THE CLIMATE CHANGE IMPACT ON THERMOKARST IN WEST-SIBERIAN TERRITORY AND GEOECOLOGICAL RISKS IN GAS INDUSTRY

[1]Samsonov R.O., [1]Lesnykh V.V.
Limited Liability Company Scientific-Research Institute of Natural Gases and Gas Technologies – VNIIGA Z, Moscow, Russia

[2,3]Yu.Polishchuk,
[2]Ugra State University, Khanty-Mansiysk, Russia
[3]Instittute of Petroleum Chemistry, RAS, Tomsk, Russia

[4]N.Bryksina
[4]Ugra Research Institute of Information Technologies, Khanty-Mansiysk, Russia

Keywords:

Geo-ecological risk, gas industry, permafrost, thermokarst, global warming, remote sensing

Abstract

The basic expected consequences of climatic change in the territory of Russia are systematized. It is shown, that changes of climate can lead to an increase in number and scales of emergencies at the gas industry objects. Examples of monitoring of changes of individual components of the environment in the territory of Western Siberia with use of remote sensing of the Earth surface are given.

Climatic change and emergencies in gas industry.

The global climate change is the generally acknowledged fact, and expected consequences of climatic changes may affect many branches of economy and social sphere of the majority countries in the world [1]. The researches executed by organizations of the Russian Academy of Sciences and the Ministry of Emergencies of Russia have allowed to allocate and range about 40 factors of strategic risks in the basic spheres of the vital activity of the state. These factors have been integrated into five basic spheres of the vital activity of the state: economic, political, social, natural-industrial and R&D. The study has shown, that one of the important factors of strategic risks are consequences of the global climatic change [2].

The given problem is directly connected with the problem of energy security, the maintenance of which substantially depends on the sustainable operation and development of the gas industry of Russia at large and the Gazprom's industrial

complex in the first place. Negative consequences of global change of climate are one of threats to reliable gas supply to internal consumers and to performance of obligations on export contracts. As scales and intensity of climatic changes have stochastic nature, it is expedient to carry out the assessment of corresponding impact with use of the risk concept [3]. As applied to the considered processes of interaction of natural and technological factors it is expedient to use the concept of geoecological risk. Geoecological risks include both the risks caused by cumulative negative influence of natural and technological factors on the environment and population's health in zones of industrial objects of the gas industry operation (techno-natural risks), and the risks caused by the influence of natural factors on the gas industry development (natural-technological risks). The special urgency of researches on identification and assessment of the geoecological risks related to climatic changes, is caused by the necessity of accelerated development of natural gas and liquid hydrocarbons fields in the territory of the Yamal peninsula and of the Barents Sea shelf.

The materials of the Third National Report of the Russian Federation concerning the global climate change show that with a high degree of probability climatic changes can be expected in the territory of Russia [4]. It is marked, that consequences of the climate changes can be different for various regions and fields of activity. The basic trend of the climate change is the warming accompanied by increased aridity. Most intensively the process of warming will show up to the east of Ural while near to the Black Sea the cold snap is possible. But this is only one side of process. The other side, of no less importance, lies in the strengthening of nonuniformity of the natural phenomena and the growth of the frequency of extreme statuses.

According to experts, the greatest changes of climate and scales of consequences can be expected in northern regions of the country. An increase of the average temperature of air by 4 ^{0}C will entail irreversible changes in permafrost regions. Already now in Western Siberia intensive thawing of frozen breeds (up to 0,04 m /year) is marked. Within 20-25 years it is expected, that the border of thermokarst in Western Siberia will move 30-80 km to the north, and on islands – up to 200 km. By 2050 the zone of permafrost will move up to 150-200 km. According to model assessment by the end of the summer season the top layer of ground can thaw to the depth of 0.1-0.2 m in the Extreme North and almost to 2 m near the southern border of permafrost. Because of warming by the middle of the 21st century the thickness of active layer of ground may increase by 0,6 m in the southern zone of permafrost [5]. The warming of climate will lead to irreversible natural processes that will have negative consequences for settlements and explored territories. Thawing of permafrost will lead to the growth of technological emergencies due to collapse of buildings and constructions and damage of communications.

Already at present in Western Siberia the annual number of failures and accidents at oil and gas pipelines, with the total length in Russia about 350 thousand km, accounts for about 35 thousand. About 21percent of failures are connected with mechanical impacts, including those with loss of stability of the bases and deformation of support. There are numerous examples of infringement of integrity and destruction of houses and industrial buildings, ruptures of pipelines due to permafrost degradation. It is expected, that with the increase of average annual temperature of air by 2 degrees the carrying ability of the bases will decrease by 50 percent [1].

The threat to integrity of the infrastructure objects is especially great where the frozen ground contains plenty of ice. Such areas include a significant part of the valley of the Lena river, the West Siberian plain, Chukotka and the most part of island territories of the north of the European part of the country. In the listed regions there are large oil and gas complexes, power transmission lines, Bilibinsk nuclear power station.

One of the climatic change consequences may become an increase of frequency of such short-term extreme weather conditions as strong snowfalls, hail, storms, late frosts, abnormally low or high temperature of air. The trends of change of dangers and threats connected with the climate change are shown in Table 1 [6].

Table 1. Trends of change of dangers and threats by Federal Districts of Russia

Federal District	Trends of dangers changes				
	Flooding	Forest fires	Degradation of permafrost	Initiated technological emergencies	Bio-social emergencies
North-Western	-	-	↑	↑	↑
Central	-	-	-	-	-
Southern	-	-	-	-	-
Volga-Ural	↑	↑	↑	↑	↑
Siberian	↑	↑	↑	↑	↑
Far Eastern	-	↑	↑	↑	↑

↑ - increase of danger;

- no changes.

Since the majority of gas fields and significant number of gas pipelines are in the territory of northern areas in the zone of distribution of permafrost, as the analysis of Table 1 shows, the climate change will probably lead to the growth of geoecological and other risks.

The possible forms and scales of geoecological risks manifestation, as applied to underwater crossings and linear sections of operating main gas pipelines on the territories of Western Siberia, are studied in detail in [7]. The processes initiated by the climate change, will render significant influence on the system of main gas pipelines in the territory of Yamal peninsula, where significant part of linear sections may be found in bogs or at the bottom of lakes, which will lead to the growth of frequency of emergencies.

Monitoring of climate change consequences on the basis of remote sensing data

The prospects of gas production in Russia are connected with the development of the north territory, which requires the pipeline system expansion and building of other objects of the gas and oil industry in permafrost. Due to the global warming, started in 1970-ies, the increasing of geocryologic processes in permafrost is expected. The accident rate in the gas and oil pipeline systems and other objects of oil and gas industry in West Siberia is going to grow that will lead to increasing of geoecological risk and significant financial damage. So the study of changes of the bog landscape cryogenic conditions in West- Siberian permafrost is relevant problem. It cannot be

solved without using of the Earth surface remote sensing data. Due to the progress in the information-space technology development, the spatial resolution of space images has considerably increased, that gives an opportunity to study changes of cryogenic conditions of the bog landscape using high-resolution space images under impact of climatic changes.

Among indicators of cryogenic conditions the most important ones are geomorphologic indicators. The main of them in permafrost conditions are thermokarst, polygonal relief and antinodes.[8,9]. The analysis of remote sensing data in geocryological researches has shown that thermakarst lakes can be used as the most prospective indicator of cryogenic landscape changes.

The territory of the Sredne-Hulymskoye oil field has been selected for studying changes of permafrost rocks state using space images. The test area for researches is situated between the upper streams of Levaya Khetta and Hugeyaha, which are big left tributaries of the river Nadym. The thermokarst lakes, formed as a result of undersurface ice melting, are the objects for researches. Geocryological processes caused by the global warming lead to declining durability of permafrost rocks. It results in thermokarst lakes' area reduction and their full disappearance.

Research of dynamics of cryogenic objects changes on the test area was carried out using five space images taken at different time. They are:

Landsat - 1 (scanner MSS), 10.08.1973.
Landsat - 5 (scanner MSS), 26.06.1988.
Resurs - F2 (scanner MK 4), 14.06.1993.
Landsat - 7 (scanner ETM), 03.07.2002.
Spot - 5 (scanner HRV), 20.07.2005.

Fig. 1 represents a fragment of the test area space image (1973) where 11 thermokarst lakes are indicated with numbers. Changes of the lakes water surface areas were measured with use of the software ERDAS Imagine using space images taken in different times for the study of dynamics of the thermokarst lakes' state.

Fig. 2 represents fragments of space images taken at different time, showing consecutive stages of decreasing area of thermokarst lake 9, isplayed according to numbering in Fig 1.

Measurements of water surface area of lake 9 carried out in different years have shown that the water surface area of lake 9 in 1993 (Fig. 2-b) declined down to 60 percent of the initial area, measured in 1973 (Fig. 2-a). The process of area declining is still continued. It is confirmed by space images taken in 2002 and 2005 (Fig. 2-c and Fig. 2-d accordingly). During more than 30-year period the lake's area has decreased to 40 percent of initial size.

The analysis of dynamics of the area changes for all 11 lakes (Fig. 1) has shown that some lakes had disappeared at all or had been transformed in disappearing lakes. An example of disappearing lake is given below. Measurements of areas of all 11 lakes made with space images are presented in Fig. 3 as a family of graphs that show dependence of the lake area on time.

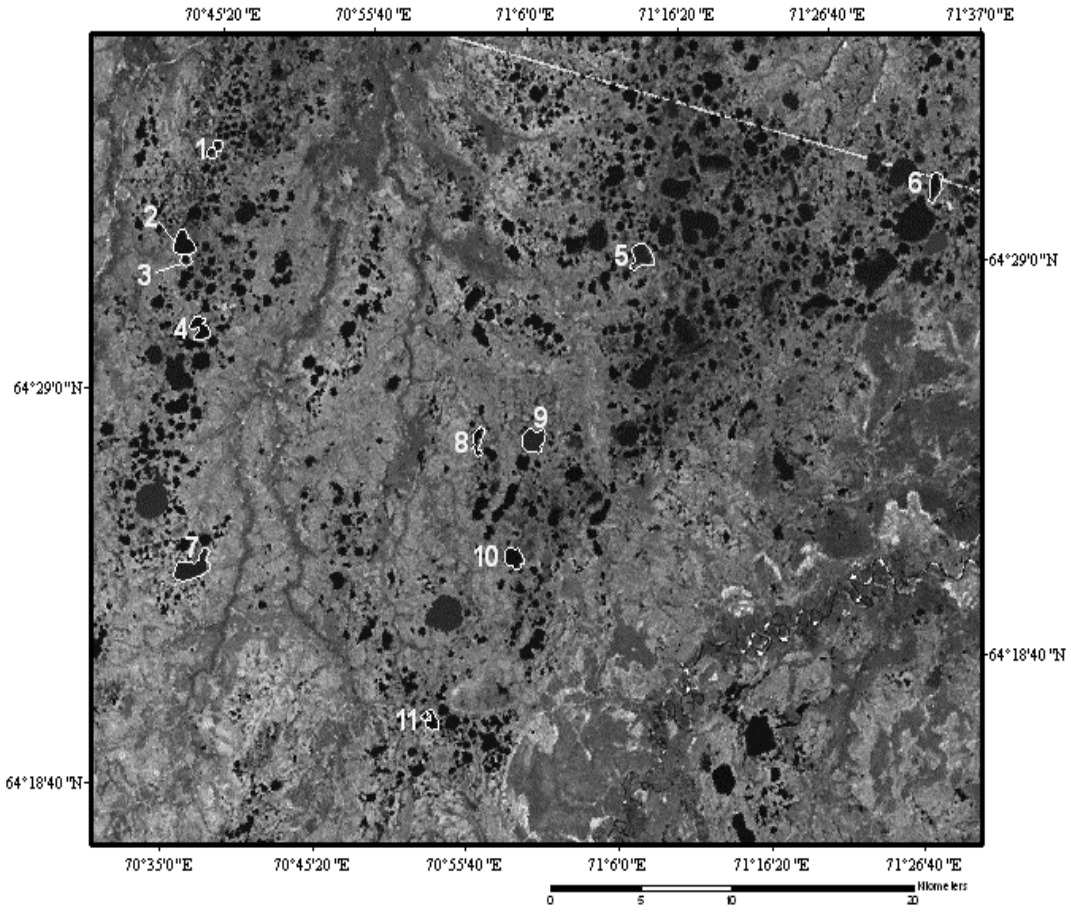

Fig. 1. Fragment of space images Landsat-1 (10.08.1973г.)
with indicated thermokarst lakes

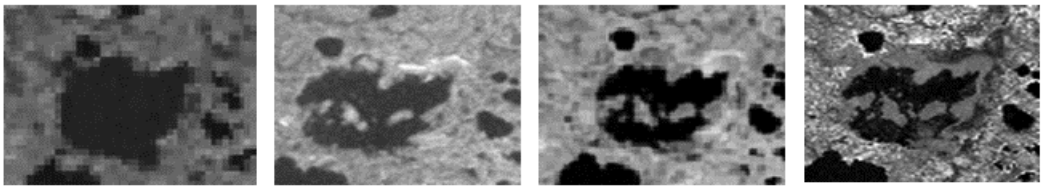

Fig. 2. Space images fragments of consequent stages of thermokarst lake 9 decrease. Designation: a-Landsat-1 (1973), b-Resurs -F2 (1993),

c- Landsat-7 (2002), d- Spot-5 (2005)

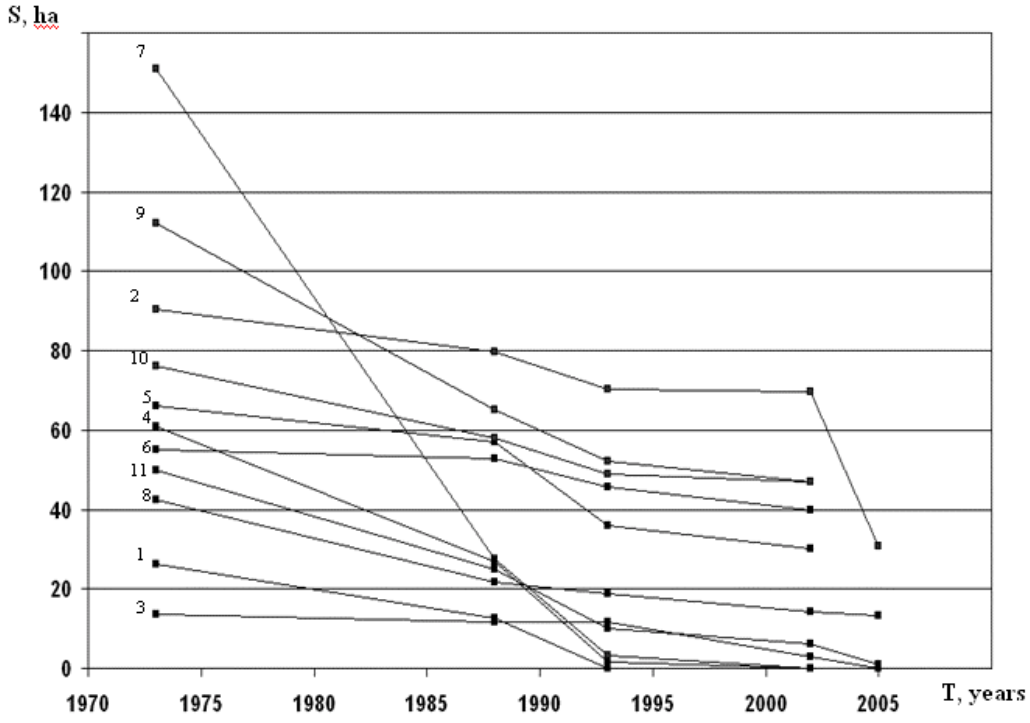

Fig. 3. Changes of thermokarst lakes' areas in time

Fig. 3 represents disappeared lakes indicated with numbers 1, 3, 4, 7, 11. The other 6 lakes have reduced their areas. It allows to make conclusion about swift degradation of frozen rocks under the influence of global warming. This conclusion is confirmed by results of researches of American scientists [10], who on the basis of analysis of space images of West- Siberian permafrost territory determined that during the period from early 1970-ies till the end of 1990-ies the amount of big lakes (with area exceeding 40 ha) had declined from 10,882 to 9,712 and 125 big lakes had disappeared completely.

Conclusion

As the executed analysis shows, the consequences of the global climate change for the gas industry objects are not only probable, but also might be large-scale events.

Expected consequences of climatic changes require a system of engineering adaptative measures. Such measures can include a complex of actions aimed at the preservation of the soil temperature, technical and biological rehabilitation and a complex of antierosion actions. Monitoring of the soil thermal condition should play an important role.

It is known that the north territory of Russia warms up considerably faster than others regions of the world. For the last century an average annual temperature (according to existing data [11]) has increased by more than 3°C. Bog landscapes spreading in the permafrost area are most sensitive to temperature alterations because of permafrost melting [12]. Thermokarst lakes are the most convenient object for distant monitoring of the global warming influence on the permafrost rocks state and the study of bog landscape dynamics on the basis of space images taken at different times.

References

1. Proceedings of the World Conference on the Climate Change. Moscow, October, 2003.

2. Strategic Risks of Russia: assessment and forecast / EMERCOM of Russia, 2005.- 392p.

3. Akimov V., Lesnykh V., Radaev N. Risk in nature, industry, society and economy, 2004, Moscow – 352 c.

4. National Report on Climate Change, Moscow, 2002 – 29 p.

5. Meleshko V.P. et al. Change and variability of climate of Northern Eurasia in the 21st century: calculations on ensemble of climatic models. – In Proceedings of the International Conference on Problems of Hydrometeorological Safety, September, 2006, Moscow.

6. Faleev M.I., Akimov V.A., Lesnykh V.V. Problem of global climate change and strategic risk management. - In the book "Kiyoto Protocol: the Responsibility and Prospects for Business", Moscow, 2002, pp. 9-11.

7. Khomyakov P.M. Impact of global climate change on gas industry. - www.rodnoverije.com/misc/homyakov-gasprom.html.

8. Gudilin I.S., Komarov I.S. Applying air methods for geologic-engineering and hydro geological researches.- M.: Nedra, 1978, - 319p.

9. Polishchuk Yu.M., Tokareva O.S. Monitoring of permafrost rocks state changes under global warming using space images // Vestnik of Ugra State University, 2006. - № 3. - pp. 87 – 90.

10. Smith L.C., Sheng Y., MacDonald G.M., Hinzman L.D. Disappearing Arctic Lakes // Science, 2005. – V. 308. – No 3. - pp. 14.

11. Jones P.D. and Moberg A. Hemispheric and Large-Scale Surface Air Temperature Variations: An Extensive Revision and an Update // Journal of Climate, 2003. - Vol. 16. - No 2. - pp. 206-223.

12. Callaghan, T.V., Jonasson, S. Arctic ecosystems and environmental change // Phil Trans Roy Soc Lond A., 1995. – No 352. - pp. 259-276.