ANALYSIS OF THE DYNAMICS OF TIME CHARACTERISTICS OF SEASONS OF
THE YEAR IN THE SUBTAIGA SUBZONE (HEMIBOREAL FORESTS) OF THE
WEST SIBERIAN PLAIN OVER THE PERIOD FROM 1936 TO 2015

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Abstract. This work is devoted to analysis of dynamic variations of the structure of winter season of the year and their climatic characteristics (time indices: dates of the beginning, end, and duration; indicators of the hydrothermal regime: sums of temperatures, average daily air temperatures, and precipitation) in the subtaiga subzone of the West Siberian plain over the period from 1936 to 2015.

Key words: climate change, timing, subtaiga subzone (hemiboreal forests), seasons of the year, the West Siberian plain.

Global change of climate and dependent natural environment is one of the main modern issues. The world's temperature has increased by approximately 0.85 °C over the last 130 years [1]. Especially high rates of temperature growth are recorded in the northern hemisphere, and in Siberia, they are the highest [2]. The most noticeable changes of the climatic seasons of the year are those in winter season, and therefore it is necessary to study the dynamics of its time and temperature conditions. We considered the temperature conditions earlier [2]. In this paper, we will consider the changes in the structure of winter season in the subtaiga of the West Siberian plain according to the weather station of Tomsk.

We identify winter season in its natural boundaries using a complex genetic method [4]. The essence of the method is that when establishing the seasonal structure of the year for each specific region of the globe with relatively uniform climate conditions, it is necessary to simultaneously take into account chronological development of all climate formation factors (solar radiation, atmospheric circulation, nature of the underlying surface) and the natural phenomena associated with them.

The season consists of three structural units (phases): moderately frosty winter, hard frosty winter (central phase), and pre-spring. The beginning of the winter season is defined by the dates of formation of a stable snow cover and the start of stable frosts, and the end of this season is characterized by the date of the end of stable frosts and accumulation of maximum water reserves in the snow cover. The beginning and end date of the central phase of winter is determined by a stable transition of the mean daily air temperature through -16 °C on the branch of decline and the increase of temperature [2]. Until 1970, the mean daily air temperature of -18 °C was taken as the criterion [4]. The accumulated data bank on the annual structure of winter season, according to the weather station of Tomsk, for the period from 1936 to 2015 allowed us to carry out a comparative analysis of climate regimes for the three periods: from 1936 to 1970, from 1971 to 2006, and from 2001 to 2015.

The average long-term structure of winter on the study area is of three-phase type. Different types of winter season were observed on the study area over the period from 1936 to 2015 (Table 1). Three-phase type of winter is the most frequent (3ph), while the winters with unstable thermal regime (UTR) are in the second place followed by nucleus-free winters (N-F); less often are two-phase winters without the first (2ph w1) or without the third phase (2ph w3). The nucleus-free winters (N-F) are those without the hard frosty phase due to relatively warm weather of the central months of the season; winters with unstable thermal regime (HTR) are those characterized by repeated changes between the heat and cold waves lasting less than a month [4].

The models of climatic regimes for the selected structure types of the winter seasons are presented in Table 2.

The analysis of Table 2 allows us to draw the following conclusions.

The three-phase type of winter in the average perennial in the first period begins on October 29 and ends on March 22. In the second period, the date of start of winter shifted to a later date (November 6), and the date of the end of this type of winter shifted to an earlier one (March 14). Consequently, the duration of this type of season decreased from 145 days in the first period to 129 in the second; the accumulated negative temperatures decreased from -2354.3 °C to -1873.6 °C; the mean daily air temperature increased by 1.7 °C (Table 2).

Table 1. Frequency (%) of structure types * of the winter season at the weather station of Tomsk

| Structure Type | Frequency (%) |
|----------------|---------------|
| 3ph            | 67.3          |
| 2ph w1         | 26.0          |
| 2ph w3         | 6.7           |
| N-F            | 1.0           |
| UTR            | 1.0           |

* The frequency (%) is calculated based on the number of occurrences of each structure type over the period from 1936 to 2015.
Periods

| Years from 1936 to 1970 | 3ph | 2ph without: | N-F | UTR |
|-------------------------|-----|--------------|-----|-----|
|                         |     |              |     |     |
| 1936-1970               | 78  | 0            | 3   | 14  | 5   |
| 1971-2006               | 58  | 3            | 5   | 9   | 25  |
| 2001-2015               | 73  | 0            | 7   | 7   | 13  |

* The conventions for the structure types of the winter season: 3ph - three-phase winter structure, 2ph w1 – two-phase without the first phase (moderately frosty winter), 2ph w3 – two-phase without the third phase (pre-spring), N-F – nucleus-free winter, UTR – the winter with unstable thermal regime.

From the second period to the third, there is a significant reduction (14 days) in the duration of the three-phase types of winters; however, with slightly changed sums of accumulated temperatures, the average daily temperature became lower by 1.3 °C in the mean (Table 2). According to our research, the frequency of three-phase types of winters was the highest (78%) over the period from 1936 to 1970. In the second period, there was a decrease to 58%, and in the third period, the frequency increased again to 73% (Table 1).

**Table 2.** The models (average long-term values) of the climatic regimes of different types of the winter seasons, according to their structure, for Tomsk over the period from 1936 to 2015

| The type of winter season* according to its structure | Start dates | End dates | Winter duration | Sum of temperatures, °C | Average temperature, °C | Total precipitation, mm |
|------------------------------------------------------|-------------|-----------|-----------------|--------------------------|-------------------------|------------------------|
| 3ph                                                  | 29.10       | 22.03     | 145             | -2354,3                  | -16,2                   | 114,7                  |
| 2ph w1                                               | -           | -         | -               | -                        | -                       | -                      |
| 2ph w3                                               | 11.11       | 11.03     | 121             | -2160,3                  | -17,9                   | 121,9                  |
| N-F                                                  | 28.10       | 23.03     | 147             | -1853,4                  | -12,6                   | 134,3                  |
| UTR                                                  | 5.11        | 22.03     | 138             | -1957,5                  | -14,2                   | 104,5                  |

**Years from 1971 to 2006**

| 3ph                                                  | 6.11        | 14.03     | 129             | -1873,6                  | -14,5                   | 149,2                  |
| 2ph w1                                               | 14.11       | 7.03      | 114             | -2018,2                  | -17,7                   | 139,9                  |
| 2ph w3                                               | 29.10       | 4.03      | 127             | -1815,2                  | -14,2                   | 183,6                  |
| N-F                                                  | 10.11       | 7.03      | 118             | -1442,2                  | -12,2                   | 174,1                  |
| UTR                                                  | 12.11       | 10.03     | 119             | -1588,7                  | -13,3                   | 166,0                  |

**Years from 2001 to 2015**

| 3ph                                                  | 15.11       | 9.03      | 115             | -1824,9                  | -15,8                   | 136,2                  |
| 2ph w1                                               | -           | -         | -               | -                        | -                       | -                      |
| 2ph w3                                               | 4.11        | 9.03      | 126             | -2573,2                  | -20,4                   | 145,9                  |
| N-F                                                  | 17.11       | 11.03     | 115             | -1440,3                  | -12,5                   | 183,6                  |
| UTR                                                  | 12.11       | 5.03      | 115             | -1448,1                  | -12,6                   | 172,6                  |

* structure types: see the conventions for Table 1.
The winters with unstable thermal regime and nucleus-free winters are most often repeated after three-phase types of winters. In the second period, their total increased to 34%. The frequency of these types of winters in the first period was 19%, with 34% in the second, and 20% in the third period (Table 1).

In general, it is characteristic of nucleus-free winters and UTR winters in the third period to have their start shifted to a later date and the end to earlier date, which expectedly led to a decrease in the season duration. In addition, a noticeable increase in precipitation is observed over the first period to the third, especially in UTR winters (Table 2).

Two-phase winters repeated less often than the above described in all compared periods. Thus, a two-phase winter without the first phase (moderately frosty winter) happened only once in the second period (1997/98); a two-phase winter without the third phase (pre-spring) was in the first period (1970/71), in the second period (1980/81, 1987/88, 1988/89), and in the third period (2009/10).

Thus, the winter season differs in structure, whereby change both its temporal characteristics and hydrothermal parameters. Over the past 80 years, three-phase winters have prevailed, while the other types of winters have been less frequent. The winters without the first or third phases were much less common, although they began to be repeated more often in the second and third periods. This allows us to assume that since the 1970s, winters have become shorter and more comfortable from the point of view of the temperature regime in the subtaiga of the West Siberian plain.

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