INDICATION CAPACITY OF LANDSCAPE STRUCTURE OF THE RUSSIAN ALTAI FOR PAST AND CURRENT CLIMATE CHANGES

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Abstract
Inner Asia consists of some large mountain systems separated and bounded by vast plains located at different altitude. The northern part of Inner Asia includes spacious mountain range, i.e. mountains in the south of Siberia, in northern China, Mongolia and north-eastern Kazakhstan. The Russian Altai is the territory of natural contrasts. It is practically the north of Inner Asia in "miniature". The landscape map of the Russian Altai (1: 500000) covering 5315 patches was developed. A total of 266 species of landscape are distinguished in the Russian Altai. In the article proposed to identify the most informative landscapes for the analysis of the effects of global climate changes. Such landscapes can be called indicator geosystems. Calculated that about 15% of all Russian Altai landscapes are indicator geosystems. They are glaciers and another glacial-nival landscapes, geoecotones, landscapes in the extreme conditions, peat lands and cryogenic landscapes. High dynamics of indicator geosystems should be considered when creating a transport and industrial infrastructure and when evaluating the risk of negative processes for settlements.
Key words: Russian Altai, mountain landscape, indicator, glacier, geoecotones, peat lands.

Introduction

There is growing concern about the increasing anthropogenic effect on the earth's climate system and its impact on nature and human beings. The world community must take action to both investigate the problem and try to solve it. In recent years fundamental international (IPCC, 2007) and Russian (Assessment Report, 2008) works have been published, with detailed analyses of the reasons for and scale of human impact on climate system as well as currently-observed effects and future forecasts.

The centers of continents are especially sensitive to climatic changes, for here the major cyclonic and anticyclonic air masses converge. Any moderate strengthening or weakening of these types of air circulation may have pronounced effects on adjacent areas. The vegetation reflects this climatic setting, and the landforms and lake sediments carry the imprints of the climatic history. Such areas can have special interest for investigation of the response of these landscapes to global mechanisms of climatic change (Blyakharchuk et al., 2007). Mountains are highly suitable natural polygons for monitoring and modeling vegetation and climate changes, as this is where a great variety of plant species, vegetation zones, and landscapes is found within relatively short distances. This enables us to detect even the beginnings of climatic and biotic changes. Inner Asia consists of some large mountain systems separated and bounded by vast plains located at different altitude. The northern part of Inner Asia (Altai-Khangai-Sayan physical-geographical country) includes spacious mountain range, i.e. mountains in the south of Siberia, in northern China, Mongolia and north-eastern Kazakhstan. It is a complex mountain-depression formation at the boundary of bioclimatic belts and longitude sectors distinguished by the features of North, Central and Middle Asia and the influence of Atlantic and Pacific air masses. The positional analysis is proposed to determine a key factor or a number of factors that separate the regional geosystem and give its difference from the adjacent ones. All in all, 10 physical-geographical regions were distinguished within the territory mentioned; some of them are considered for the first time.

The Russian Altai is a large mountain region situated in the west of this territory. It is practically the north of Inner Asia in "miniature". Peculiarities of the Russian Altai:
a) position close to the center of Asian anticyclone; b) contrast of water-thermal regime, including humid and semi-arid features within the same landscape; c) presence of depressions with standstill cold air in winter and heated one – in summer; d) weak continentality of peripheral areas; e) strong current glaciation. The landscape map of the Russian Altai was developed (Chernykh, Samoylova, 2011). The study is made in the context of the Russian geographical tradition of landscape science which, first and foremost, interprets a landscape as a natural phenomenon. The landscape map of the Russian Altai (1: 500000) covering 5315 patches was developed. A total of 266 species of landscape are distinguished in the Russian Altai. In the context of global climate change, the focus should be on landscapes that record the changes. We identified the most informative landscapes for the analysis of the effects of global climate changes. Such landscapes can be called indicator landscapes. Calculated that about 15% of all Russian Altai landscapes are indicator landscapes. They are glaciers and another glacial-nival landscapes, geoecotones, landscapes in the extreme conditions, peat lands and cryogenic landscapes. High dynamics of indicator geosystems should be considered when creating a transport and industrial infrastructure and when evaluating the risk of negative processes for settlements.

Analysis and discussion

Glacial-nival landscapes. Glaciers are one of the best indicators of climate change and a nearly global retreat of glaciers has been recently reported (Kargel et al., 2005; Barry, 2006). Snow patches and glaciers of current mountain glaciation are most vulnerable; they are exposed to the prevailing degradation process caused by an increase in air temperature and a reduction in solid precipitation. The degradation of large glaciers is accompanied by their breakup into smaller glaciers.

Of all Siberian mountains, the Altai Mountains are most widely glaciated. Results of a glacier inventory in the Russian Altai based on the analysis of aerial photographs of the 1950s and field surveys of the 1960s were published in the various volumes of the Catalogue of Glaciers of the USSR (CG). According to the summary of the CG data by Dolgushin and Osipova (1989), glaciers covered 910 km^2 in the Russian Altai. In the 2000s, investigations of area changes of small samples of glaciers were conducted in the Russian Altai (e.g. Narozhny and Nikitin, 2003; Pattyn et al., 2003; Surazakov et al., 2007). An inventory including 91 glaciers was undertaken by Kadota and Gombo (2007) for the Mongolian Altai. These studies show that most glaciers have retreated since the mid-20th century, however, the reported retreat rates vary considerably between individual glaciers and regionally. In different regions of the Mongolian Altai, glaciers lost between 10% and 30% of their surface area since the middle of the 20th century (Kadota and Gombo, 2007). In Russian Altai, the Sofiyskyi Glacier retreated twice as fast as the Malyi Aktru [Pattyn et al., 2003].

The work conducted by Y.K. Narozhny (2001) shows that the number of glaciers in Altai (Aktru basin, Severo-Chuyskiy (North Chuya) Ridge) increased by 25% due to the disruption of large glaciers. Total glaciation area is reduced by 11%, with different rates of glacier degradation (from 8–50%). The volume of glaciers decreases more intensively (by 19–34%). The deglaciation rate increased by almost 1.5 times. It was assumed that the clear negative trend observed in their annual mass balance variations would not change in the near future. Shahgedanova et al. (2010) glacier surface area in the North and South Chuya Ridges of the Altay Mountains was evaluated using 2004 ASTER imagery and glacier retreat since 1952 was assessed using data published in the Catalogue of Glaciers of the USSR (1974, 1977). The glaciated area has declined and a number of glaciers have fragmented due to the increasing summer temperatures. 126 glaciers (not smaller than 0.5 km2 in 1952) have lost 19.7 ± 5.8% of their net surface area. Providing that an increase in summer temperatures started in the Altai after the 1980s and glacier front fluctuations and mass balance records for individual glaciers show that their shrinkage accelerated since the 1990s, it can be concluded that glaciers of the Altai reacted rapidly to the observed climatic warming. Almost all explorers of the Altai-Sayan Mountains mentioned the glacier fluctuations in the late Holocene. A review of the research history of Holocene glaciation in the Altai was recently presented by Agatova et al. (2012). But until recently, the paleoglaciological construction was poorly provided with radiocarbon dating. The lack of statistically significant radiocarbon dating of the moraine complexes resulted in varying interpretations of the time of their formation. For instance, the A Shnitnikov's 1900-year rhythms were used for moraine timing. Landscape approach formed the basis for paleogeographic investigations performed in the Khaidun river basin. We proceeded from the assumption that the regional changes in natural conditions, superimposed on the landscape structure, refracted individually. The impact of these changes on the landscape structure and the associated direction of its evolution its determined not only by the magnitude of these changes, but the actual landscape characteristics as well.

As a result of landscape mapping and subsequent comparative analysis of landscape structures of moraine complexes of different phases of Historical and Aktru stages in the head of the Khaidun river valley, it was found that the dynamics of glaciation in the Late Holocene on the background of minor short-period fluctuations of meteorological parameters were largely determined by the position, geographical features and self-development of glacial and the adjacent landscapes. The comparative analysis of position of Late Holocene moraine complexes shows that the initially larger glacier in the Khaidun river valley degraded more intensively than the one in the tributary valley. This is explained by the "bad" orientation of the Khaidun river valley and its wide width, so the valley is better insolated and blown. In addition, the granularity and a diversity of landscape structures of all-aged moraines do not show the compliance.

Geoecotones. The dieback and migration of trees at tree lines and natural selection and gene flow within the forest range are the major mechanisms of their adaptation to climatic changes (Davis, Show, 2001; Rehfeldt et al., 2004). Monitoring of the upper and lower tree lines in mountains provides a simple and useful tool to develop data supporting vegetation cover alterations associated with climate change (Guisan et al., 1995; Shiyatov et al., 2001). Tree line monitoring appears to be most effective in mountains, because here, distances between vegetation boundaries measured by hundreds of meters are comparable with plant migration rates – meters per year. Thus, one vegetation belt may be replaced by another during one century in a warming climate.

Peat lands. Peat deposits of bogs are traditional sources of information about environmental changes in paleogeographical studies. The inner parts of the Altai-Sayan region experience little precipitation and low temperatures, unfavorable conditions for bog development. Currently, a few examples exist that characterize continuous evolution of individual landscapes supported by the data from peat profiles. Peat deposits of bogs are traditional sources of information about environmental changes in paleogeographical studies. The inner parts of the Russian Altai experience little precipitation and low temperatures, unfavorable conditions for bog development. For example, at the Kosh-Agach weather station, the annual precipitation is only 110 mm and the mean annual air temperature is −6.7 °C (Sevastyanov, 1998). Currently, in the Russian Altai, few examples exist that characterize continuous evolution of individual landscapes supported by the data from peat profiles. Recently, some bogs have been found in peripheral parts of the Russian Altai that are slightly warmer and more humid. For instance, we found peat deposits of up to 2 m thick in the middle mountains, located in the west of the Russian Altai (Chernykh et al., 2013). In the northeast, in the river valleys of low mountains, thick peat deposits reaching 7 m in depth have been studied (Inisheva et al., 2011). Our study sites were in the Malye Chily River valley, which enters Lake Teletskoye from the west. The moraine dam splits the valley into two parts. The upper part of the valley (Archa River valley) is wide and wate logged, whereas the lower part is narrow. The dam created a large lake in the Malye Chily River valley, with numerous bays in the valleys of its tributaries. Further, the dam's incomplete breakthrough created a vast wetland. A second, smaller lake was formed in the valley of an unnamed stream to the north of the dam. Part of the second lake still exists as Lake Ezhilyukel. First, we studied the whole waterlogged territory in the Yaryshkol and Archa River valleys. Upstream, peat thickness decreases. In sites adjacent to river beds, lacustrine silts are found at the surface. Two profiles in lacustrine-boggy deposits were constructed in locations with maximum peat thickness. Peat samples were taken from each profile for botanical analysis, and a radiocarbon date was obtained for each profile. The analysis suggests that Lake Ezhilyukel was partially emptied about 8000 yr BP. The complete emptying of the lake in the Archa valley occurred around 6000 yr BP (Chernykh et al., 2014)

Cryogenic landscapes. The stability and degradation of permafrost areas are extensively discussed regarding future climate changes as potentially important source of greenhouse gases (Schuur et al., 2008, 2009; Elberling et al., 2010, 2013), infrastructure stability (Wang et al., 2003, 2006) and farming potential (Mick and Johnson, 1954; Merzlaya et al., 2008). Permafrost is an important driver of ecosystems because thermal characteristics of the ground directly control or indirectly influence Denali's local hydrology, patterns of vegetation, and wildlife communities. Increased mean annual air temperatures result in warming of permafrost. A naturally or artificially caused decrease in the thickness and/or areal extent of permafrost (National Research Council of Canada Technical Memorandum, No.142.1988). Expressed as: a thickening of the seasonal active layer; a lowering of the permafrost table; a reduction in the areal extent of permafrost; or the complete disappearance of permafrost.

Floodplains. From 1976 to 2006, the annual precipitation in the Altai-Sayan mountain system increased insignificantly, but the increase occurred in the warm season (April – September), while in winter, precipitation slightly decreased and, consequently, water resources also decreased at the beginning of the spring snow melting (Sukhova, 2008). Due to more intensive spring warming which covers more altitudinal zones for shorter periods, which in turn has stimulated simultaneous snow melting (on a basin area that has grown larger since warming) and considerable precipitation and flooding since the 1980s, the negative trend of the maximum run-off of most rivers in Altai and Western Sayan (Katun, Biya, Tomj, etc.) has become positive. Therefore the probability of dangerous floods has increased for large rivers (Semenov, 2011).

Conclusions

Calculated that about 15% of all Russian Altai landscapes are indicator landscapes. They are glaciers and another glacial-nival landscapes, geoecotones, landscapes in the extreme conditions, peat lands and cryogenic landscapes. This allows us to consider the territory of the Russian Altai as a promising ground for monitoring the dynamics of natural processes.

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