Duration of the growing season (with stable air temperatures above 5 and 10 °C) in Eastern Transbaikalia

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Abstract. The timing and duration of the growing season is a significant factor affecting the sustainability of landscapes and the functioning of a number of sectors of the economy. As part of the work carried out on the geo-administrative regions of ZabUGMS on the territory of Eastern Transbaikalia for the period 1976–2018 a significant increase was revealed in the duration of the growing season (with stable air temperatures above 5 and 10 °C). The analysis of the dynamics of the dates of the onset of stable transitions in the spring and autumn periods is carried out.

1. Introduction

Current research indicates that vegetation season became longer in a number of Russian regions [1]. It is noted that the changes are characterized by spacial heterogeneity even within individual regions [2]. This fact dictates the need for monitoring of temperatures [3] including the dates when stable temperature periods begin, and how long they last at the regional level. Such research allows to assess possible effects of warming on environmental sustainability of ecosystems, a number of socially and economically significant aspects of sectoral economy (agriculture, forestry, power generating sector, transport, housing and public utility sector, etc), and develop strategies to adapt regional economy to reduce losses and use the benefits associated with the trends observed [4, 5].

Vegetation season means the season of the year when the local conditions permit grown and development of plants. It is provisionally defined by the time between stable transition of daily temperature in spring and autumn above/below 5°C; within this time active vegetation period with the temperature above 10°C is distinguished.

Natural conditions in the Eastern Zabaikalye are characterized by landscape diversity [6]. The territory is mainly represented by taiga, forest-steppe and steppe zones. The ruggedness of relief causes a significant horizontal and altitudinal zonality. The climate is extremely continental with a long and cold winter and a warm and short summer [7]. Economic development of the region is based on natural and resource specialization, the territory is included in the East-Siberian economic region. The most developed are mining industry, transport, agriculture and forestry.

2. Materials and methods

The calculation of dates when stable temperature go above/below 5 and 10 °C and the length of periods with such temperatures are made on the basis of standard 8-time observations of daily temperatures at 27 meteorological stations of the Zabaikalye weather control and environmental monitoring service,
located in 6 geoadministrative districts of the Trans-Baikal Territory in 1976-2018. Average values for the base period of 1981-2010, recommended by the World Meteorological Office are taken as climate normal. Linear trends of long-term changes are calculated by the least square method, their statistical significance was assessed using Student's t-test. Three-dimensional visualization was made by ArcGIS.

3. Research results and discussion
The analysis showed that the spring stable transition above 5°C on the research territory on average is observed on 2 May, and on 20 May it goes above 10°C. In autumn stable transition below 10 and 5°C is observed on 8 September and 26 September accordingly. At this time the transition dates are exactly opposite spring transitions: most commonly any given stable transition through a certain temperature is characteristic for highland northern taiga and western regions, it is the latest for steppe south-eastern regions (table 1). At the same time the length of a stable period above 5°C in the Eastern Zabaikalye on average is 147 days varying from the minimum values in the highland northern regions of the research territory (134 days) to the maximum values in the steppes of the south-western part (157 days) (Figure 1a). Such spatial distributions is characteristic of the duration of the period with stable temperatures above 10°C, which length is generally 111 days (Figure 1b).

Table 1. Average dates of stable transition of daily temperature through 5 and 10°C and the duration of stable periods with the studied gradation in various geoadministrative districts of the Zabaikalye weather control and environmental monitoring service in 1976–2018

| District | Spring transition date | Autumn transition date | Duration of the period, days | Spring transition date | Autumn transition date | Duration of the period, days |
|----------|------------------------|------------------------|----------------------------|------------------------|------------------------|----------------------------|
| Western  | May 3                  | September 24           | 144                        | May 24                 | September 4           | 103                        |
| Central  | April 30               | October 1              | 154                        | May 17                 | September 12          | 118                        |
| Southern | April 29               | September 29           | 153                        | May 18                 | September 10          | 115                        |
| Southeast| April 27               | October 1              | 157                        | May 15                 | September 14          | 122                        |
| Eastern  | April 30               | September 27           | 150                        | May 17                 | September 11          | 117                        |
| Northern | May 9                  | September 19           | 134                        | May 27                 | September 2           | 98                         |

During the research period the range between the earliest date of stable transition through 5°C and its latest date in spring is on average about 30 days (Table 2), and 26 days in autumn. At the same time the earliest transition through 5°C in spring happened on 3 April 1998 in Kaylastuy (south-eastern regions), and the latest on 29 May 1980 in Chara (northern regions). In autumn the latest stable transition through 5°C was registered on 19 October in Kaylastuy in 2004 and in 1990 and 2004 in Mangut (southern and south-eastern territories), and the earliest on 30 August 1996 and 2005 accordingly in Chara and in Tupik (northern regions).

The earliest spring date of stable transition above 10°C and the latest date in the western regions were registered on 11 May (2002) and on 5 June (1976) respectively, in the central regions – 2 May (2013 r.) and 2 June (1980), in the southern – 3 (2017) and 30 May (2008), in the south-western – 30 April (2000) and 30 May (1995), in the eastern – 5 (2000) and 31 May (1980), in the northern – 15 May (1979) and 9 June (1976). The earliest transition through 10°C happened in 2015 in Kaylastuy (25 April), and the latest in 1976 in Chara (21 June).
In autumn the latest date of stable transition below 10 °С and the earliest date in the western regions were registered on 16 September (2004) and on 25 August (1979) respectively, in the central regions – 27 September (1988) and 1 September (1996), in the southern – 21 September (1988) and 28 August (1981), in the south-western – 22 September (2016) and 6 September (1992), in the eastern districts – 21 September (1988) and 28 August (1981), in the northern regions – 15 September (1983) and 21 August (1979). The latest stable transition below 10 °С happened in 2006 in Solovyevsk (6 October), and the earliest in 1979 in Chara (15 August).

It should be noted that early spring and late autumn transitions through 5 and 10 °С were generally registered during the latest two decades, and late spring and early autumn transitions in mid 80’s and 90’s of the XX century.

Average dates of stable temperature transitions through 5 and 10 °С in the Eastern Zabaikalye in 1976-2018 and their climate normals (Figure 2) coincide. However the comparison of their average values for almost regular intervals (1976-1997 (22 years) and 1998-2018 (21 years) with average values for the base period showed that during the first period the dates of stable transitions happened on average 2–3 days later in spring and earlier in autumn, and during the second period, on the contrary, happened 2 days earlier in spring and later in autumn.

Analysis of long term motion of the dates of stable transition of atmospheric temperatures for the researched period showed that on average on the territory of the Eastern Zabaikalye earlier occurrence of the researched periods in spring (Figure 3a) and later in autumn (Figure 3b) is observed. Accordingly their duration becomes longer as well.

In 1976–2018 the length of stable period with the temperature above 5 °С in the region on average increased by 2.7 days/10 years (the trend is statistically valid at 5% significance point), The biggest increase is characteristic for the central and northern district, the smallest increase is characteristic for the western and eastern districts accordingly. In spring stable transition of temperature across 5 °С at the researched territory on average now happens earlier by 2.2 days/10 years (the trend is statistically valid), and in autumn by 0.5 days/10 years later respectively. This trend is statistically not valid.
Table 2. The earliest and the latest spring and autumn dates of stable transition of daily temperatures through 5 °C in the Eastern Zabaikalye across geo-administrative districts in 1976–2018

| Characteristic | District          | Western | Central | Southern | Southeast | Eastern | Northern |
|----------------|-------------------|---------|---------|----------|-----------|---------|----------|
|                |                   |         |         |          |           |         |          |
| **Spring**     |                   |         |         |          |           |         |          |
| Average date   | April 19          | April 12| April 12| April 10 | April 18  | April 26|          |
| Earliest Years at different stations | 2011 | 2011 | 2009 | 2011 | 2015 | 2000 | 2007 |
|                | 2018 | 2018 | 2011 | 2018 | 2015 | 2000 | 2009 |
| Average date   | May 18            | May 13  | May 13  | May 12  | May 17   | May 23  |          |
| Latest Years at different stations | 1976 | 1982 | 1979 | 1987 | 1991 | 1976 | 1976 |
|                | 1982 | 1987 | 1982 | 2006 | 2006 | 1980 | 1980 |
| Amplitude, days | 29    | 32    | 31    | 32    | 29    | 27    |          |
| **Autumn**     |                   |         |         |          |           |         |          |
| Average date   | September 12      | September 17 | September 18 | September 17 | September 15 | September 4 |
| Earliest Years at different stations | 1989 | 1983 | 1983 | 1983 | 1983 | 1996 | 1996 |
|                | 1999 | 1989 | 1984 | 1984 | 1984 | 1997 | 1997 |
|                | 2003 | 1989 | 1985 | 1985 | 1985 | 2005 | 2005 |
| Average date   | October 7         | October 14 | October 13 | October 13 | October 9 | October 5 |
| Latest Years at different stations | 2006 | 2005 | 2004 | 2004 | 1979 | 1979 |          |
|                | 2012 | 2014 | 2005 | 2005 | 1991 | 1979 |          |
|                | 2015 | 2015 | 2006 | 2006 | 2004 | 2004 |          |
| Amplitude, days | 25    | 27    | 25    | 26    | 23    | 30    |          |
Figure 2. Average dates of stable temperature transitions through 5 and 10 °C in the Eastern Zabaikalye on average in 1981–2010 (1), 1976–2018 (2), 1976–1997 (3) and 1998–2018 (4).

Figure 3. Dynamics of the dates for transition of daily temperature through 5 °C (1) and 10 °C (2) in spring (a) and in autumn (b) on average in the Eastern Zabaikalye in 1976–2018 and their linear trends

The increase of the length of the stable period with the temperature above 10 °C in the region on average is 3.1 days/10 years (the trend is statistically valid). The biggest increase is characteristic for the southern, central and eastern districts, and the smallest – for northern districts. The validity of the
trend is not confirmed only in the north of the region. The spring transition through 10 °C happens in the researched region on average earlier by 1.7 days/10 years (the trend is statistically valid), in autumn the transition is later by 1.4 days/10 years (the trend is statistically invalid at 5% significance point).

Thus, in 1976–2018 in the Eastern Zabaikalye increased duration of stable periods with the temperature above 5 and 10°C (vegetation season) was identified. This is characteristic for the whole territory under research, however it is not homogeneous across the region. The increase is mainly explained by earlier occurrence of the researched period in spring and later occurrence in autumn, and the maximum values of the occurrence date trends are noted in springtime.

4. Conclusion
In the Eastern Zabaikalye in 1976–2018 increased duration of stable periods with the temperature above 5 and 10°C (vegetation season) was identified. This is characteristic for the whole territory under research, however it is not homogeneous across the region. The increase is mainly explained by earlier occurrence of the researched period in spring and later occurrence in autumn, and the maximum values of the occurrence date trends are noted in springtime.

In the light of global warming the scientific data we received should be used to develop new mechanisms to adapt economy sectors to climatic changes in order to ensure economic stability and environmental safety of the region.

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