Analysis of surface wetness changes in mires of Southwestern Siberia during the Little Ice Age (550–50 cal yr BP)

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Abstract. In this study, peat deposits of some mires are investigated using various palaeoecological proxies to reconstruct the palaeohydrology of the mires. The goal of our research is to compare the variations in surface wetness of the mires during the Little Ice Age in an area of Southwestern Siberia, including southern taiga, forest-steppe, and mountain regions, and to consider our results in the context of the previously obtained palaeoclimatic reconstructions of the study area. As a result, an increase in the surface wetness is observed 600–400 cal yr BP in the mires of southern taiga, followed by a drying 300–200 cal yr BP. On the contrary, there is a low surface wetness 300–400 cal yr BP in a mire from the forest-steppe zone, with an increase in the surface wetness 400–300 cal yr BP and then a short drying 300 cal yr BP. As for a mire from the Western Sayan Mountain region, an increase in the surface wetness 500–400 cal yr BP is observed, followed by a drying 300–200 cal yr BP, as well as in the mires from the southern taiga. Thus, the climate humidity varied during the Little Ice Age and differed by the local regions in Southwestern Siberia.

1. Introduction
Modern climate fluctuations, which are noticeable for everyone, make us think about the causes and mechanisms of these fluctuations and compare them with the climatic fluctuations of the recent past. A series of meteorological observations makes it possible to trace the changes in the climatic characteristics during the last century, at best in two hundred years, at individual meteorological stations. For longer time periods, the results of palaeoclimate and palaeoecological reconstructions can be used from various natural archives (mainly on lake and peatland sediments). In the last millennium, several key periods are distinguished, characterised by relatively contrasting climatic conditions. Among them, the Little Ice Age (LIA) is closest to the present (550–50 yr BP from 1950) [1]. The main feature of the LIA is cooling established at different points of the globe, mainly in the northern hemisphere [1, 2]. If it was a cold period in terms of the temperature characteristic of the climate, the data vary in terms of the humidity of the climate [3–5]. Cold climate in the LIA was also revealed in the paleoecological records for Southwestern Siberia [2]. However, of most interest are the data on the climate humidity during this period. The area of Southwestern Siberia covers various latitudinal vegetation zones and subzones: southern boreal forest or taiga, sub-boreal forest, forest-steppe, steppe, including mountainous regions. The main natural archives of palaeoclimatic data in this area are lake and peatland sediments. The humidity of the regional climate can be judged on the basis of data on the surface wetness in the mires, proceeding from the fact that synchronous unidirectional changes in the surface wetness in different mires of one region are most likely caused by the effect of regional climate fluctuations [6]. The aim of our research is to compare the variations in the surface wetness of mires in the LIA in southern taiga, forest-steppe, and mountain regions in Southwestern
Siberia and to contrast them with the results of previously obtained palaeoclimatic reconstructions of the study area.

2. Materials and methods
The data on the palaeohydrology of the peat deposits in six mires located in the southern taiga subzone, forest-steppe, and in the Western Sayan Mountains in Southwestern Siberia were analysed (Fig. 1 1-6). At different sites, data on the palaeohydrology were obtained using the spore-pollen method, analysis of testate amoebae, and the degree of peat humification (Fig. 2). Based on the data on testate amoebae, a quantitative reconstruction of the water-table depth (DWT) was carried out [7–10]. The data on the degree of humification, with the exception of [11], were transformed relative to the mean value of humification for each type of peat according to the procedure proposed in [7], representing the surface wetness changes in the mire. The spore-pollen data allowed reconstructing the mean annual precipitation by the information-statistical method of Klimanov in [12] and Bukreeva in [9]. The radiocarbon dates for the studied objects were calibrated in the BACON program [13] and presented in the number system Before Present (BP, years ago from 1950). The results of the reconstructions in the mires were compared with previously obtained reconstructions (Fig. 1 7-12) [4, 14–16]. In our research, only objects in which the time resolution of the samples was suitable for the analysis of environmental conditions during the LIA were used.

3. Results
The results of a comparison of the surface wetness of three bogs of the southern taiga subzone (Figs. 2a-d), as well the paleoprecipitation from the data of two bogs (Figs. 2e and g) showed that, on the
whole, an increase in the surface wetness of the bogs was observed 600–400 yr BP, followed by a drying 300–200 yr BP. It is important to note that the reconstructions based on different palaeocological methods and on different objects were rather different. Because of a relatively low time resolution of the reconstructions (70–160 years per sample), only general trends in the surface wetness changes in mires in the LIA can be judged.

![Figure 2. Dynamics of surface wetness in mires in Southwestern Siberia during the last 800 years reconstructed according to different palaeocological proxies. DWT – water-table depth marked in black; lh, lh_transform – peat humification indices marked in blue; precipitation marked in red; a, b – hollow of the ridge-hollow complex in Bakcharsky bog [7]; c – Temnoye bog, peat core T16; d, e, f – Krugloye bog [9]; g – Petropavlovskoye bog [12]; h, i – Dolgon’koye swamp [8, 11]; k, l – Bezrybnoye mire [10].](image)

The palaeohydrological data based on the testate amoebae analysis from the Dolgon’koye swamp located much further south in the forest-steppe zone (Fig. 1c) indicate its relatively low surface wetness 500–400 yr BP, which then increased 400–300 yr BP (Fig. 2h). Short-term drying of the swamp surface was observed 300 yr BP (Figs. 2h and i). Conversely, the data for the degree of humification with a higher resolution represented a series of short-term (20–50 years) changes in the surface wetness of the Dolgon’koye swamp in the LIA (Fig. 2i).

The results of reconstruction of the water-table depth in the Bezrybnoye mire located in the Western Sayan Mountains (Fig. 1d) revealed a period of increase in the surface wetness 500–400 yr BP, followed by a gradual drying of the mire surface 300–200 yr BP (Figs. 2k and l).

4. Discussion
The obtained results showed that the surface wetness in the bogs in the south of the taiga zone changed in a similar way, and this was confirmed by the data of different palaeocological methods representing the palaeohydrological reconstruction, which can be judged as changes that were controlled by the humidity fluctuations in the regional climate. These data are consistent with the results of reconstructing the surface wetness [4] in the mire in the middle taiga subzone of Western Siberia (Fig. 1f), where an increase in the surface wetness of the mire was revealed 500 yr BP, followed by its decrease with a maximum drying of 300–250 yr BP. Similar dynamics of the surface wetness were observed [14] in the two bogs in the sub-boreal forest (Fig. 1g) and in the southern taiga subzones (Fig. 1h), although in the last bog a tendency to dry out appeared a little earlier, in 400–300 yr BP, and then, again, there was an increase in the surface wetness 300–200 yr BP.

The dynamics of the surface wetness in the LIA from the Dolgon’koye swamp in the forest-steppe differs from the bogs in the southern taiga. Furthermore, in [15] an increase in the climate humidity in the sub-boreal forest subzone was noted 700–500 yr BP, in contrast to the forest-steppe zone within
the studied region of the Tobol-Ishim interfluve (Fig. 112). In the following period, 500–300 yr BP [15], the differences in the climate humidity smoothed out, and during the last 300 years there was a general tendency to increase the amount of precipitation on the background of moderately warm conditions [15].

The results of spore-pollen analysis [16] from sediments of Lake Big Yarovoe located in the steppe zone in the Ob-Irtyshev interfluve (Fig. 110) showed an increase in the role of the taiga biome in the LIA as compared to the biomes of the steppe and desert areas, indicating an increase in the climate humidity. Simultaneously, a short-term draining of Lake Big Yarovoe was revealed at the end of the LIA [16] according to the diatom analysis of its sediments. Studying the spore-pollen spectra from the sediments of Lake Manzherok located further south in the forest belt of the piedmont of Altai Mountains [Blyakharchuk, unpublished] (Fig. 111) showed an increase in the pollen of *Betula* and *Artemisia*, which represented a wide distribution of the forest-steppe landscapes and drier climate conditions. Meanwhile, in the Bezyrbnoye mire located in the forest belt of Western Sayan Mountains the dynamics of its surface wetness in the LIA was similar to the dynamics of surface wetness from bogs in the southern taiga and different from that of the swamp Dolgon’koye in the forest-steppe zone.

5. Conclusions
In the LIA, a cooling is noted in the territory of the entire globe, while the data on the humidity of climate during this period are very contradictory. On the one hand, the dynamics of the surface wetness in the mires of Southwestern Siberia and, most likely, the climate humidity varied in individual local regions of the territory. On the other hand, the surface wetness in the mires, as well as the humidity of climate, changed during the LIA. In studies with a higher time resolution, a series of short-term increases and decreases in the mire surface wetness have been revealed. To clarify the possible causes and patterns of these changes, an increase in the number of investigated natural archives is required, if possible, with a higher time resolution of palaeoecological reconstructions (less than 50 years per sample).

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