Application of ALOS and Other Satellite Data to Study Landscape Changes Related to Petroleum Fields and Their Exploration and Exploitation

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Abstract

The study of landscape changes connected with cryogenic processes development has been done in the northern part of Timan-Pechorian petroleum province (North-West of Russia) in subarctic region using multitemporal satellite data: ALOS AVNIR (10.09.2006), and LANDSAT (08.03.1988 and 07.21.2000). Most numerous are the changes caused to drainage of thermokarst lakes. Processing and comparison of multitemporal satellite data were realized on the basis of GIS software (ERDAS Imagine, Map Info). Detection of changes was made in automatic mode using the methods of color compositing and by visual interactive analysis. The fact confirmed melting of permafrost connected with global warming has not revealed using satellite data. The advantage of ALOS AVNIR data for study of cryogenic processes has shown.

***Keywords*:** ALOS AVNIR, LANDSAT, landscape changes, thermokarst lake, global warming

1. GEOLOGICAL SETUP OF THE AREA

The study area is situated in the northern part of Timan-Pechorian petroleum province (North-West of Russia) in subarctic region (tundra zone). It characterized by extreme climatic conditions and underlined continuous permafrost with thickness ranging from 50 to more than 200 meters that has caused wide development of cryogenic processes such as thermokarst, thermoerosion, frost swelling of hillocks, polygonal grounds, slope processes and others. Quaternary deposits are widespread in this area and consist of moraines, glaciofluvial, fluvial, glaciolacustrine and lacustrine sediments. The area includes intensive exploited petroleum fields. Their exploitation can disturb the natural environment and cause strengthening of intensity of cryogenic processes. Global warming can cause melting of permafrost and the changes in cryogenic processes development, which can complicate the exploitation of petroleum fields and lead to accidents on oil and gas pipeline.

The results of our previous work which deal with the comparison of LANDSAT imagery obtained in different years (in July-August of 1986-1988 and in July-August of 2000) in the northern part of Timan-Pechorian petroleum province for the area more than 150 000 km^2 have shown that most numerous are the changes connected to drainage of thermokarst lakes [1]. More than 700 lakes or their parts are dried up, while the increase of lake areas or formation of new lakes practically does not occur. Dried thermokarst lakes are situated mainly within the limits of low seaside plains, lacustrine and marsh landscapes composed mainly peat and sandy sediments, and also on the large rivers valleys. The changes of a coastal line also confirm the tendency of drainage of the territory: there is accumulation of sand deposits on separate sites of a coast. The largest changes are marked in area of a mouth of the Pechora river and also to the north of a mouth of the Korotaikha river.

2. OBJECTIVES

The main objective of our research is the study of landscape changes above petroleum fields caused by natural factors as well as human activity using ALOS and other satellite data. This paper is devoted to monitoring of changes caused by natural factors such as cryogenic processes development (preferably changes in thermokarst lakes and shore line) using ALOS AVNIR, and LANDSAT multitemporal satellite data. The problem of global warming is discussed.

3. DATA USED

In this study the follow images were used: LANDSAT 4 TM acquired in August 03, 1988, LANDSAT 7 ETM+ acquired in July 21, 2000 and ALOS AVNIR data acquired in October 09, 2006. Summer (July-August) and early autumn (September) are optimal seasons to study landscape changes connected with natural factors. In June the changes are seasonal and caused by snow melting.

Other part of the year (end of October – end of May) the area is covered by snow.

LANDSAT sensors have 7 spectral bands with spatial resolution 30 meters (except band 6 – 60 meters): band 1 – 0,450 - 0,515 µm; band 2 – 0,525 - 0,605 µm; band 3 – 0.63 - 0.69 µm; band 4 – 0.7 5- 0.90 µm, band 5 – 1.55 - 1.75 µm; band 6 – 10.4 - 12.5 µm; band 7 – 2.09-2.35 µm, and ETM+ has band 8 (panchromatic) – 0.52 - 0.90 µm with spatial resolution 15 meters.

ALOS AVNIR acquires images in 4 spectral bands with spatial resolution 10 meters: band 1 – 0,42 - 0,5 µm, band 2 – 0,52 - 0,60 µm, band 3 – 0,61 - 0,69 µm, band 4 – 0,76 - 0,89 µm.

4. METHODOLOGY

Computer processing and analysis of the data were realized on the basis of GIS software (ERDAS Imagine, Map Info) and includes: creation of databases of satellite images obtained in different years; geometrical and radiometric corrections of satellite images, image to image rectification, interactive interpretation of different satellite images with compilation of vector layers, processing of satellite images for change detection; estimation of cryogenic progressing and disturbance of natural environment. Used in the study LANDSAT data are acquired in different years, but in one season (Fig. 1, 2). So it is possible to detect changes in automatic mode using the standard techniques: color compositing, image differencing, principal component analysis and others [2]. Most simple approach is the generation of RGB color composite from pair of images acquired in different years. The bands with equal wavelength (for example nearinfrared - band 4 of LANDSAT) and with histogram equalized are used. The thermokarst lakes are the simple objects for change detection. The lakes with water are black on the image of this band but dried lakes are gray and sometimes white. So if the image acquired later goes to red and early image goes to green and blue, on the resultant image dried lakes will be red and the lakes without changes will be black (Fig. 3).

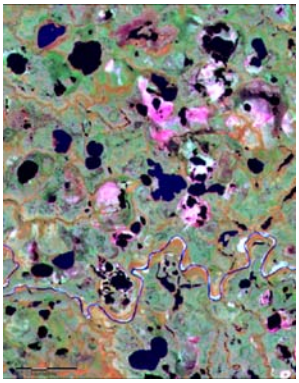

Figure 1. Landsat 4 TM RGB 453 (03.08.1988)

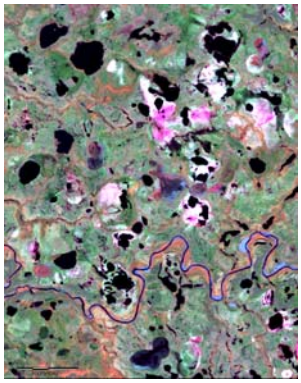

Figure 2. Landsat 7 ETM+ RGB 453 (21.07.2000)

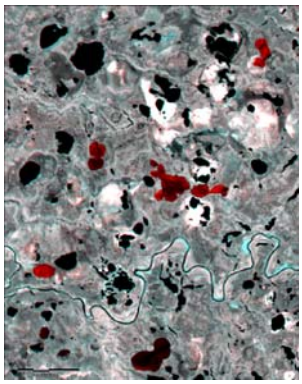

Figure 3. Result of change detection. R-Landsat 7(4), G and B–Landsat 4(4)

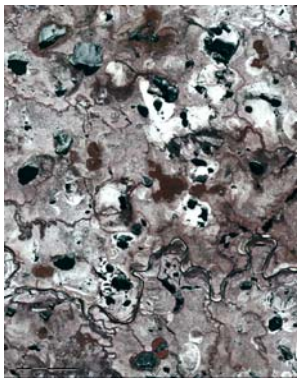

Figure 4. ALOS AVNIR RGB 432 (10.09.2006)

New lakes should be blue. But we observe only light blue sites connected with increase of soil moisture (Fig. 3).

1, 2, 3, 4 spectral bands of ALOS AVNIR have the same wavelength that 1, 2, 3, 4 spectral bands of LANDSAT. But thin snow cover is observed on ALOS AVNIR data acquired in October. Some lakes have frozen and covered by ice. So the spectral response from these lakes will be differing than from lakes with water on LANDSAT images of summer season. Dried lakes on ALOS AVNIR also have another tone due to seasonal changes in vegetation. On color composite image RGB (bands 4, 3, 2 of ALOS AVNIR) dried lakes are brown, lakes with water are black, lakes with ice – light blue (Fig. 4). The fastest way of comparison of ALOS AVNIR and LANDSAT data differing on spatial resolution and seasonal aspect is visual interactive analysis using the GIS software.

5. RESULTS AND DISCUSSION

The analysis of ALOS AVNIR data acquired in October of 2006 for the area near 22 000 km^2 confirms the tendency of thermokarst lakes drainage that has shown in our previous work [1]. Comparison of ALOS AVNIR data of 2006 with LANDSAT data of 1988 has allowed revealing 85 lakes or their parts, which are dried up. From them 47 lakes have dried up to 2000 and remain dry for 2006 (comparison of ALOS with LANDSAT data of 2000). 38 lakes have dried up in whole or their parts continued to dry up from 2000 to 2006. On Fig. 1 – 4 we can see the process of drying of the lakes from 1988 to 2006. The increase of lake areas or formation of new lakes practically does not occur (except the lakes, which were formed due man-made activity). It testifies that processes of global warming have not find yet reflection in changes of thermokarst lakes. In fact when frozen ground intensively thaws, surface subsidence and formation of new lakes should occur. On ALOS AVNIR data we can observe frost swelling of hillocks on the bottom of dried thermokarst lakes that testified that the ground frosting is increased (Fig. 5).

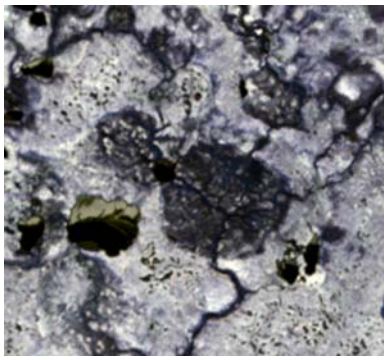

Figure 5. ALOS AVNIR RGB 432 (10.09.2006). Frost swelling of hillocks on the bottom of dried lakes

The comparative analysis of coastal line using LANDSAT data of 1988 and 2000 and ALOS AVNIR of 2006 has shown that location of a coastal line within study area remained stable in the period from 1988 up to 2000, but in 2006 flooding small sites of beaches on islands and in delta of the Korotaikha river and increase of soil moisture on seaside plain is detected. The additional supervisions are necessary for final conclusions about the reason of these changes. They can be caused by seasonal or daily changes as well as by processes of climate warming.

Restoration of a tundra vegetative cover disturbed in the process of petroleum fields' exploration occurs rather quickly. Vegetation on temporary roads and boreholes areas is marked already in the satellite image of 2000 in comparison with 1988, and in 2006 the disturbances become practically not distinguished.

The advantage of ALOS AVNIR data for study of cryogenic processes is their high spatial resolution that allows to detect microforms of relief caused by ground frosting, small lakes which can caused by permafrost melting, changes in character of vegetation and other features, which poorly distinguished on LANDSAT images with spatial resolution 30 meters.

We hope that father monitoring of landscape changes using multitemporal ALOS data in automatic mode shall allow to receive interesting scientific results.

6. CONCLUSION

The study was concluded as follows:

- Application of multitemporal satellite data and GIS in evaluating the changes in thermokarst lakes and coastal line is a feasible and effective approach. This approach can be used for landscape changes monitoring of the study area in the future.
- The tendency of thermokarst lakes drainage revealed using comparison of LANDSAT and ALOS AVNIR data shows that the processes of global warming have not led yet to intensive melting of permafrost.
- ALOS AVNIR data due to their high spatial resolution is an effective tool for study of cryogenic processes and landscape changes.

7. ACKNOWLEDGEMENT

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8. REFERENCES

[1] I. Smirnova, A. Rusanova, and N. Smirnova, "Processing and Interpretation of Remotely Sensed Data based on GIS for Study of Exogenic Geological Processes in the North-Eastern part of Timan-Pechorian Petroleum Province", Proceedings of III International Conference "Remote Sensing of Natural Environment", Minsk, Byelorussia, 2006, pp. 166-168.

[2] ERDAS Field Guide, 5th Edition. ERDAS Inc. Atlanta, Georgia, 1999. 672 p.