diversity. Annual precipitation sum in the Polesye decreases. This reduction, when compared to the end of the previous century and the beginning of this century is about 100 mm or even bigger. This reduction is largely due to the precipitation in the warm half-year (Fig. 2).

Considerable changes occurred also in the wind patterns of the Polesye, comparing the period of 1945 to 1970, the wind rate in Brest and especially in Gomel regions was reduced by 15-20%. This reduction of wind rate is explained by the change in the total circulation of atmosphere, rather than anthropogenic factors or methodical reasons. It is also confirmed by the observations of the wind rate at the same latitude in the belt of Russia.

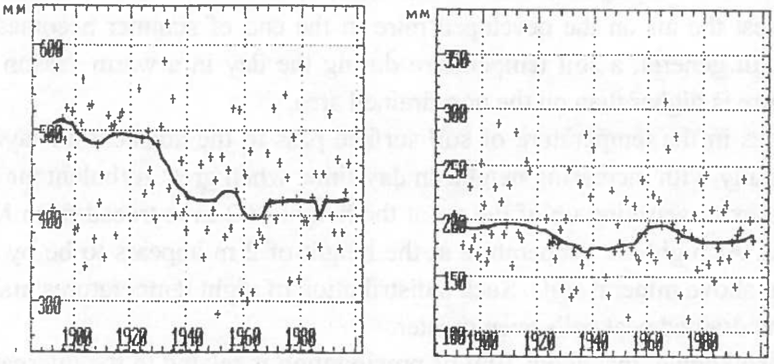

Fig. 2. Changes in precipitation in the southern part of Belarus taking into account warm (IV-X) and cold (XI-III) seasons.

Let us now discuss one of the most important factors in the climatic changes – variations in the properties of bedding layer as a result of large-scale amelioration of the Polesye and adjoining states.

Influence of amelioration on the regional climate of Belarus

In a number of works it was stated that there is no sufficient data to confirm that amelioration affects the climate of the Polesye region and neighbouring regions. Amelioration changes microclimatic conditions of mires and bogged lands only. Let us now consider whether this statement is correct.

Drainage of peat-mire soils results firstly in the variation of heat-physical soil properties (heat conductivity, heat capacity, moisture conductivity, etc.) A decrease in heat conductivity in peat-mire and 2.0-2.5 fold increase when compared to mineral soil was found. Volumetric heat capacity of peat soils results in considerable warming up during the day and cooling at night; hence the number of frosty days increases and warming up of tillage layer in spring slows down. Redistribution of the incoming solar radiation and transformation of phase moisture occur, albedo increases and radiation balance decreases. In the first half of the warm period the balance at the developed mire is less by 3-7%, and total evaporation for a warm period is 10-13% more than in the non-drained areas [9]. At the developed mires a 1.5-3.5 times higher moisture condensation on the soil surface, intensification of condensation and evaporation inside the soil is observed together with daily moisture rotation in the soil-atmosphere system. Total evaporation is higher on mires that were developed intensively for agricultural crops, especially in the first half of the warm period: at this time of the year the air on the developed mires is under intensive transpiration and hence more humid than on non-drained areas. After harvest the air on the developed mire in the end of summer becomes hotter and drier. In general, a soil temperature during the day in a warm season on the drained mire is higher than on the non-drained area.

Changes in the temperature of soil surface pass to the adjacent air layers and fade gradually with increasing height. In day-time, when great turbulent air mixing occurs, no extra warming up of the air at the height of 2 m is traced from May till September. At night air temperature at the height of 2 m appears to be by 1-2 ^{o}C lower than above mineral soils. Such a distribution of night temperatures makes the frost on the drained peat soils even greater.

It is also known, that about 10% of precipitation is related to the internal moisture rotation, which depends on the changes in the bedding. Change in the value of internal moisture rotation may cause the change of precipitation of several tens of mm in a warm season.

Air humidity may rise only in the first half of summer by 0.3-3% when ameliorated soils are used intensively for farming and at certain water regimes.

Observation data on temperature and precipitation collected so far allow to consider the above issue more profoundly in order to assess possible regional climatic changes affected by the amelioration.

Most intensive amelioration in Belarus was performed during the twenty year period from 1965 to 1984. The preceding period (1945–1964) is taken as a reference.

Temperature changes in the period of twenty years preceding intensive amelioration and subsequent periods in the southern part of Belarus where ameliorated lands are the biggest are presented in the Table 1. As a comparison, data for the northern Belarus, where intensive amelioration was not carried out are also given. Due to amelioration in the south of Belarus in June and July of 1965–1984 a decrease in temperature occurred in comparison to the preceeding period (1945 –1964). This conforms to the data collected for cultivated and non-ameliorated areas [7]. In August either lower decrease in temperature is observed or temperature rises. That does not contradict the observation data on cultivated and non-ameliorated areas either. In the northern areas a substantially lower temperature fall is noted, or even temperature rise in July and August (1985–1993).

Hence, the average monthly temperature variation of at least 0.3-0.4 ^{o}C is due to the intensive amelioration bordering areas of South Belarus, Ukraine and Poland.

Comparison of the decreased precipitation levels in the chosen periods showed that the rise by 11-25 mm in the precipitation level was observed in June - July during the period of intensive amelioration and the subsequent years (1985-1993). In August during active amelioration and after it, a decrease of precipitation level

Table 1. Temperature variation in summer months in southern and northern areas of Belarus

Month	South Belarus	North Belarus	Temperature difference between South and North
	Temperature difference T (1945-1964)-T (1945-1984)		
VI	0.62	0.22	0.40
VII	0.72	0.31	0.41
VIII	0.36	0.05	0.31
	Temperature difference T (1945-1964)-T (1985-1993)		
VI	0.51	0.05	0.46
VII	0.20	-0.08	0.28
VIII	-0.25	-0.32	0.07

by 10-35 mm was observed. These results do not contradict the experimentally established fact that an increase of total evaporation on mires that were intensely developed for agricultural crops, especially in the first half of the warm period after harvest on the cultivated mires tooke place when air becomes warmer and drier.

Considering the above, one can draw conclusion that using intensely ameliorated soils in agriculture, the increases air moisture in the first half of summer and decreases it in the second half occurred. Precipitation level should rise in the first half of summer and fall in the second.

Therefore, amelioration resulted in 10-31 mm regional changes of precipitation amount in southern part of Belarus.

As a conclusion it should be noted that comparison of June and July temperatures in the background period (1945–1964) with the temperatures of the months in the active amelioration period (1965–1984) and the last decade, showed that temperature reduction appears to be lower in the last decade than in the active amelioration period. This can be related to the compaction of drained peat land and its mineralization as well as to the more thick grass cover formed and extensive agricultural utilization of drained areas. Observations of nature on the developed and non-drained peat land proved that peat cover and agricultural crops reduce temperature decrease in June-July on the developed peat mires. In the period of active amelioration, open peat surfaces covered greater areas than in the last decade. That evidently resulted in more substantial changes of natural heat and moisture cycles on those anthropogenically damaged territories.

While analysing precipitation dynamics, decrease of wind velocity observed by the Belarussian meteorological stations can be related to evaporation and air moisture decrease, and hence abatement of local moisture rotation and decrease in precipitation. In comparison to the rest of Belarusian territory, relatively greater decrease of wind velocity (almost by 20%) occurred in the last two decades in south-east areas of the state. On the same areas a greater decrease of precipitation in the end of spring and in summer has occurred lately.

In the northern part of Belarus changes in precipitation differ from the southern part. Thus, rise in precipitation in the north of the state is observed during all summer months in the last years; an increase in the level of precipitation is especially intense in that time in comparison to the active amelioration period (by 25-35 mm).

Therefore, there are reasons to assume that amelioration of southern Belarusian areas and the adjoining states (Ukraine, Poland) resulted not only in microclimatic changes but also in the regional changes of climate in Belarus.

Assessment of anthropogenic "signal" in the changes of climate

Investigations on the peculiarities of climate in towns show that a town influences practically all climate parameters such as: formation of "heat islands", reduction of solar radiation inflow, precipitation amount, number of foggy days, wind rate reduction and especially frequency of high velocities. The greatest differences in air temperature are observed at night hours at cloudless, windless weather. Average annual temperature in big towns is higher in comparison to suburbs by several tenths of °C. In the case of very big towns temperature difference exceeds 1 °C [1]. According to some earlier studies, a marked difference in "town - suburb" temperatures is stipulated by the presence of "heat islands" in towns.

The conducted analysis of mean values and differences in the mean daily values of temperature in Maryina Gorka and Minsk in the period 1966–1997 show a rise in mean daily temperatures both in Minsk and Maryina Gorka. The rise is well marked in winter and spring (about 1 °C). In summer and fall a small increase of differences in mean daily temperatures in Maryina Gorka and Minsk in the period 1966–1990 was observed. The rise in the differences in mean daily temperatures in winter and spring (Fig. 3) is less distinct. After the 1990 the difference in mean daily temperatures in Maryina Gorka and Minsk has not risen, which probably results from aerosol pollution of Minsk. In fact, mean dust concentration in the period of 1975–1989 was 230 μkg g^{-3}, and in the period of 1990–1998 only 55 μkg m^{-3}. The difference in the mean dust concentration Minsk and Berezinskiy Biospheric Reserve (background station) in 1987–1991 exceeded 70-160 μg m^{-3}, and in the past years it was less than 40 μg m^{-3}, i.e., aerosol pollution in Minsk as a result of the decrease of industry production and arrangement of nature protection undertaken there resulted in a considerable reduction.

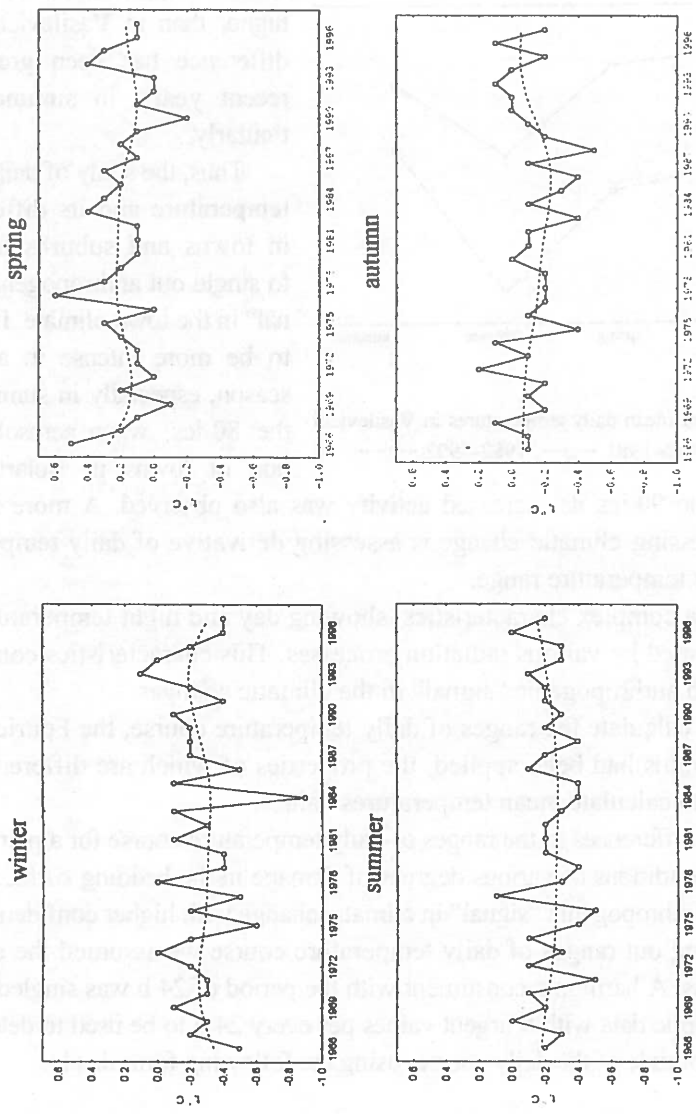

Fig. 3. Differences of mean daily temperatures in Maryina Gorka vs. Minsk.

Therefore, analysis of diffe-rences of mean daily values of temperature in Maryina Gorka and Minsk show that in Minsk it is warmer during greater part of the year by several tenths of a degree than in Maryina Gorka.

Differences of mean daily temperatures in Vasilevichi and Gomel (taking into account geographical locations of stations) are presented in Fig. 4. It is clear, that all year

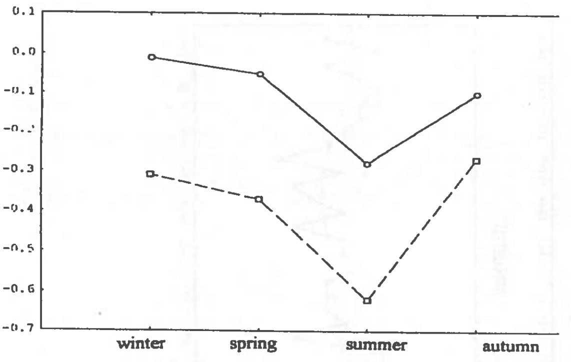

Fig. 4. Differences of mean daily temperatures in Vasilevichi vs Gomel. 1966-1981 —o—, 1982-1992 --▫--.

round temperature in Gomel is higher than in Vasilevichi. This difference has been greater in recent years, in summer particularly.

Thus, the study of daily mean temperature and its differences in towns and suburbs allowed to single out anthropogenic "signal" in the town climate. It seems to be more intense in a warm season, especially in summer. In the 80-ies, when aerosol pollution of towns in Belarus was higher than in the 90-ies its increased activity was also observed. A more significant task of assessing climatic change is assessing derivative of daily temperature values, i.e., daily temperature range.

First, this is a complex characteristics, showing day and night temperature pattern which is formed by various radiation processes. This characteristics contains a more accentuated anthropogenic "signal" in the climatic changes.

Secondly, to calculate the ranges of daily temperature course, the Fourie transformations apparatus had been applied, the properties of which are different from transformations to calculate mean temperatures values.

Hence, these differences in the ranges of daily temperature course for a pair of stations located in conditions of various degrees of damage in the bedding surface allow to single out the anthropogenic "signal" in climatic change with higher confidence.

While working out ranges of daily temperature course we assumed the ergodicity of the process. A harmonic constituent with the period of 24 h was singled out of a number of synoptic data with 8 urgent values per every 24 h to be used to determine the $\left|\overline{H}_{xy}(f)\right|$ amplitude of the daily course, using the following formula (1):

$$\left|\overline{H}_{xy}(f)\right| = \frac{\left|\overline{G}_{xy}(f)\right|}{\overline{G}_{xx}(f)} \tag{1}$$

where:

$$\overline{G}_{xy}(f) = \frac{2}{n_d T} \sum_{k=1}^{n_d} X_k(f,T) Y_k(f,T) \tag{2}$$

where: $\overline{G}_{xy}$ - assessment of mutual one-side spectrum for a pair of sets of X_k realizations and Y_k, $(k\text{-}1)T \le t \le kTD$, k=1, n_d, two stationary ergodic occasional processes {x(t)} and {y(t)}; f – frequency; X_k, Y_k – finite Fourie transform of kth realization $X_k(t)$ and $Y_k(t)$ of the length of T of every process. $X_k(t)$ regarded as δ - function, $y_k(t)$ a series of synoptic hours data on air temperature for a kth day was regarded; T=24 h – a period of function $y_k(t)$ for each k; n_d a number of realizations $y_k(t)$, $(k\text{-}1)T \le t \le kT$, k=1, n_d, i.e., a number of observation days, for which an amplitude of daily temperature course is to be determined.

As $x(t) = \delta(t)$, so $X(f) = 1$ for all frequencies f, and:

$$\overline{G}_{xy}(f) = 2/T, \quad \overline{G}_{xy}(f) = \frac{2}{n_d T} \sum_{k=1}^{n_d} Y_k(f,T) \tag{3}$$

It is possible to apply the formulae (1).

To find out an occasional error ε_r in the evaluation of the amplitude computing $|H_{xy}(f)|$ the formula (4) was used:

$$\varepsilon_r = \frac{\sqrt{1-g^2(f)}}{|\gamma_{xy}(f)|\sqrt{2n_d}} \tag{4}$$

where: $\gamma^2_{xy}(f)$ - function of coherence, estimated through:

$$\gamma^2_{xy}(f) = \frac{|\overline{G}_{xy}(f)|^2}{\overline{G}_{xx}(f)\overline{G}_{yy}(f)} \;. \tag{5}$$

While describing the results in the variation of extreme daily temperatures, data on the basic factors are needed to determine a daily temperature course.

Let us enumerate factors forcing temperature rise at night, in italics factors which are also valid during the day time:

1) Q_o decrease (surface heat emission due to the turbulent heat exchange) as a result of:
   - wind speed abatement in town;
   - turbulent exchange abatement in the lower (100–300 m) atmospheric layer due to the formation of stable night stratification;
2) B_a increase (in the flow of the atmospheric radiation back) related to the close-ups of atmospheric window transparency due to the following reasons:
   - rise of contents of greenhouse gases in the atmosphere. Rise of minimum temperature along with greenhouse gases appears to be higher than the rise of maximum temperature;

- more powerful cloud cover above town than in the rural sites due to specific thermodynamic conditions and increased content of condensation; increased aerosol pollution in towns;

3) Q_l value (heat loss for drainage to soil) changes the sign at night and is more meaningful in towns than in suburbs ("heat island"– town – is getting cool slower and monotonously);
4) B_o decrease (proper flow of terrestrial radiation) and, respectively, decrease of B * (outgoing radiation) due to the reduction in the value of index of sky openness in town canyons;
5) LQ'_o decrease (heat loss through evaporation) due to small areas under town vegetation;
6) presence of "heat islands" in a town, stimulated by anthropogenic factors $-H_a$. H_a peak values may reach 100 wt m^{-2} [3];
7) availability of moisture island;

Note, that the link between minimum temperature and cloudiness depends on the season. In summer and spring the link is negative and statistically not important, and in winter and fall – positive and also statistically insignificant. The relation of mean annual values of minimum temperature and cloudiness is weak negative.

The maximum (day) temperatures are promoted by a considerable S decrease (of the flow of total incoming solar radiation) due to:

- conditions, promoting formation of convection clouds;
- contamination of air with aerosols at cloudless sky. When the air is very polluted and the sun is not high, the relaxation of total radiation may exceed 30%. This decrease is getting a bit smaller with the increase of back radiation B_a due to heating of aerosols by the incoming and reflected (at the albedo of the snow cover of over 0.6 -) solar radiation.

The decrease of day temperatures is mitigated by the reduction of A albedo due to the influence geometery of town canyons. Besides, it should be noted that the character of aerosol impact upon the minimum and maximum temperatures rise is determined by the properties of these aerosols. Availability of cloudiness suggests the role of anthropogenic aerosols in the reduction of total radiation of about 0.5%. Because of that, the smallest influence of aerosols on the thermal regime is registered in cold season when cloudiness is maximum.

Analysis of differences in daily ranges of temperatures in Maryina Gorka and Minsk shows that they are determined by season: maximum differences in daily temperature ranges are observed in summer, and the minimum in winter (Fig. 5a).

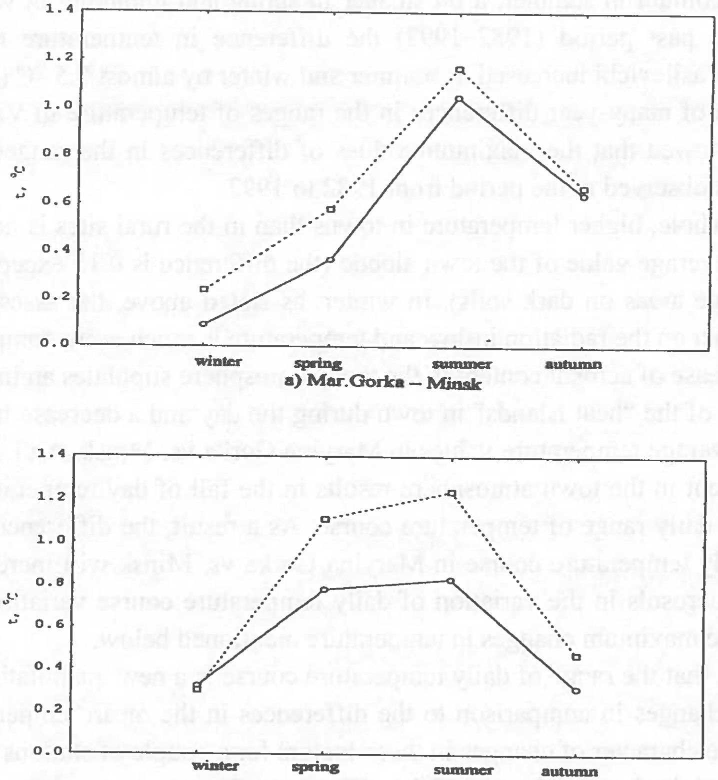

Fig. 5. Differences in the ranges of daily temperature courses. 1966-1981 —o—, 1982-1992 --□--.

Distinct many years changes in daily ranges of temperature differences in Maryina Gorka vs Minsk are also noted. They appeared to be higher in the 80-ties of these century. Year-by-year analysis of variation in the differences of daily temperature ranges in Maryina Gorka vs. Minsk allowed to reveal positive trends in the differences of daily temperature ranges through all the year seasons except for autumn. However, as in the case of analysing mean daily temperature differences in Maryina Gorka vs. Minsk, a decrease in differences of daily temperature ranges is observed in these stations in the last years (Fig. 6).

Therefore, the amplitude of daily temperature course is smaller in Minsk than in Maryina Gorka. This temperature fall may be related to either the rise of minimum night temperatures or to the reduction of day (night) temperatures, or to both of them.

The analysis by analogy of variation in the ranges of daily temperatures course was carried out for the part of stations Vasilevichi – Gomel. As in the case of Minsk –

Maryina Gorka, the difference of temperature ranges in Vasilevichi and Maryina Gorka is maximum in summer, a bit smaller in spring and minimum in winter and fall. For the past period (1982–1992) the difference in temperature ranges in Gomel and Vasilevichi increased in summer and winter by almost 0.5 ^{o}C (Fig. 5b).

Analysis of many-year differences in the ranges of temperature in Vasilevichi vs Gomel showed that the maximum values of differences in the ranges of temperature was observed in the period from 1982 to 1992.

On the whole, higher temperature in towns than in the rural sites is not related to a higher average value of the town albedo (the difference is 0.15 except for forest and tillage areas on dark soils). In winter, as stated above, the assessment of aerosol impact on the radiation inflow and temperature is much more complicated.

The increase of aerosol content in the town atmosphere stipulates an increase in the intensity of the "heat islands" in town during the day and a decrease in the difference of average temperature values in Maryina Gorka vs. Minsk. An increase in aerosol content in the town atmosphere results in the fall of day temperatures and reduction of daily range of temperature course. As a result, the differences of the range of daily temperature course in Maryina Gorka vs. Minsk will increase. The key role of aerosols in the variation of daily temperature course variation is also proved by the maximum changes in temperature mentioned below.

The fact, that the range of daily temperature course is a new quantitative factor of climatic changes in comparison to the differences in the mean temperatures is proved by the character of changes in these factors for a couple of stations Maryina Gorka – Minsk in the past decade. If the difference of mean temperatures does not form a trend, then the difference of ranges in the daily temperature course Maryina Gorka vs. Minsk has a positive trend all the year round.

It is of special interest to assess the anthropogenic "signal" in the town climate and to evaluate the reason for the changes in the ranges of daily temperature courses. It means studying variations in the minimum and maximum air temperatures.

Analysis of differences in the maximum and minimum temperatures in big towns and other settlements revealed that the average maximum temperature in big towns is lower than in other rural localities. A drop in the maximum temperatures in summer, spring and fall in big towns compared to other settlements in the past years proved lowering of temperature in warm season due to the reduction of radiation inflow. It is caused by the increase of aerosol content in big towns and by other factors stated above.

Figure 7 presents differences in the maximum and minimum temperatures at the stations indicated by seasons and for the whole year. The picture shows, that the maximum temperature at the station Maryina Gorka is higher than at the station

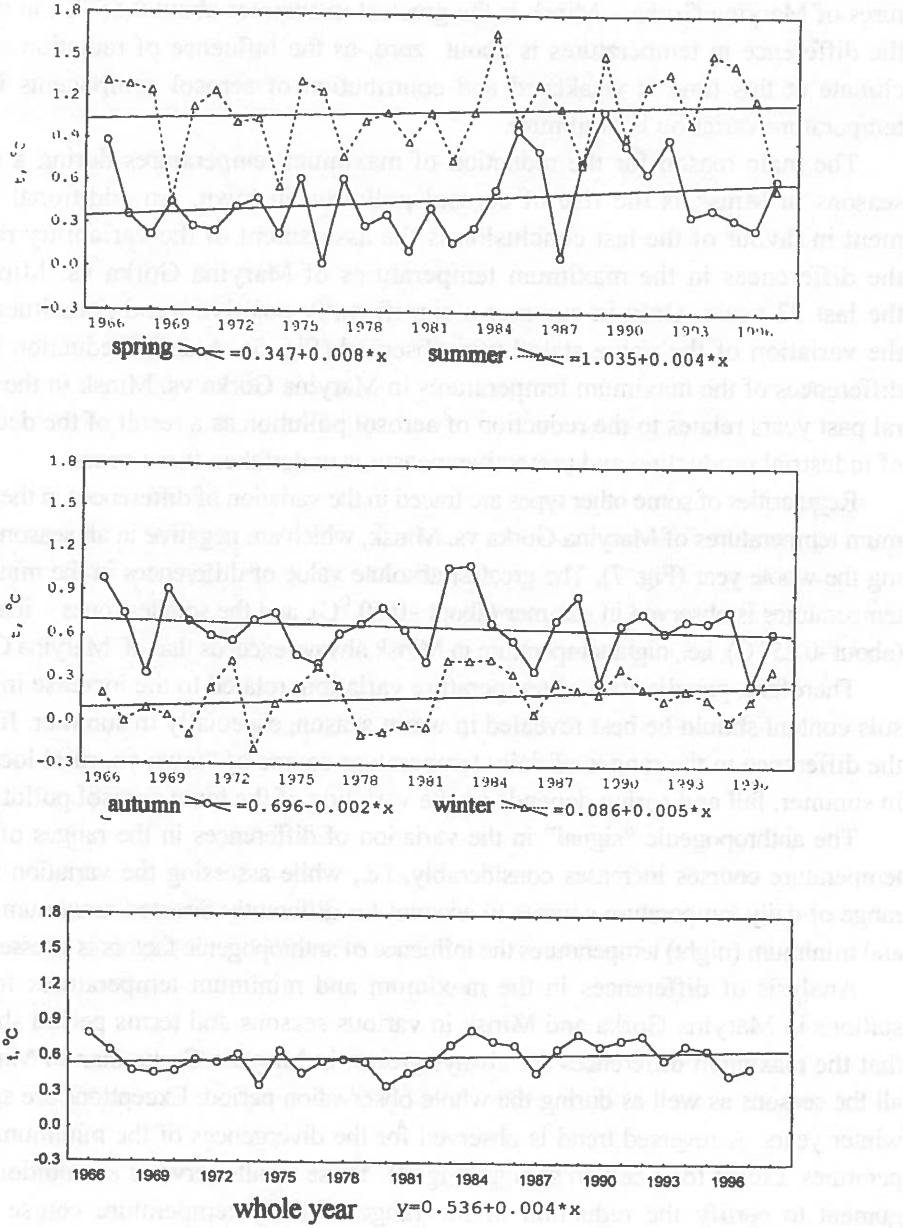

Fig. 6. Differences in the ranges of daily temperature courses. Maryina Gorka vs. Minsk.

Minsk in all seasons and during the year. The difference in the maximum temperatures of Maryina Gorka – Minsk is the greatest in summer about 0.55 °C, in winter the difference in temperatures is about zero, as the influence of radiation on the climate at this time is weakened and contribution of aerosol components in the temperature variation is minimum.

The main reason for the reduction of maximum temperatures during a warm seasons in Minsk is the rise of aerosol pollution in town. An additional argument in favour of the last conclusion is the assessment of the variability rate of the differences in the maximum temperatures of Maryina Gorka vs. Minsk in the last 32 years. Only in summer a significantly positive trend constituents in the variation of the value stated was observed (Fig. 5). A small reduction in the differences of the maximum temperatures in Maryina Gorka vs. Minsk in the several past years relates to the reduction of aerosol pollution as a result of the decrease of industrial production and protective measures undertaken these years.

Regularities of some other types are traced in the variation of differences in the minimum temperatures of Maryina Gorka vs. Minsk, which are negative in all seasons during the whole year (Fig. 7). The greatest absolute value of differences in the minimum temperatures is observed in summer (about –0.60 °C), and the smallest ones – in spring (about -0.25 °C), i.e., night temperature in Minsk always exceeds that of Maryina Gorka.

Therefore, peculiarities of temperature variation, related to the increase in aerosols content should be best revealed in warm season, especially in summer. In fact, the difference in the ranges of daily temperature course of "town vs. rural locality" in summer, fall and spring depends on the variation of the town aerosol pollution.

The anthropogenic "signal" in the variation of differences in the ranges of daily temperature courses increases considerably, i.e., while assessing the variation in the range of daily temperature courses to account for differently directed maximum (day) and minimum (night) temperatures the influence of anthropogenic factors is stressed.

Analysis of differences in the maximum and minimum temperatures for the stations in Maryina Gorka and Minsk in various seasons and terms period showed that the maximum differences are always greater in Maryina Gorka than in Minsk in all the seasons as well as during the whole observation period. Exceptions are several winter years. A reversed trend is observed for the divergences of the minimum temperatures, except for a certain springs (Fig. 7). These results serve as an additional argument to certify the reduction in the range of daily temperature course when compared to the rural sites and small towns, i.e., anthropogenic activity "cuts off" the range of daily temperature course in big towns. This process is best revealed in warm season and especially in summer. The impact of urbanization on total radiation and heat balance is distinguished in day and at night, and interdependent

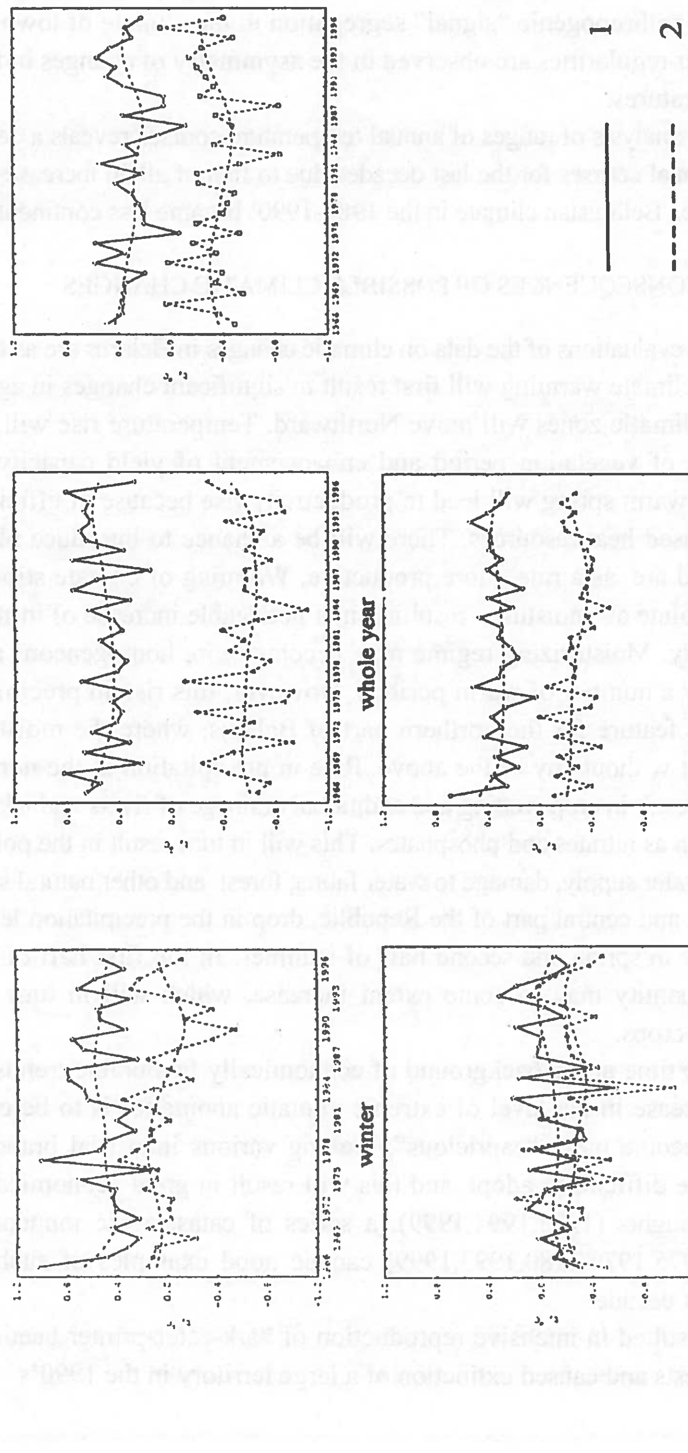

Fig 7. Differences in the maximum (1) and minimum (2) temperatures of Maryna Gorka vs. Minsk stations.

compensation of variation in single components of the balance greatly complicates the problem of anthropogenic "signal" segregation in the climate of towns and rural sites. Similar regularities are observed in the asymmetry of changes in the mean monthly temperatures.

Preliminary analysis of ranges of annual temperature courses reveals a decrease in the range of annual courses for the last decades due to first of all an increase in winter temperatures, i.e., Belarusian climate in the 1980-1990' became less continental.

CONSEQUENCES OF POSSIBLE CLIMATIC CHANGES

Preliminary evaluations of the data on climatic changes in Belarus are as follows:

In Belarus climate warming will first result in significant changes in agriculture and forestry. Climatic zones will move Northward. Temperature rise will result in the lengthering of vegetation period and enhancement of yield capacity. Earlier sowing, due to warm spring will lead to productivity rise because of efficient utilization of increased heat resources. There will be a chance to introduce plants that are ripe late and are, as a rule, more productive. Warming of climate stipulates an increase of absolute air moisture, resulting in a noticeable increase of in-mass precipitation quality. Moisturizing regime may become more homogeneous as a specific feature for a number of warm periods. However, this rise in precipitation is a characteristic feature for the northern part of Belarus, where the moistening of soil is sufficient without any of the above. Rise in precipitation in the north of the Republic may result in crop wetting and additional drainage of rivers and lakes of nutritious salts such as nitrates and phosphates. This will in turn result in the pollution of ponds, broken water supply, damage to water fauna, forest and other natural sites.

In the south and central part of the Republic, drop in the precipitation level may occur, especially in spring and second half of summer. In the first half of summer precipitation quantity may to some extent increase, which will in turn increase water supply to crops.

At the same time at the background of economically favourable trends in temperature an increase in the level of extreme climatic anomalies is to be expected. Climate will become more "capricious", making various industrial branches and agriculture more difficult to adopt, and this will result in great economical losses. Three great droughts (1992,1994,1999), a series of catastrophic inundation and floods (1974,1975,1979,1980,1993,1999) can be good examples of such phenomena in the past decade.

Droughts resulted in intensive reproduction of bark-eater-printer beetle, which endangered forests and caused extinction of a large territory in the 1990's.

Results of the climate warming for biological systems are as follows:

1) negative consequences:
   - total aridization of vegetation cover, followed by a negative introduction of steppe types and forest-steppes in a boreal one, including forest ecosystems with parallel ousting of boreal cenotic elements, where there are important forest trees, such as spruce, alder, pine, exist;
   - increase of probability of appearance of extreme climate phenomena (droughts, hurricanes, mass snow-falls, redundant precipitation, etc.), causing direct damage by frosts or initiating epiphytoties and outbursts of mass reproduction of forest pests;
   - deterioration of assimilation conditions due to the increase of the atmospheric transparency;
   - deterioration of water supply conditions due to total ground water table decrease on large areas as a result of complex of anthropogenic and climatical factors;
   - abundance of farm and forest pests, calling for mass application of pesticides, and hence, water and soil pollution;
2) positive results:
   - prolonged vegetation period;
   - relaxation of physical evaporation from the soil surface and surface waters, as well as transpiration due to wind abatement in some zones;
   - total acceleration of elemental circulation in the forest ecosystems;
   - rise of plants productivity due to the reduced CO_2 level limit reduction as a result of its concentration increase in the atmosphere;
   - enrichment of bio-diversity by the introduction of thermal types – and xerophyle European-small-Asian and Euro-Siberian – Aral-Caspian biotic complexes.

The climate warming will be favourable for energy balance and production and construction industry. Warm winters will reduce consumption of organic fuel and decrease polluting effluents. Increase of winter temperature will improve conditions of outdoor construction works and decrease expenses on various types of construction work.

REFERENCES

1. **Bendat J., Pearsol A.:** Applications of Correlation and Spectrum Analysis. M. 1983.
2. **Brazdil R., Machu R., Budikova M.:** Temporal and Spatial Change in Maximums and Minimums of Air Temperature in the Czech Republic in the period of 1951-1993. Contemporary Climatology. Ed. Brazdil R., Kolar M., Brno, 93-102, 1994.
3. Climate of Belarus. Edit. Corr.member NASB Loginov V.F. EGS ASB, 23, 4, 1996.

4. **Karl T.R., Kukla G., Gavin J.:** Global warming: evidence for asymmetric diurnal temperature change. Geoph. Res. Lett., 2253-2256, 18, 1991.

5. **Loginov V.F.:** Reasons and Consequences of Climate Changes. Minsk. Nauka i Tekhnika, 320, 1992.

6. **Loginov V.F.:** Amelioration impact upon the regional climate of Belarus. Natural Resources, 24-27, 1997.

7. **Loginov V.F., Mikutskiy V.S.:** Variation of extreme daily temperatures in the conditions of various anthropogenic load. Natural Resources, 1, 1997, 129-134.

8. **Loginov V.F., Pugachevskiy A.V.** Belarusian climate change and forest vegetation dynamics. Proceed. of Int. Sci.-pract. Conf. "State and Monitoring of Forest on the Border of XXI Century", Minsk, April 7-9, 29-32, 1998.

9. **Shebeko V.F.:** Change of Microclimate Due to Mires Amelioration. Minsk. Nauka i Tekhnika, 286, 1997.