The aim of the project is to evaluate, using satellite data and remote sensing techniques, the environmental changes in the Caspian Sea in the current century under the impact of natural and anthropogenic factors. This requires a comprehensive analysis of large amounts of 1999-2022 satellite remote sensing data and multiyear hydrometeorological data. The project aim has been achieved exclusively due to the creation of the See the Sea information service (STS) at the Space Research Institute RAS, which is an integral part of the IKI-Monitoring Center for Collective Use.

The project participants, together with representatives of IKI-Monitoring, have chosen those data to be included in its archives that are the most suitable for the project, depending on the survey parameters (spatial resolution, swath width, polarization), recording formats and coverage of the entire Caspian Sea area. During the project, efforts were taken to ensure continuous acquisition of operational satellite remote sensing data of the Caspian Sea water area in automatic mode, their systematization, analysis and integration into the STS.

Seven main tasks were scheduled in the project. One more task emerged during the project implementation: the necessity to conduct in situ measurements to validate the satellite data was realized.

For many years, the primary environmental problem of the Caspian Sea has been oil pollution, which is connected both with oil production and transportation and sea level changes resulting in secondary pollution, river runoff and even seismic activity, which provokes natural oil hydrocarbon releases from the sea bottom.

The project identified areas where the sea surface is most frequently contaminated by oil-containing films and identified the sources of this contamination, namely: the Neftyanye Kamni oil production region, the region of active mud volcanism on the western side of the South Caspian Depression, the region of natural seabed hydrocarbon seeps in the southwestern part of the Caspian Sea near Cape Sefid Rud, the region of natural seabed hydrocarbon seeps in the eastern part of the Central Caspian near Cheleken Peninsula, and main shipping routes.

Throughout the entire duration of the project mapping of oil pollution of the Caspian Sea water surface was carried out in the regions of permanent pollution of the sea surface with oil-containing films. Spatial contours and quantitative characteristics of detected oil spills were loaded into the STS phenomena registry, which ensured the possibility of oil pollution mapping in the area of interest for any time period.

Analysis of satellite data received in the South Caspian Depression enabled identification of numerous surface oil spills caused by mud volcanism. The frequency of oil occurrences is determined by the seismological situation in the South Caspian and adjacent areas.

A statistical analysis of the array of sea surface oil pollution events has been carried out and quantitative assessments of their interannual, seasonal and spatial variability have been obtained. It is shown that the main contribution to the integral oil pollution is made by permanent pollution in the area of Neftyanye Kamni (60-65%), as well as by mud volcanic activity on the seabed in the area of the South Caspian Depression (18-23%). A smaller contribution to the overall pollution is made by natural petroleum seeps from the seabed on the Iranian and Turkmen shelves, 7-10% and 8-11%, respectively.

Based on the analysis of multi-year series of high and medium resolution optical satellite data obtained over the South and Middle Caspian in 1999-2022, the areas of regular intensive blooms in the North, Middle and South Caspian were identified. They include: in the North Caspian, the region adjacent to the Volga delta and the southern part of the North Caspian; in the Middle Caspian, the boundary area with the North Caspian, along the west coast the area of outflows of the Sulak and Terek rivers, the area of the Absheron Peninsula on the border with the South Caspian; in the South Caspian, near the southern part of the Absheron Peninsula, along the southwestern coast. In the central part of the South Caspian, abnormal blooms of algae, predominantly blue-green algae, were observed. The most intense anomalous blooms were observed in 2001 and 2005, and in 2008, 2009, 2010, and 2017. Based on the results of the analysis, maps of phytoplankton intensive blooms were constructed.

Seasonal and interannual variability and current century trends in air and sea surface temperature, sea level, precipitation, humidity, and cloudiness were investigated. It was determined that the amplitude of air and sea surface temperature variation has strongly increased in recent years, although the trend values remain approximately at the same level. The analysis of the time series of mean monthly values of atmospheric precipitation showed that there is a negative trend in the Middle Caspian, although in some years there were record values of atmospheric precipitation. Altimetric data confirmed that the level of the Caspian Sea is dropping and by December 2022 actually approached the 1977 low.

Availability of high and medium spatial resolution satellite data made it possible to determine with great accuracy the dates of freezing and thawing of the ice cover in the North Caspian Sea, its duration, and the maximum ice area in each winter period. A strong interannual variability of these parameters was found, especially after 2012, with a growing amplitude of fluctuations. It is shown that with the average decrease in the Caspian Sea ice cover related to the regional climate change, there are some years when the sea ice extent increases significantly.

Based on the analysis of multi-year satellite data series, work has been done to identify changes in the character of typical hydrodynamic processes in the Caspian Sea, such as eddy processes, internal waves and storm surge phenomena. Their spatial characteristics, frequency of manifestations, seasonal variability were compared. The main regions of eddy formation were determined. Using the STS toolkit, schematic maps of the areas of regular eddy activity identified from satellite radar and optical data were compiled. It is shown that mesoscale and submesoscale hydrodynamic processes significantly affect the transport of pollutants.

In 2022, in order to validate the satellite data, in situ measurements were carried out, concurrently with satellite overpasses, near the mouths of the Terek and Sulak rivers. The main characteristics of plumes of these rivers were determined, the results of satellite observations and in situ measurements were compared.

During the project, the STS has continuously been developed and new tools for solving arising problems were created.

A total of 22 scientific publications with the project results in leading peer-reviewed Russian and foreign scientific journals, indexed in Web of Science and/or SCOPUS, were published during the entire period of the project. Three of them are in Q1 journals. The results of the project were presented at 12 international conferences, a total of 31 reports were made.

On the basis of the project, a monograph entitled “Satellite methods in the study of the Caspian Sea variability” was written by O.Yu. Lavrova, M.I. Mityagina, and A.G. Kostyanoy (Moscow: IKI RAS, 2022, 250 p., ISBN 978-5-00015-058-0).

Materials dedicated to this project are available at http://www.iki.rssi.ru/asp/dep_proj/proj_20060.htm