Intensity of Cryogenic Processes in Central Yakutia in the context of GAME-Siberia Study

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Abstract

This paper illustrates the peculiarities of permafrost processes manifestation in various landscapes during the intense GAME observations in Central Yakutia. Observation results that were achieved at the Spasskaya Pad station near Yakutsk within the frameworks of the GAME-Siberia project and at Permafrost Institute stations are used in this paper.

Keyword: permafrost, landscape, process, stress, succession.

The period of intensive GAME-Siberia observations (1996-2000) in Central Yakutia coincided in time with climatic and cryoecological stresses in permafrost and in the environment as a whole. Thus the environmental investigations during this period were most effective for the study of critical situations in permafrost and its sensitivity.

The results of observations at the Spasskaya Pad study area of the GAME-Siberia Project and the Permafrost Institute's sites Neleger, Yukechi and Umaibyt located near Yakutsk are used in this analysis.

Earlier we analyzed the retrospective schemes of changes in air temperature, precipitation, soil temperature and seasonal thaw depth for Central Yakutia (Fedorov, 2001). The period of intensive GAME-Siberia observations (1996-2000) coincided in time with a considerable increase in mean annual air temperature (Fig. 1) and in thawing index, and a decrease in precipitation. These changes resulted in warming of soil temperatures in Central Yakutia in the late 1990s, which caused the activation of cryogenic processes and notably modified the permafrost-landscape conditions. Thawing of the upper layers of ground ice in disturbed and forest-free areas of the inter-alass landscapes triggered thermokarst. We related it to the development of cryoecological stress in the landscapes (Fedorov, 1996).

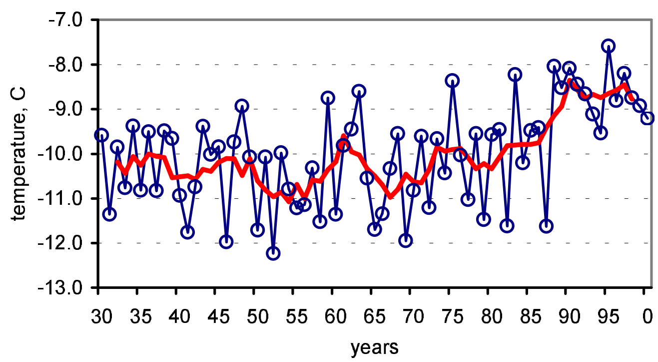

Fig. 1. Variability of mean annual air temperature in Yakutsk (thin blue line – actual data, thick red line – 5-year mean)

Field observations of thermokarst-related surface subsidence in Central Yakutia show that settlements occurred at flat locations of the forest-free inter-alass areas, which had not been subject to thermokarst earlier (Fig.2). In small thermokarst depressions, settlement rates of up to 10-15 cm/yr were measured during this period (Fig.3).

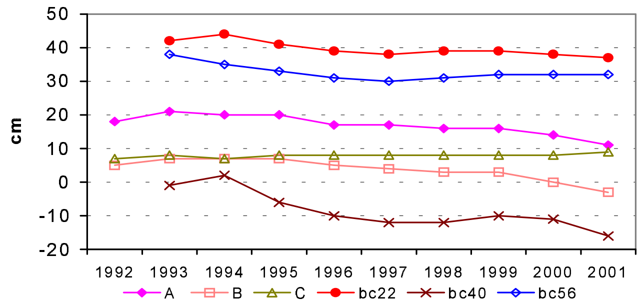

Fig. 2. Surface subsidence of flat inter-alas areas, site 2.
A, B, C – markers on flat inter-alas areas; bc22, bc40, bc56 – markers near small thermokarst depression.

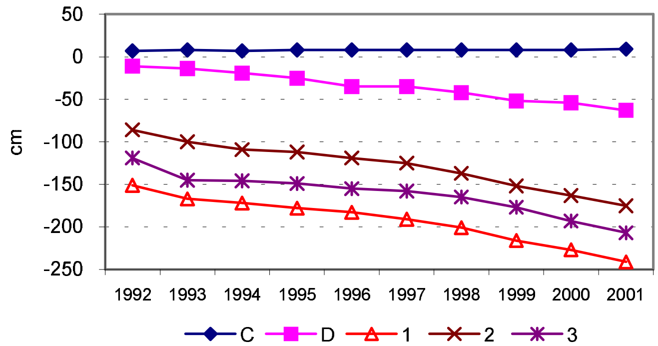

Fig. 3. Surface subsidence in thermokarst depression, Yukechi, site 2.
C – check point, undisturbed inter-alas area; D – incipient thaw depression; 1-3 – centers of polygons within thaw depression.

The rates of cryogenic processes are primarily dependent on soil hydrologic regime. We estimated the effect of active-layer moisture on the permafrost landscapes. Y.I.Torgovkin constructed GIS-based spatial models of active-layer thickness and moisture content variability over the period of intensive GAME-Siberia observations for the area adjoining the Spasskaya Pad study area. In spatial interpretations, we used a landscape map of a 10 x 12 km area where 45 terrain units at a patch ('urochische') level were identified. The number of landscape contours was 704 units. Analysis of the maps shows that active layer thickness and soil moisture content strongly vary from year to year. However, the general patterns of variations are practically identical for the patch types. The wettest conditions were observed in 1997 and 1999. Cryogenic processes were most intensive in the summer of 1999, when soil thawing was deepest. In this season, thaw depth values of 1.4-1.5 m occurred in 52.3% of the map area and moisture contents above 20% occurred in 49.5% of the area.

At present, both permafrost warming and cooling are observed in Central Yakutia. A decrease of permafrost temperature is primarily related, along with other factors, to the recovery of forest vegetation at successional stands after anthropogenic disturbance. Successional stands following fires and tree cutting occupy significant areas. They cover about 30% of the Spasskaya Pad area. We established the general patterns in vegetation succession in Central Yakutia. Investigations at the Umaibyt site show that the period of complete vegetation recovery is 130 years (Fig.4). We estimated the effect of vegetation succession on the permafrost thermal regime and active-layer thickness.

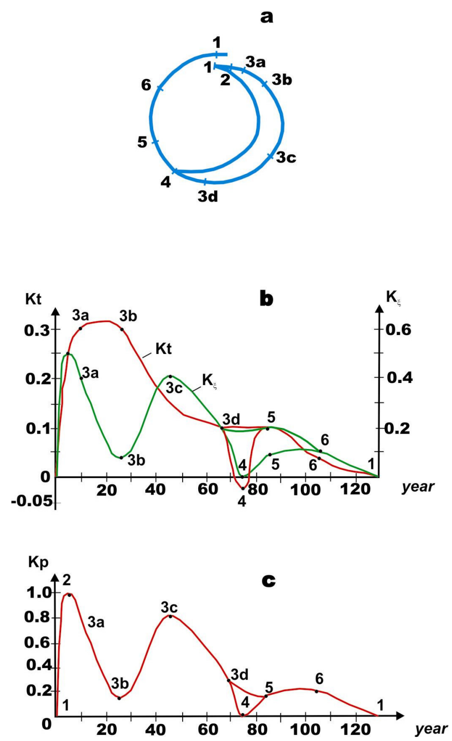

Fig.4. A succession scheme of landscape evolution at Umaibyt site (a), variability of ground temperature (Kt), seasonal thaw depth (K_ξ) – (b) and protective thickness (Kp) – (c).

Ground temperatures in the recovering birch and birch-larch forests have cooled by 0.3-0.5°C over the period from 1980 to 2000. Based on this model, both retrospective and predictive models of permafrost can be developed.

Observations indicate that the GAME-Siberia study period fell on the time of cryoecological stresses in the Central-Yakutian landscapes. The data obtained during the GAME-Siberia Project will provide a basis for understanding the development of critical situations in permafrost landscapes and for determining permafrost sensitivity criteria.

Reference

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