# Climate change monitoring on the basis of phytophenological observations in Kaliningrad region

# Suivi du changement climatique sur la base d'observations phytophénologiques dans la région de Kaliningrad

G.M. Barinova[1], M.I. Kokhanovskaya[1]

**Abstract**

Increase of the frequency of extreme weather situations and unpredictable meteorological processes in Kaliningrad (previously Königsberg, East Prussia) region is shown for 30 years period. Findings of the monitoring of regional climate change on the basis of phytophenological observations are presented. Comparison of archive data from East Prussia (XIXth century) and results of current research in Kaliningrad region is provided. It is shown that phytophenological shifts are connected with air temperature anomalies in spring months. Also some problems of regional phytophenological monitoring as participating scientific project are discussed.

**Keywords**

climate change, monitoring, phenoindicator plants, Kaliningrad Region, East Prussia.

**Résumé**

La fréquence des situations météorologiques extrêmes et des processus météorologiques imprévisibles à Kaliningrad (anciennement Königsberg, en Prusse orientale) est en augmentation sur une période de 30 ans. Les résultats des observations phytophénologiques permettent de suivre le changement climatique régional. Les données d'archives de la Prusse orientale (XIXe siècle) ont été comparées aux résultats issus de la recherche actuelle dans la région de Kaliningrad. Il est démontré que les changements phytophénologiques sont liés à des anomalies de température lors des mois de printemps. En outre, certains problèmes de suivi phytophénologique au niveau régional, comme la participation au projet scientifique, sont discutés.

**Mots-clés**

changement climatique, surveillance, plantes phénoindicatrices, région de Kaliningrad, Prusse orientale.

*(1) Immanuel Kant Baltic Federal University, ul. Aleksandra Nevskogo, Kaliningrad, Russia – ecogeography@rambler.ru*


https://doi.org/10.4267/pollution-atmospherique.5009

## 1. Regional climate change for the last 30 years

Recent studies show that together with climate warming there is an increase of thermal and hydrological characteristics extremeness. As a consequence, there is an increase of dangerous natural processes, and also some changes in vegetation and wildlife (Kasimov et al., 2012; Faschchuk, 2010). In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), among effects of climate change in Europe earlier greening and fruiting in temperate and boreal zone, earlier arrival of migratory birds are shown (IPCC, 2014).

The climate of the Kaliningrad region is transitional from maritime to continental. It is characterized by mild autumn and winter; the frost-free period is quite long. The mean annual air temperature is 7,2 °C. The region is a humid area (750-800 mm of rain per year) together with seasonality and inter-annual and intra-annual variability in precipitation. Precipitation falls mainly in the form of rain (Geographical atlas of Kaliningrad region, 2002).

Main trends in air temperature change in Kaliningrad region correspond to the trends in the average temperature of the Northern Hemisphere. There was a growth of surface temperature since the last quarter of the XIX$^{th}$ century to the 40s; then relative cooling to early 70s occurred; rapid temperature rise in the last decade of XXth century, and especially at the beginning of the XXI$^{th}$ century followed (Barinova et al., 2004).

Anomalies of mean annual air temperature calculated as deviations from the average for the period 1961-1990 range from + 2,5 °C (1989) to -1,6 °C (1956, 1973).

An essential feature is the increase in the value of anomalies, since the late 70s of the last century. An asymmetry in the number of positive and negative deviations during the study period is registered: the number of positive anomalies is twice more than the number of negative ones. Maximal positive deviations exceeding 1,5 °C were observed in 1975, 1989 (the warmest year in the twentieth century), 1990, 2000, 2002, 2006, 2007, 2008. Maximal negative deviations were observed in 1956, 1987 (these are the coldest years). Maximal anomaly of the mean annual air temperature is marked for 1989 and is 2,5 °C. In the last decade several times they registered temperatures which were the highest in all the history of meteorological observations in Königsberg-Kaliningrad. The mean annual temperature in 1989, 1998, 2007 and 2008 exceeded 9 °C. In January 2007 a maximum temperature +12,6 °C was recorded, in July 2010 the maximum temperature reached +33,8 °C. It is noteworthy that there is an extraordinary stability of positive anomalies of air temperature since 1989.

Inter-annual variations in mean monthly air temperature are stronger during the cold season. The difference between the highest mean monthly temperature in January in 2007 (+3,5 °C) and the lowest in 2006 (-6,6 °C) was 10,1 °C. Mean monthly air temperature fluctuation in summer months range from minimal 3,6 °C (June) to 5,1 °C (July). In autumn months of the last decade, inter-annual variations in mean monthly air temperature are less than in spring (table I).

This conclusion is supported by an assessment of the linear trends in air temperature, made for the two periods 1949-2010 and 1980-2010 (table II). As one can see, change in the mean monthly air temperature (warming) is the most significant in the last 30 years (1980-2010) in July (0,82 °C / 10 years) and in April (0,79 °C / 10 years).

Linear trend of air temperature in January was 0,36 °C per decade, the trend of air temperature in October for this period was negative. Thus, the temperature changes in different seasons are inhomogeneous and are the strongest in spring and summer. Onaverage in 1949-2010 temperature increases by 0,23 °C / 10 years, in 1980-2010 - by 0,42 °C / 10 years.

Analysis of the precipitation growth rate reveals that in the period 1949-2010 precipitation increase was typical for January, July and October (4,00 mm / 10 years). In spring months there was a decrease in precipitation in April (-1,96 mm / 10 years). During the period of the most intensive warming (1980-2010) precipitation change got slower in October and April, and increased significantly in July up to 12,53 mm / 10 years (table III).

As O. Kryshnyakova and V. Malinin estimated, the precipitation growth rate in the European part of Russia for the period of intensive warming (1979-2005) was 10,2 mm / 10 years (Kryshniakova et al., 2010). In the same period in Kaliningrad there was a negative trend in the precipitation amount change, which confirms the regional nature of the climate change manifestations.

Sharp inter-annual fluctuations in hydrothermal conditions were observed in recent decades, as illustrated in table IV. Such conditions cause phenological variations in vegetation development time, including “early spring” period.

In Kaliningrad region abnormal conditions during the active growing season (April - July) were observed in 2002, 2007 and 2008. Following table gives the deviations of precipitation and air temperature in Kaliningrad from multiyear averages (norm for the period 1961-1990).

As the table shows, the spring-summer period of 2002 was very dry and warm, especially in May, when the precipitation was 54% of norm and the air temperature exceeded the long-term average (1960 - 1990) on 4,4%. In 2007 the late spring and early summer were characterized by abundant rainfall, especially in May and July (269% and 232% of norm). May 2008, on the contrary, was very dry (28% of normal precipitation). This could agree with the IPCC experts estimations saying that extremes (droughts, floods, storms, etc.) impacts will remain significant with high confidence (IPCC, 2014).

## 2. Phytomonitoring in East Prussia / Kaliningrad region

Phenological monitoring results for 120 years

It is well recognized that permanent and long-term phenological observations conducted on a certain area, in a particular region, allow to identify trends in long-term dynamics of natural processes and provide climate change information.

Table I. Range of fluctuations of mean monthly air temperature over the period 2000-2009.
***Gamme de fluctuations des températures moyennes mensuelles sur la période 2000-2009.***

| Month | Maximum (year) | Minimum (year) | Difference maximum – minimum |
|---|---|---|---|
| January | 3,5 (2007) | -6,6 (2006) | 10,1 |
| February | 3,7 (2008) | -3,9 (2003) | 7,6 |
| March | 6,9 (2007) | -1,2 (2006) | 8,1 |
| April | 11,0 (2000) | 6,0 (2003) | 5,0 |
| May | 16,2 (2002) | 11,3 (2004) | 4,9 |
| June | 17,7 (2007) | 14,1 (2001) | 3,6 |
| July | 21,2 (2006) | 16,1 (2000) | 5,1 |
| August | 20,7 (2002) | 16,7 (2000) | 4,0 |
| September | 15,3 (2006) | 11,1 (2000) | 4,2 |
| October | 11,0 (2000) | 5,7 (2003) | 5,3 |
| November | 6,3 (2000) | 2,4 (2007) | 3,9 |
| December | 2,6 (2004) | -5,6 (2002) | 8,2 |

Table II. Evaluation of linear trends by decade for air temperature in Kaliningrad and different periods (four months and two historic periods).
***Évaluation des tendances de températures par décennie à Kaliningrad pour différentes périodes (quatre mois et deux périodes historiques).***

| period | January | | April | | July | | October | | year |
|---|---|---|---|---|---|---|---|---|---|
| | $R^2$ | °C/10 years | $R^2$ | °C /10 years | $R^2$ | °C /10 years | $R^2$ | °C /10 years | $R^2$ |
| 1949-2010 | 0,04 | 0,41 | 0,17 | 0,35 | 0,12 | 0,29 | 0,00 | 0,02 | 0,17 |
| 1980-2010 | 0,00 | 0,36 | 0,25 | 0,79 | 0,22 | 0,82 | 0,02 | -0,28 | 0,15 |

Table III. Evaluation of linear trends in precipitation in Kaliningrad for different periods of time.
***Évaluation des tendances pour les précipitations à Kaliningrad pour différentes périodes.***

| period | January | | April | | July | | October |
|---|---|---|---|---|---|---|---|
| | $R^2$ | mm/10 years | $R^2$ | mm/10 years | $R^2$ | mm/10 years | $R^2$ |
| 1949-2010 | 0.06 | 4.17 | 0.03 | -1.96 | 0.00 | 0.48 | 0.01 |
| 1980-2010 | 0.00 | -0.46 | 0.01 | -1.85 | 0.08 | 12.53 | 0.01 |

Table IV. Extreme hydrothermal characteristics in Kaliningrad.
***Caractéristiques hydrothermales extrêmes à Kaliningrad.***

| Year | Precipitation, % of norm | | | | Temperature deviations from the norm | | |
|---|---|---|---|---|---|---|---|
| | April | May | June | July | April | May | June |
| 2002 | 65 | 54 | 104 | 55 | 2,0 | 4,4 | 1,2 |
| 2007 | 53 | 269 | 145 | 232 | 1,7 | 1,8 | 2,2 |
| 2008 | 130 | 28 | 78 | 66 | 2,1 | 0,4 | 1,0 |

Kaliningrad region (part of the former East Prussia) belongs to the southern subzone of mixed forests, which has specific vegetation. According to the phytogeographic zoning, Kaliningrad region vegetation belongs to the Baltic-Belarusian subprovince which is part of the Northern European taiga province of forest zone. Most modern forest phytocenoses of the region have signs of planting and contain a variety introduced species. Forests on the territory of modern Kaliningrad region occupy a very small part of it - 17-18% of the total area.

Flora of region is rather diverse. In natural state there are more than 1,400 species of vascular plants. In the structure of flora there is a high proportion (10%) of rare or threatened plants. First of all, these are cladotypes such as *Lunaria rediviva L.* and *Hippophaë rhamnoides L.*; endemic plants as *Linaria loeselii Schweigg*, *Viola × litoralis Spreng*.; plants on the border of their area - *Orchis morio L*., *Quercus petraea (Matt.) Liebl.*, *Fagus sylvatica L*., *Hedera helix L*. and other species (Kaliningrad region, 1999).

The tasks of our work included comparison of data collected during the seasonal development of plants observations in East Prussia in 1893 (Jentzsch, 1894) and data obtained from volunteer observers in 1993 and 2012 using the same method.

The method of observation in the framework of "the Springway" ("Der Frühlingseinzug") project included fixing the phenophases of 48 plants. 47 species and one variety can be used as spring and summer phenoindicators. Some species are associated with natural, some - with cultural landscapes:

- *Corylus avellana L.*
- *Hepatica nobilis Mill.*
- *Tussilago farfara L.*
- *Daphne mezereum L.*
- *Viola odorata L.*
- *Ficaria verna Luds.*
- *Chrisasplenium alternifolium L.*
- *Gagea lutea Schuit.*
- *Pulmonaria officinalis L.*
- *Anemone nemorosa L.*
- *Caltha palustris L.*
- *Primula veris L.*
- *Viola tricolor L.*
- *Taraxacum officinale Webb.*
- *Ribes rubrum L.*
- *Fragaria vesca L.*
- *Cardamine pratensis L.*
- *Prunus spinosa L.*
- *Padus racemosa (Lam.) Gilib.*
- *Cerasus vulgaris Mill.*
- *Lamium album L.*
- *Pyrus communis L.*
- *Malus domestica Borkh.*
- *Vaccinium myrtillus L.*
- *Convallaria majalis L.*
- *Aesculus hippocastanum L.*
- *Syringa vulgaris L. (lila)*
- *Syringa vulgaris L. (alba)*
- *Sorbus aucuparia L.*
- *Vaccinium vitis-idaea L.*
- *Iris pseudacorus L.*
- *Centaurea cyanus L.*
- *Secale cereale L.*
- *Nuphar luteum Sm.*
- *Rubus idaeus L.*
- *Lychnis viscaria L.*
- *Leucanthemum vulgare L.*
- *Nymphaea alba L.*
- *Sambucus nigra L.*
- *Rosa canina L.*
- *Achillea millefolium L.*
- *Triticum aestivum L.*
- *Hypericum perforatum L.*
- *Lilium candidum L.*
- *Tilia cordata Mill.*
- *Tanacetum vulgare L.*
- *Calluna vulgaris Salisb.*
- *Parnassia palustris L.*

At the end of the XIX$^{th}$ century the project was organized by Botanical Society of Prussia and was based on public participation: volunteer observers were school teachers, clergymen, pharmacists, housewives.

One hundred years later, in 1993, a remarkable scholar and teacher Galina Georgievna Kucheniova organized a series of observations where thirteen schools of Kaliningrad region participated in the data collecting. In 2012 environmental organization "Ecodefense!" under the direction of Alexandra Koroliova continued the project which now was called "Springway 2012-2014: Evidence of climate change in 120 years" with 58 schools. Collected materials were presented on the website www.springway2013.ru. Observations were carried out in different parts of the Kaliningrad region both in urban landscapes and in the natural environment.

Dates of phenological events were analyzed both being compared with average (table V), and interannual. Deviation can be positive (later, delayed) or negative (earlier, advanced). Long-term dynamics of phenological data in the observed area was evaluated as a possible regional indicator of global climate change.

The estimation of total phenological trends caused by climate variability over 120 years, reveals the presence of distinct tendencies in the seasonal phenological events timing. Table VI shows the terms of the beginning of flowering of ten indicator plants selected by the Prussian botanists.

As we can see, during the current warming in 2012 compared with 1893 there was a significant shift of the date of the indicator plants first flowering in early spring by an average of 12 days. Especially significant shifts are observed for *Daphne mezereum L., Hepatica nobilis Mill., Corylus avellana L.* The order of species flowering has also changed. In 1893, the earliest flowering specie was *Corylus avellana L., Tussilago farfara L., Hepatica nobilis Mill.* and in 2012 they were *Daphne mezereum L.*, *Corylus avellana L., Hepatica nobilis Mill.*

Trends in plants-indicators of "medium spring" flowering range from 7-9 days (*Primula veris L.*, *Convallaria majalis L.*) to 15-21 days (*Taraxacum officinale Webb.*, *Pyrus communis L.*, *Malus domestica Borkh*. and other). The maximum change is registered for the first flowering of *Lamium album L.* - 34 days (table VII).

Analysis of terms for plants-indicators of summer season does not show any clear trend to change.

Thus, the current warming induces a significant shift to the earlier dates of indicator plants flowering.

In 1893, "early spring" fits into the gap from March 25 (*Tussilago farfara L.*) to April 9 (*Anemone nemorosa L.*, *Chrisasplenium alternifolium L.*) and is 15 days long. In 2012, the period of the "early spring" indicators flowering plant increased to 34 days: the earliest flowering is March 4 (*Daphne mezereum L.*) and the latest - April 7 (*Viola odorata L.*).

The period between the flowering of plants-indicators of "medium spring" in 1893 was 34 days long (April 24 - *Taraxacum officinale Webb.*, May 28 - *Lamium album L.*); in 2012 - 25 days long (April 9 - *Taraxacum officinale Webb.*, May 4 - *Convallaria majalis L.*), so the gap got shorter in the recent period.

Between the flowering of plants-indicators of summer season in 1893 there was 19 days and in 2012 there is 22 days,thus practically unchanged.

Spatial difference in the terms of phenoindicators flowering can be traced on line Svetlogorsk - Gvardeysk - Chernyahovsk. (Svetlogorsk is situated on the Baltic sea coast, 40 km from Kaliningrad; Gvardeysk is 40 km to the east from Kaliningrad and Cherniahovsk is about 90 km in the same direction). As the distance from the coast grows flowering of plants occurs 6-7 days earlier (table VIII).

The gap between the "early spring" indicators flowering in Wehlau (now Znamensk which is about 55 km to the east from Kaliningrad) in 1893 was from March 27 to April 15, i.e. 18 days, more than in Königsberg (Kaliningrad). In 2012 this gap was the period from March 9 (*Corylus avellana L.*) and April 12 (*Anemone nemorosa L.*), i.e. 33 days, the same as in Kaliningrad (table IX).

Terms of "medium spring" indicators flowering in Wehlau-Znamensk for the period 1893-2012 have significant trends - from 6-9 days (*Ribes rubrum L.*, *Cardamine pratensis L.)* to 23-24 days (*Cerasus vulgaris Mill.*, *Malus domestica Borkh.*). The gap between the flowering of "medium spring" plants was 28 days in 1893 and 48 days in 2012, so it became much longer (table X).

Identified discrepancy in the flowering terms, in our opinion, indicates the response of plants to the increasing variability of hydrothermal conditions in a period of intensive global warming, as well as increased anthropogenic impact in urban areas ("heat island").

At the same time, Russian scientists point to the absence of changes in herbaceous and woody plants flowering in the Urals during the 1972-2005 period. They only identified weak trend toward earlier flowering in the last two decades of the twentieth century for *Tussilago farfara L.* and *Salix caprea L.*) (Gordienko et al., 2009). And the analysis of the dynamics of seasonal vegetation development in North-West Russia over a longer period (1829-1999) revealed bioclimatic changes that can be described as a conditional transfer region of St. Petersburg to the south-west up to 1000 km in the spring, to 250-500 km summer, up to 100-250 km in the autumn (Bulygin, 2002).

Scientists from the Baltic countries comparing phenoindicators flowering in 1971-1985 and 1986-2000, show terms changed for 9 days for *Alnus incana (L.) Moench*, 12 days for *Corylus avellana L.,* 6 days for *Syringa vulgaris L.* and 4 days for *Philadelphus* (Kalvane et al., 2009). A large, international meta-analytic study integrating more than 125,000 sets of observations for 542 plants and 19 animals in 21 European countries for the 1971-2000 revealed that in 78% of cases the terms have shifted to an earlier date, but only in 3% of cases, they have become significantly later (Menzel et al., 2006).

Analysis of seasonal changes at plants in connection with climatic factors

Table V. Phenological seasons in Kaliningrad region with characteristic phenoindicators (Barinova, 2002).
***Saisons phénologiques dans la région de Kaliningrad et ses caractéristiques phénoindicatrices (Barinova, 2002).***

| Seasons | Beginning | End | Length, days | Some phenoindicators |
|---|---|---|---|---|
| Spring | 11,03 | 9,06 | 91 | Larks arrival<br>Flowering of *Alnus glutinosa* and *A. incana*, *Corylus avellana*, *Tussilago farfara*, *Salix caprea*, *Acer platanoides*<br>The first sortie of dragonflies<br>Flowering of *Sambucus nigra* |
| Summer | 10,06 | 4,09 | 87 | The emergence of mushrooms-“ kolosoviki” (mushrooms appearing during wheat ears development)<br>Flowering of *Philadelphus*, *Epilobium*, *Nymphaea*<br>Starting raspberries ripening<br>First *Calluna* flowering |
| Autumn | 5,09 | 27,12 | 114 | Starting *Tilia cordata* yellowing<br>Recent instances of black swift<br>Starting birch leaf fall<br>Last meeting of the swallows<br>Frost in the air<br>Starting of soil freezing |
| Winter | 28,12 | 10,03 | 73 | Formation of stable snow cover<br>Soil freezing |

Table VI. Change of periods of phenological events in Königsberg-Kaliningrad - “early spring”, 1893-2012.
***Changement de périodes dans les événements phénologiques à Königsberg - Kaliningrad – « début du printemps », 1893-2012.***

| Indicator plants | Date of flowering beginning | |
|---|---|---|
| | 1893 | 2012 |
| *Corylus avellana L.* | March 26 | March 9 |
| *Hepatica nobilis Mill.* | April 5 | March 17 |
| *Tussilago farfara L.* | March 25 | March 21 |
| *Daphne mezereum L.* | April 8 | March 4 |
| *Viola odorata L.* | April 7 | April 7 |
| *Ficaria verna Luds.* | April 8 | March 26 |
| *Chrisasplenium alternifolium L.* | April 9 | March 25 |
| *Gagea lutea Schuit.* | April 8 | April 5 |
| *Pulmonaria officinalis L.* | April 8 | March 26 |
| *Anemone nemorosa L.* | April 9 | April 4 |

Table VII. Change of terms of phenological events in Königsberg-Kaliningrad - “medium spring”, 1893-2012.
***Changement de périodes dans les événements phénologiques à Königsberg - Kaliningrad – « printemps moyen », 1893-2012.***

| Indicator plants | Date of flowering beginning | |
|---|---|---|
| | 1893 | 2012 |
| *Primula veris L.* | April 24 | April 17 |
| *Taraxacum officinale Webb.* | April 24 | April 9 |
| *Ribes rubrum L.* | May 11 | April 24 |
| *Cardamine pratensis L.* | May 10 | May 1 |
| *Padus racemosa (Lam.) Gilib.* | May 14 | May 1 |
| *Cerasus vulgaris Mill.* | May 18 | May 1 |
| *Lamium album L.* | May 28 | April 24 |
| *Pyrus communis L.* | May 19 | May 1 |
| *Malus domestica Borkh.* | May 22 | May 1 |
| *Convallaria majalis L.* | May 12 | May 7 |

Table VIII. Terms of phenological events in Kaliningrad region - "medium spring", 2012.
***Périodes des événements phénologiques dans la région de Kaliningrad – « printemps moyen », 2012.***

| Indicator plants | Svetlogorsk | Gvardeysk | Chernyahovsk |
|---|---|---|---|
| *Taraxacum officinale Webb.* | April 18 | April 12 | April 11 |
| *Padus racemosa (Lam.) Gilib.* | May 6 | May 30 | April 29 |
| *Cerasus vulgaris Mill.* | May 5 | April 30 | - |
| *Lamium album L.* | May 5 | May 1 | April 29 |

Table IX. Change of terms of phenological events in Wehlau-Znamensk - "early spring", 1893-2012.
***Changement de périodes dans les événements phénologiques à Wehlau - Znamensk – « début du printemps », 1893-2012.***

| Indicator plants | Date of flowering beginning | |
|---|---|---|
| | 1893 | 2012 |
| *Corylus avellana L.* | March 27 | March 9 (Gvardeysk) |
| *Hepatica nobilis Mill.* | March 29 марта | March 21 марта (Gvardeysk) |
| *Tussilago farfara L.* | April 2 | March 21 (Gvardeysk) |
| *Daphne mezereum L.* | - | - |
| *Viola odorata L.* | April 15 | April 12 (Gvardeysk) |
| *Ficaria verna Luds.* | April 11 | March 28 (Gvardeysk) |
| *Chrisasplenium alternifolium L.* | April 9 | March 25 (Gvardeysk) |
| *Gagea lutea Schuit.* | April 10 | April 9 |
| *Pulmonaria officinalis L.* | April 6 | March 29 |
| *Anemone nemorosa L.* | April 5 | April 12 |

Table X. Change of terms of phenological events in Wehlau-Znamensk - "medium spring", 1893-2012.
***Changement de périodes dans lesévénements phénologiques à Wehlau - Znamensk – « printemps moyen », 1893-2012.***

| Indicator plants | Date of flowering beginning | |
|---|---|---|
| | 1893 | 2012 |
| *Caltha palustris L.* | May 10 | April 27 |
| *Taraxacum officinale Webb.* | April 29 | April 12 |
| *Ribes rubrum L.* | May 5 | April 29 |
| *Cardamine pratensis L.* | May 9 | April 30 |
| *Padus racemosa (Lam.) Gilib.* | May 20 | May 30 |
| *Cerasus vulgaris Mill.* | May 22 | April 29 |
| *Lamium album L.* | May 18 | April 26 |
| *Pyrus communis L.* | May 25 | May 5 |
| *Malus domestica Borkh.* | May 27 | May 3 |
| *Convallaria majalis L.* | May 27 | May 10 |

length of the season with temperatures above 10 °C is 4,89 days / 10 years. And the number of days with temperatures above 10 °C ranges moves from 126 (1980) to 185 (2000).

The positive trend for the GDUs (baseline 10 °C) is stronger (figure 2). For the thirty-year period this value ranged from 1942,1 °C (1980) to 2919,0 °C (2006). Long-term average GDUs during the period of 1980-2010 is 2388,0 °C.

Climate extremeness, determined by the characteristics of inter-annual variability of temperature and precipitation, with ongoing warming will lead to increased environmental effects. Also it may help to create conditions for adapting and improving the agriculture management, together with the optimization of the urban environment, and others (Barinova et al., 2012).

Of course, it is necessary to take in consideration that changing of flowering terms can be correlated not only with the temperature or moisture conditions in the spring and summer months, but with the number of sunny days, solar flux (including photosynthetically active radiation), microclimatic conditions plant growth (see, for example (Körner et al., 2010).

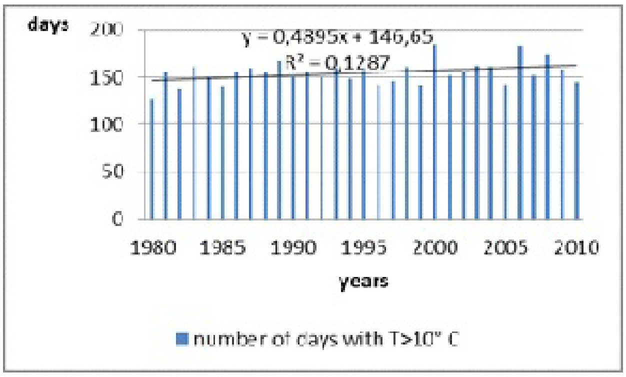


Figure 1. Number of days with temperature higher than 10 °C for the period 1980-2010.
***Nombre de jours avec une température supérieure à 10 °C pour la période 1980-2010.***

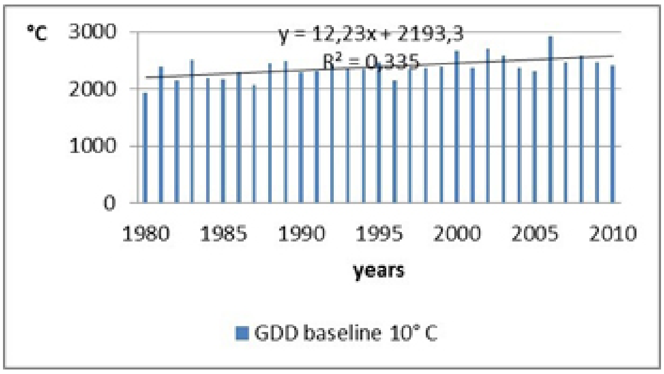


Figure 2. Growing degree days (growing degree units) baseline 10 °C for the period of 1980-2010.
***Augmentation de degrés jours (unités de degré croissant) selon la base de 10 °C pour la période de 1980 à 2010.***

## 3. Methodological problems of collecting data in participatory projects

There are some methodological problems which should be considered while planning research within such participatory projects.

The first important question is the homogeneity of data. Also the competence of the observer plays a significant role.

Analyses of collected in 2012-2014 data reveal most frequent errors: first is connected with time span. Some volunteer observers do research more actively on weekends and holidays. There is a question of observers' motivation also: in the beginning of spring there are more volunteers who are more eager to participate.

Monitoring the response of biota in the current climate warming is a very difficult task due to the variety of factors that influence on vegetation. Such monitoring requires extensive network of observation points. Volunteer observers more often do research near their home or their school where microclimatic conditions are very diverse and "heat island" could influence. Some parts of Kaliningrad region are difficult to access (no settlements, no transport infrastructure).

Schools and schoolchildren participation has some advantages (volunteer labour in conditions of lack of funds, stability, constant structure) and disadvantages (motivation and competence problem).

We remind that some of these problems could be typical for the monitoring in 1893 as well. In order to overcome them systematic work is needed.

Despite the fact that these problems can reduce the scientific value of the data, the project retains its educational value (environmental and climate education, local history).

## Références bibliographiques


Kasimov N.S., Klige R.K. (2012). Main factors of modern global nature changes. Modern global nature changes. V.3. Factors of global changes*. M. Nauchnyj mir*. p. 11-40.

Fashchuk D.Ya. (2010). Sea and watersheds as an integrated hydroecological system in a changing climate. *Problems of regional ecology,* n° 1, p. 77-88.

Intergovernmental Panel on Climate Change (IPCC). (2014). Fifth Assessment Report. Working group 2. Climate Change 2014: Impacts, Adaptation, and Vulnerability. [En ligne]: http://www.ipcc.ch/report/ar5/wg2/

Geographical atlas of Kaliningrad region. (2002). ed. V.V. Orlionok. Kaliningrad: Izd-vo KGU; CNIT.

Barinova G., Krasnov E., Zotov S. et al. (2004). Climate changes in the Baltic region for the recent 1000 years: history of research/ History of oceanography. *Materials of VII international congress on history of oceanography*. Kaliningrad: Izdatelstvo KGU, p. 393-396.

Kryshniakova O.S., Malinin V.N. (2010). To the assessment of trends in precipitation variations in European Russia. *Vestnik Baltijskogo federalnogo universiteta*. Vyp. 1. p. 64-69.

Kaliningrad region: Sketches of nature / Comp. D.Ya. Berenbejm. (1999). Sc. ed. V.M. Litvin. 2-e izd. dop. i rash. Kaliningrad: Yantarhyj skaz. 229 s.

Jentzsch, Alfred. (1894). Der Frühlingseinzug des Jahres 1893: Nach den phänologischen Beobachtungen des Preussischen Botanischen Vereins und des Botanischen Vereins der Provinz Brandenburg [Spring collection of 1893: according to phenological observations of the Prussian Botanical Society and the Botanical Society of the Province of Brandenburg]. *Leupold.*

Barinova G.M. (2002). Kaliningrad region. Climate. Kaliningrad: *Yantarnyj skaz.* 196 p.

Gordienko N.S., Sokolov L.V. (2009). Analysis of long-term changes in seasonal phenomena in plants and animals of Ilmensky reserve due to climate factors. *Ekologija,* n° 2, p. 96-102.

Bulygin N.E. (2002). Manifestation of short-period variations in climate and its modern warming in dynamics of seasonal development of plants and vegetation in the northwest of Russia. *Izvestija Sankt-Peterburgskoj lesotehnicheskoj akademii.* n° 168, p. 32-39.

Kalvane G., Romanovskaja D., Briede A. et al. (2009). Influence of climate change on phenological phases in Latvia and Lithuania. *Climate Research.* vol. 39, p. 209-219.

Menzel A., Sparks T., Estrella N. et al. (2006). European phenological response to climate change matches the warming pattern. *Global Change Biology* n° 12, p. 1969-1976.

Barinova G.M., Gaeva D.V. (2012). Climate changes: agroecological challenges and responses in Southern Baltic. *Regional effects of global climate changes (reasons, effects, forecasts). Materials of international scientific conference*. Voronezh: Nauchnaja kniga, p. 369-371.

Barinova G., Koroleva Yu., Krasnov E. (2012). Indicative modeling and spatial evaluation of air pollution risk. Horst Kremers, Alberto Susini (eds). Risk models and applications. Collected papers. CODATA – Germany e. V. p. 23-24.

Körner C., Basler D. (2010). Phenology under global warming. *Science.* Vol 327. p. 1461-1462.