Warm season degree-days in south-western Belarus and their dynamics

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1. Introduction

During the last decade the question of the influence of natural and anthropogenic factors on climatic changes is widely discussed. There is a consensus among the international Earth Science community that most of the ongoing “global warming” (an increase of global surface air temperature to unprecedented values for the period of instrumental observations) has occurred due to anthropogenic emissions of greenhouse gases (Intergovernmental Panel on Climate Change, IPCC, 2007). The IPCC Report projects for the middle of the 21st century an increase of approximately 2.5°C for the annual surface air temperature of the Northern Hemisphere and for the northern extratropical land areas where Belarus resides, higher temperature changes are expected. For Belarus, such changes are rather significant and will have a serious impact on the economy. In particular, the temperature increases will lead to a longer duration of the vegetation period. The nation is located in an area of sufficient moisture supply (droughts are quite rare here) and the projected temperature rise (if the moisture supply (precipitation) remains the same), will allow higher production and harvest of agricultural crops. The temperature rise will inevitably cause structural changes in the hydrological cycle. First it will cause an increase in total evaporation. Associated with it changes in precipitation are also possible. Predicted climatic changes in surface energy and water budget in Belarus imply a necessity to account for these changes in planning of agriculture, water supply, melioration, and other human activities.

2. Climatology and changes in the seasonal cycle: Surface air temperature

Surface air temperature is one of the basic climate characteristics. In the warm season, it is mostly defined by the surface radiation balance while during the cold period of the year, advection heat sources (i.e., atmospheric circulation) significantly contributes to its climatological pattern. We shall describe the seasonal cycle using the average monthly surface air temperature. Maximum monthly surface air temperatures over Belarus are registered in July (63 % of years), and minimum - in January (53 % of years). In certain years the warmest months are observed in June (17 % of years) and in August (20 % of years), and the lowest - in February (32 % of years) and December (13 % of years).

For numerous engineering applications, average long-term values of surface air temperature and its derivatives (normals) are used. However, in different reference sources for these normals, the temperature values vary because different averaging periods were used in these sources.

The normals are supposed to be calculated for the “reference” period that is sufficient for an estimation of the parameters of its probabilistic distribution. It is anticipated that these parameters should remain “stable” outside of the given period for sufficiently long time. In the changing climatic conditions, this stability for any pre-selected period cannot be stipulated in advance. It is a function of the time allocation and duration of the reference period and the presence of autocorrelation in the time series. It is difficult enough to pick the climatological time series in Belarus that have statistical homogeneity. Durations of the time series are usually over 50 years. Presence of considerable missing data, changes in observational practice, replacement of the instruments, etc. may not allow receiving statistically homogeneous time series. Therefore, for analyses of these time series, we used metadata (data about the data) in addition to statistical methods. Metadata allow us to account for artificial (non-climatic) changes in our time series prior to any statistical analyses.

To design various engineering objects with limited life time we use “normals”. Their estimates start with temporal averaging of initial data. The majority of engineering objects will last for at least 20-30 years and it is necessary to consider in their design expected changes in climate. When using long time series for engineering design, it is possible to deform the actual situation because the trends, which manifested themselves mostly during the last decades, are smoothed out after the temporal averaging over the entire reference period and cannot serve as a good guide for the future climate conditions.. Therefore, we calculated climatic normals for engineering assessments, using only the last 30 years (1975 - 2004). This approach allows us to account (to some extent) for the ongoing climatic changes. To estimate the latest temperature changes over the nation, we used of the data archives of the Belorussian Republican Hydrometeorological Centre. For our research we selected the 60-year-long time series of surface air temperatures from 1945 to 2004 and averaged them over six consecutive decades. The time series were partitioned into two 30-year parts: from 1945 to 1974 - before the construction of major melioration systems in the nation and their consequent impact on environment (the land reclamation peak was in the 1972 through 1974 period) and from 1975 to 2004, which is a period of stable functioning of the constructed hydro-melioration systems.

Table 1. Average long-term values of air temperatures and their difference in the investigated territory, °C

City	Period	1	2	3	4	5	6	7	8
Brest	1975-2004	-2.7	-2.1	1.9	8.2	14.1	16.8	18.6	18.1
	1945-1974	-4.7	-3.6	0.0	7.7	13.5	17.1	18.5	17.6
	difference	2.0	1.5	1.9	0.4	0.6	-0.2	0.1	0.5
Pruzhany	1975-2004	-3.6	-3.2	0.9	7.4	13.3	16.2	17.5	17.3
	1945-1974	-5.9	-4.7	-0.6	6.9	12.8	16.6	17.9	16.9
	difference	2.3	1.5	1.5	0.4	0.5	-0.4	-0.4	0.4
Pinsk	1975-2004	-3.7	-3.2	1.2	8.0	14.1	16.8	18.4	17.7
	1945-1974	-6.3	-4.8	-0.8	7.0	13.3	17.0	18.1	17.0
	difference	2.6	1.6	2.0	1.0	0.8	-0.2	0.3	0.7
Ivacevichi	1975-2004	-3.8	-3.3	1.0	7.5	13.7	16.6	18.1	17.2
	1945-1974	-6.1	-4.8	-0.8	7.0	13.1	16.8	18.0	17.0
	difference	2.3	1.5	1.8	0.5	0.6	-0.3	0.1	0.2
Gancevichi	1975-2004	-4.2	-3.8	0.6	7.3	13.4	16.3	17.9	17.0
	1945-1974	-6.6	-5.1	-1.1	6.8	12.8	16.5	17.7	16.5
	difference	2.4	1.3	1.7	0.6	0.6	-0.2	0.2	0.4
Baranovichi	1975-2004	-4.4	-4.0	0.3	7.1	13.2	16.1	17.4	17.0
	1945-1974	-6.6	-5.4	-1.5	6.5	12.8	16.5	17.8	16.9
	difference	2.2	1.4	1.8	0.6	0.4	-0.4	-0.4	0.2

City	Period	9	10	11	12	Year	Σ_{4-10}	$\Sigma_{>10°C}$
Brest	1975-2004	13.1	8.1	2.5	-1.5	7.9	97.0	2595
	1945-1974	13.2	7.5	2.6	-1.6	7.3	95.0	2530
	difference	-0.1	0.7	-0.1	0.0	0.6	2.0	65.3
Pruzhany	1975-2004	12.4	7.3	1.7	-2.3	7.1	91.4	2412
	1945-1974	12.6	6.8	1.9	-2.2	6.6	90.5	2382
	difference	-0.2	0.5	-0.1	-0.1	0.5	0.9	30.2
Pinsk	1975-2004	12.7	7.4	1.7	-2.5	7.4	95.1	2532
	1945-1974	12.5	7.3	1.9	-2.6	6.6	92.1	2436
	difference	0.2	0.1	-0.2	0.1	0.7	2.9	96.3
Ivacevichi	1975-2004	12.4	7.3	1.6	-2.4	7.1	92.7	2455
	1945-1974	12.5	6.6	1.7	-2.3	6.5	91.0	2398
	difference	-0.1	0.6	-0.1	-0.1	0.6	1.7	57.3
Gancevichi	1975-2004	12.0	6.9	1.4	-3.0	6.8	90.8	2394
	1945-1974	11.9	6.3	1.5	-2.7	6.2	88.4	2314
	difference	0.2	0.6	-0.1	-0.3	0.6	2.4	80.0
Baranovichi	1975-2004	12.0	6.8	1.1	-3.0	6.6	89.7	2355
	1945-1974	12.4	6.5	1.2	-2.9	6.2	89.4	2346
	difference	-0.3	0.4	-0.1	-0.1	0.5	0.3	9.2

To estimate the dynamics of temperature changes over the southwestern part of Belarus, we calculated the differences of average long-term values of temperatures of air for 1975-2004 and for 1945-1974 (Table 1).

The warming over the entire southwestern Belarus in the first half of year (January - May), and the January warming were so considerable, that January ceases to be the coldest month in the year. The increase of the surface air temperature in March is connected with frequent low-snow cold seasons in 1975 – 2004, and thus with a decrease of the heat expenditures on snowmelt. As a result, most of radiation and advection spring heat influxes began contributing to the air heating. Certainly, this tendency should lead to socio-economic decisions. Growth of winter and spring temperatures leads to an increase of duration of the vegetation period for agricultural crops. For the southwest part of Belarus, this provides and (as we hope) will provide in the future more favorable temperature conditions for intensification of agricultural production. As a whole, growth of the sums of temperatures of air for the warm period (April - October) takes place also. A special importance for agriculture production is represented by an increase in the degree-days with the surface air temperature above 10°C (Figure 1).

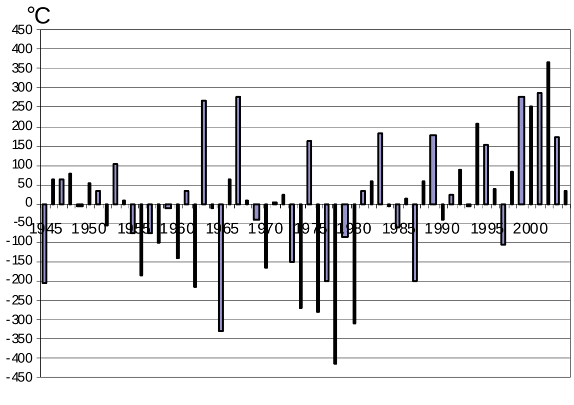

Figure 1. Deviation of the sums of air temperatures >10°C from long-term average for 1945 - 2004 in Brest

The same situation (as in Brest) is observed at other stations of the southwestern part of Belarus. The largest gain in degree-days for the last thirty years is observed in Pinsk 96.3°C (3.8 %). Taking into account that for last thirty years, the degree-days with T > 10°C increase in a direction from north to east and southwest, there was a displacement of the borders of the agro-climatic zones in Belarus by approximately 40-50 km in this direction.

3. Conclusions

In the recent past, the southwest part of Belarus had an insufficient amount of warm season degree-days for high-productive crops. In the last decades, the regional temperatures in the warm season have increased and agriculture fields began receiving additional surface heat. This provides an opportunity for intensification of agricultural production (the use of new highly productive kinds of agricultural crops). Climate of Belarus became less continental and the annual amplitudes of surface air temperature in the region have decreased.

References:

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