Study of oligotrophic bog by ground-penetrating radar

A V Klokov[1], A S Zapasnoy[1], A S Miron'chev[1], E A Dyukarev[2], S V Smirnov[2] and S S Shipilova[3]

[1] National Research Tomsk State University, Tomsk, Russia
[2] Institute of Monitoring of Climatic and Ecological Systems, SB RAS, Tomsk, Russia
[3] National Research Tomsk Polytechnic University, Tomsk, Russia

E-mail: 701-kav@mail.tsu.ru

Abstract. The work deals with study of peat deposits of oligotrophic bog and spatial distribution of snow cover by geolocation. Data from ground penetrating radar were compared with the data of conventional measurements of a peat depth and snow cover. A fairly good agreement between the thickness of the peat deposits, snow depth by using ground penetrating radar and the data of conventional measurements has been obtained.

1. Introduction

Optimization of nature resource management requires the conception of the quantitative and qualitative characteristics of biological resources involved into economic activity, the conception of the trends of their natural and anthropogenically conditional development [1, 2]. The swamp formation process is an integral part of the development of taiga ecosystems. This process is the most significant from the natural processes for the development of the natural environment including changes in the relief, in hydrological conditions, in soil and plant covers and in other components of the ecosystem.

On the territory of Western Siberia bog ecosystems occupy almost 50% of the area and they contain about 36% of the total pool of soil carbon in Russia. There are still many unresolved issues despite the significantly increased interest in these latter days in the study of bogs, especially with respect to the carbon balance. For example, an accurate estimate of areas occupied by bogs, of peat and carbon reserves, of the degree of development of bog-raising processes, of the functioning of bogs when external factors change, and so on, are the difficulty.

The aim of the work is to assess the peat reserves in the peat deposit of bog and to study the spatial distribution of snow reserves at the end of the winter period. The ground-penetrating radar “OKO-2” was used for assessment of the depth of the peat deposit and the height of the snow cover.

2. Objects and methods of research

The oligotrophic bog Timiryazevskoye was as the object of the study, which is located on the left bank of the river Tom and formed in one of the hollows of the ancient river runoff.

In summer time more than 60 sounding holes were drilled in the Timiryazevskoye bog and more than 30 descriptions of vegetation were made. The area of the bog is 14.4 hectares, the sedge-sphagnum swamp occupies 25% of this area, the most of the territory is occupied by ryam (it is about 70%), and only a small part on the borders between the ryam and swamp is represented by the ryam-hollow complexes. The average thickness of the peat deposit for the total bog is 4 meters with a maximum depth of 8 meters. The results of radiocarbon dating testify about the beginning of the bog formation process about 6,000 years ago in the local micro-fallings. The swamp area, which is an overgrown lake, is more youthful and its formation began about 4,000 years ago [3].

The antenna block AB-90 of the ground-penetrating radar "OKO-2" was used to assess the depth of the peat deposit and ensure high penetrating ability. The antenna has an average frequency of the emission spectrum of 90 MHz, which allows to make probing to a depth of 16 meters [4]. The probing was conducted by the trajectory along the perimeter of the open swamp (Figure 1).

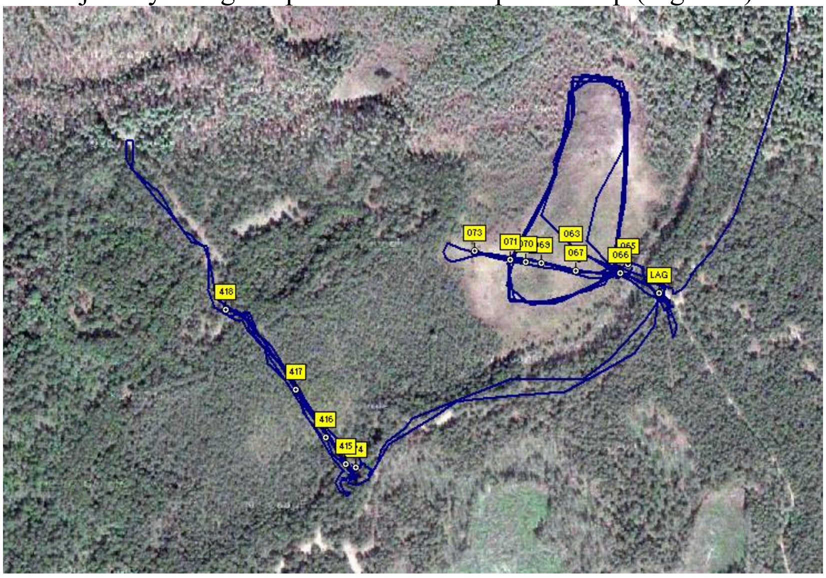

Figure 1. The trajectory of probing and points of conventional measurements of snow.

The probing path was chosen taking into account the measurements made earlier with the help of a drill.

3. The thickness of the peat deposit

The scanning step was chosen to be 5 cm for detailed relief drawing of the bog's bottom. The total length of the profile was 425 m, the sweep by depth was 400 ns.

To increase the contrast of the echogram, it is necessary to take into account the exponential attenuation of radiation with the depth when penetrating into research environment. The probing environment contains moisture, which causes a weakening of the radio signals. Correction of exponential attenuation can be carried out only on average for the research environment. The sequence of operations is as follows: at each position of the geolocator the time records of the reflected signals are converted into amplitudes of the analytical signal, and then are averaged over all positions. Under the assumption of exponential attenuation of signals, the averaged dependence is approximated by an inclined line using a semilogarithmic measure [5]. Thus, the correction of this attenuation makes it possible to equalize the contribution of all layers and, thereby, to increase the contrast of the echogram (Figure 2). In the Figure 2, the path passed by the geolocator is on the X-axis, and the temporal lag of the reflected signals is on the Y-axis. The intensity of the reflected signals is shown by gradations of gray color. The characteristic relief of the mineral bottom is visible. there The expressed increase of the bog's bottom is observed on the location from 210 meters to 320 meters. Another one layer is observed below. But it is a secondary reflection of the signal and does not contain within itself any useful information. Strong reflection in the sections 0 – 100 and 320 – 400 m, corresponding to time of 50 to 130 ns, indicates unfrozen water in the peat layer. A water lens with the capacity of 0.5 – 2 m is in this place of the bog's thickness.

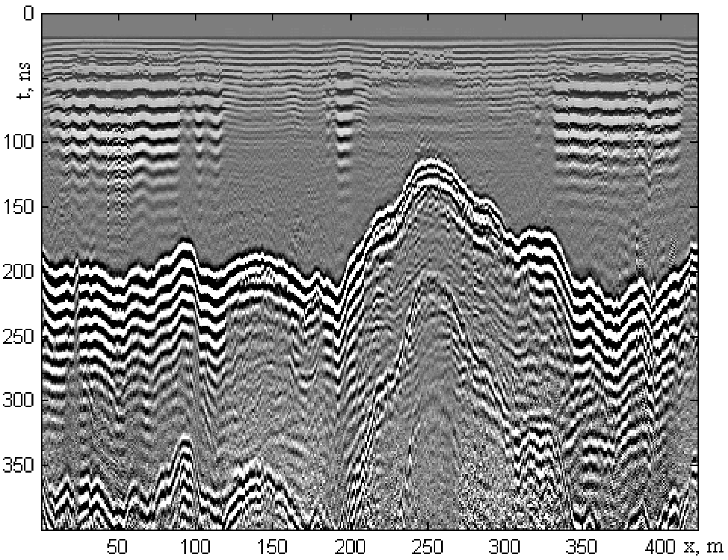

Figure 2. Raw geolocation data taking into account the exponential attenuation.

The map of the relief of the mineral bottom of the bog was constructed by 60 measurements of the peat's depth and delineation of the boundaries of the bog by the space snapshot [3]. The meanings of peat's depths along the track of probing by ground-penetrating radar were obtained based on this map. The comparison of the data of the contactless and contact methods for the depth measurements of peat deposits is shown on the Figure 3.

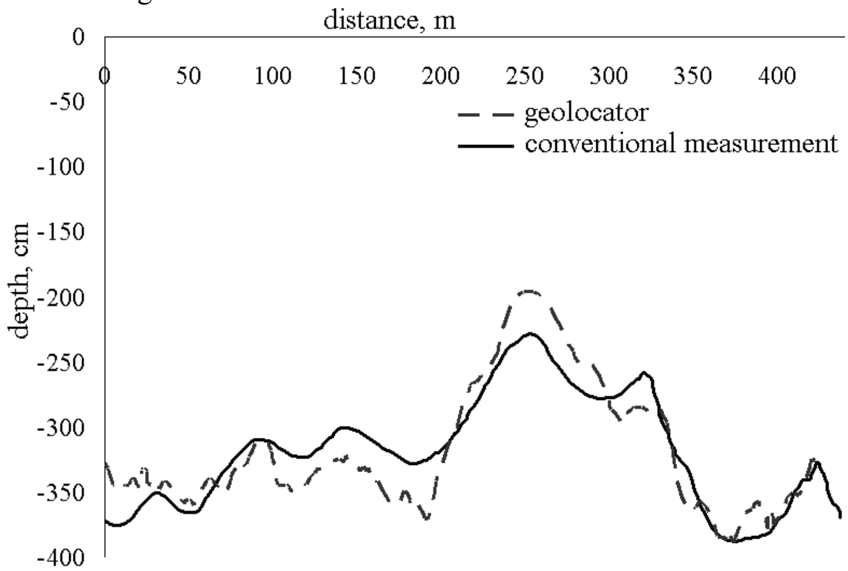

Figure 3. The comparison of the depth measurements of peat deposits with GPR and peat drill.

A good enough matching is observed as can be seen from the Figure 3. The data of the ground-penetrating radar show the microrelief of the mineral bottom of the bog, revealing even small irregularities, which cannot be detected by the contact method.

4. Snow cover

The small antenna block AB-1700 of the ground-penetrating radar "OKO-2" was used to assess the snow cover thickness. The antenna has an average frequency of the emission spectrum of 1700 MHz and maximum resolution in depth of 0.03 m [4]. The trajectory of the movement, the scanning step and the total length of the profile remained the same as when determining the depth of the peat deposit. The depth scan was 16 ns. The data processing procedure is the same that was used for determining the depth of the bog. The data considering the exponential attenuation are shown on the Figure 4. As can be seen, the contrast of the obtained picture is markedly increased after considering the attenuation.

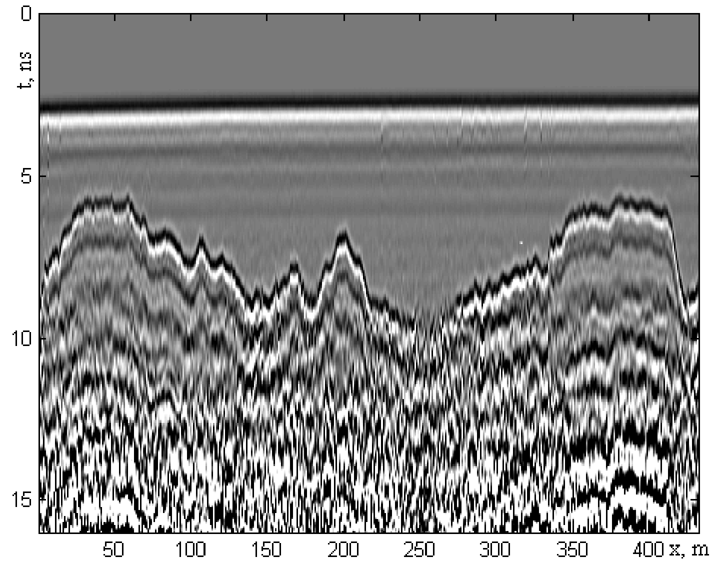

Figure 4. The geolocation data of snow cover thickness.

It is possible to restore the relief of the bog's surface using the data of probing of snow cover thickness. This is due to the fact that in winter the snow fall flat, forming practically flat horizontal surface.

The comparison of snow height measurements by a traditional method and using the ground-penetrating radar is shown on the Figure 5. A good enough matching is observed as can be seen on the Figure 5.

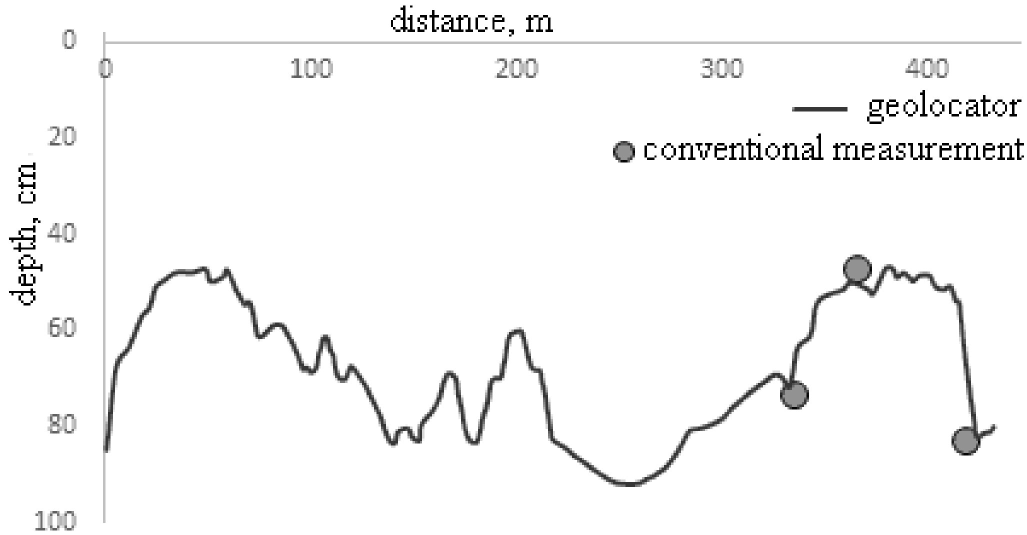

Figure 5. The geolocation data of snow cover thickness.

Unfortunately, the remaining snow-survey points were far enough from the ground-penetrating radar's track and cannot be used for comparison with geolocation measurements. The height of snow on the investigated bog varied from 50 to 80 cm. The top layer of 9 – 12 cm is a loose freshly fallen snow. A dense crust with thickness of 10 cm was located under it. In the central part of the bog under the snow there was the lay of water of 4 – 8 cm. The surface of the bog under the snow was in the form of ice or frozen peat with the thickness of 8 to 30 cm, deeper peat was unfrozen and saturated with water. The density of snow, determined by the weight method with the help of the snow-measure VS-43, was 230 and 170 kg/m^3 at the beginning (330th meter on the profile) and at the end (415th meter) of the snow-shooting track respectively.

Given that the snow cover during the study period was smooth and almost horizontal, the relief of the bog's surface will have a reverse view relative to snow height. That is, an increase in snow cover thickness on profile's sections from 50 to 350 m corresponds to a decrease in the relief of the bog's surface, and a decrease in the snow thickness at the very beginning and the end of the track corresponds to an increase in the surface relief on the outskirts of the bog.

5. Conclusion

Thus, conducted research showed a high correlation of the discovered features of the structure of the "Timiryazevskoye" bog and the snow cover thickness according to the data of geolocation and contact measurements.

Acknowledgements

The paper is based on the research results, which was conducted in the framework of the grant of the Russian Foundation for Basic Research (mol_a) No. 16-32-00619 "Study possibilities for applying jitter to increase resolution in the subsurface tomography".

References

[1] Petrov K M 1997 General ecology: interaction of society and nature *S-P, Khimiya Publ* 352
[2] Williams B K 2011 Adaptive management of natural resources–framework and issues *Journal of Environmental Management* **92** 1346
[3] Golovatskaya E A , Dyukarev E A, Smol'yaninov E E 2011 Landscape-ecological characteristic of oligotrophic bog «Timiryazevskoe» (Tomsk district, Tomsk region) *Sovremennye problemy genezisa, geografii i kartografii pochv: Sb. materialov V vserossiiskoi konferentsii s mezhdunarodnym uchastiem, 1–5 oktyabrya 2011* p 282
[4] Manual for the ground penetrating radar «OKO-2» 2011 *M.: OOO «Logicheskie sistemy» Publ.* 98
[5] Yakubov V P, Shipilov S E, Sukhanov D Ya, Klokov A V 2017 *Wave tomography* (Scientific Technology Publishing House, Tomsk) p 248