**Brief report 2019**

The goal of the project is to assess the changes in the ecological state of the Caspian Sea since the beginning of the current century under the impact of natural and anthropogenic factors. This calls for a detailed analysis of large banks of satellite data acquired over the Caspian Sea from 1999 to 2022 jointly with multi-year hydrometeorological data.

The goal is achievable due to powerful capabilities of the See the Sea (STS) information portal developed by the Space Research Institute of the Russian Academy of Sciences (IKI RAS) as part of IKI - Monitoring Center for Collective Use. STS offers oceanographers new and unique tools to work with remote sensing data, enabling comprehensive analysis of data different in physical nature, spatial resolution and time of acquisition.

A multi-factor analysis of the ecological status of the Caspian Sea is made for the first time for the entire Caspian Sea based on multi-sensory and multiplatform remote sensing data, which determines the scientific novelty of the project.

In 2019, the following works were carried out and the main results were obtained.

An extensive array of satellite data obtained over the Caspian Sea by the following sensors over the period 1999-2006 has been analyzed:

Radar data

- SAR ERS-1, -2 IMP (pixel resolution of 12.5 m);
- ASAR Envisat IMP (pixel resolution of 12.5 m);
- ASAR Envisat WSM, IMM (pixel resolution of 75 m).

Total amount of data analyzed: 1055 scenes.

Visible range data (having cloud cover <50%):

- TM Landsat-4;-5 for 1999-2000, 2006
- ETM+ Landsat-7 for 1999-2006

Total amount of data analyzed: 2720 scenes.

For 2019:

• SAR-C Sentinel-1A; -1B (pixel resolution of 10 m).

The data is being imported to STS automatically. Total amount of data analyzed: 2520 scenes.

- OLI Landsat-8
- MSI Sentinel-2A; -2B.

Total amount of data analyzed: 1491 scenes.

Data analysis was carried out in the STS information system.

All analyzed satellite data were systematized, annotated and the results of the analysis were placed in the relevant STS process and phenomenon databases.

Based on the analysis, the following tasks were solved.

1. The main parameters of oil pollution of the sea surface having various nature were determined. The generalized schematic map of oil pollution and detailed maps were made, allowing to estimate the degree of probability of pollution of various parts of the sea surface near the sources of pollution.

The areas of the most intense oil pollution of the sea surface and the sources of pollution have been identified. It should be emphasized that natural hydrocarbon emission in the Cheleken Peninsula area have not been previously noted in scientific publications and were first identified and described by us during the implementation of this project. This natural emission of hydrocarbons is located near the oil production site, which may confirm the existence of a link between the natural oil occurrences observed in remote sensing data and oil-bearing structures in the subsurface at the bottom of the sea.

The variability of the total areas of oil pollution of the sea surface has been assessed in different areas with use of satellite data. In 2005, there was a surge in the total area and frequency of oil pollution in the middle Caspian Sea (the oil production area of the Oil Rocks and the Cheleken Peninsula), followed by a decrease in the number of oil spots and their total area.

The seasonal variability of the number of oil spills detected by satellite data and their total area have been assessed. It is shown that this variability reflects the variability of hydrometeorological conditions at the time of the observation. It is confirmed that the area of oil pollution determined solely by radar data may be overestimated if the data are obtained in weak winds or calm conditions and underestimated if the data are obtained in the presence of strong winds and significant disturbances in the near-water layer of the atmosphere.

It was revealed that in 1999-2006 unauthorized discharges of oil-containing films from ships were detected more often, but their average size was less than in 2019.

Integrated estimates of oil pollution of the sea surface in areas of intense pollution have been obtained with use of satellite data. The annual integrated area of oil occurrences detected with satellite data varies between 2725 and 12104 sq km in the area of oil production of Oil Rocks, within 40-90 sq km on the Iranian shelf near Cape Sefid Rud and within 150 -350 sq km on the Turkmen shelf near the Cheleken Peninsula.

Natural oil occurrences after reaching the surface under the influence of wind and currents tend to form thin curved stripes and can spread over long distances up to 35 km in the area of cape Sefid Rud and up to 50 km in the area of Cheleken Peninsula, which significantly increases the area of the water potentially exposed to oil pollution.

The relative contribution of each type of pollution to the integral oil pollution of the Caspian Sea surface in 1999-2006 and 2019 has been estimated.

It is shown that the main contribution to the integral oil pollution of the Caspian Sea is made by the continuous oil pollution of the sea surface in the area of Oil Rocks and by the mud volcanic activity on the seabed of the South Caspian basin. The natural occurrence of hydrocarbons from the seabed contributes significantly less. It is shown that unauthorized discharges of oil-containing films from ships are not the main source of film pollution of the sea surface, but their volumes are increasing every year.

2. The maps of regular intensive phytoplankton bloom areas have been created based on the integrated analysis of optical and radar imagery in the STS system, as well as the information on the concentration of chlorophyll. In the study period, the areas of the regular manifestations of intense phytoplankton bloom were the West coast of the Middle and South Caspian, South and East coast of the Southern Caspian and virtually the whole of the North Caspian. Phytoplankton bloom is most prone to water areas located in the estuary zones of rivers flowing into the Caspian Sea. It was revealed that areas of intensive phytoplankton bloom are absent along the Eastern shore of the Middle Caspian sea.

On average, the area of the intensive phytoplankton bloom zones remained constant during the study period, with the exception of abnormal bloom in the southern Caspian in 2001 and 2005. The smallest areas of phytoplankton bloom detected with satellite data were observed in 2003 and 2006.

3. The characteristics of interannual variability and trends of the main hydrometeorological parameters of the Caspian Sea have been obtained, including sea surface temperature, air temperature, precipitation, cloud cover, wind strength and field for 1999-2006. Their spatial and temporal variability in this period have been studied.

4. The main characteristics of the ice cover in the Northern Caspian Sea have been estimated, including the winter severity index, the ice cover duration, the maximum ice cover area. The schematic maps of the ice cover in the Northern Caspian Sea for 1999-2006 and in 2019 have been created based on the satellite data.

5. The schematic maps of the Caspian Sea water circulation elements, including vortex structures, internal waves, run-up phenomena affecting the transport of pollution for 1999-2006 and 2019 have been created with use of satellite radar and optical data. The accumulation of statistics on spatial, seasonal and interannual variability of hydrodynamic processes has been started.

6. Work has been carried out to improve the information system "See the Sea", aimed at development of new tools for solving problems arising in during the completion of the project.

The results of the project have been presented in 3 publications indexed in the databases SCOPUS, Web of Science and RSCI. 6 reports have been presented at one international conference and one all-Russian conference with international participation.

The materials devoted to this project can be found on the website http://www.iki.rssi.ru/asp/dep_proj/proj_20060.htm.