The aim of the project is to evaluate 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. STS provides oceanographers with a constantly expanding toolkit to work with remote sensing data, providing the possibility of a comprehensive analysis of satellite data different in physical nature, spatial resolution, units of measurement and acquisition time. It is important to note that the implemented technologies enable the study of both spatial and temporal, including long-term, dynamics of phenomena and processes in seas and oceans.

Multi-factor analysis of the environmental state of the Caspian Sea was carried out for the first time for the entire Caspian Sea basin on the basis of multi-sensor and multi-platform satellite remote sensing data, which defines the scientific novelty of the project.

The works performed in 2022 and the main results obtained are described below.

During the fourth stage of the project, the work included continuous automatic acquisition of 2022 operational satellite remote sensing data on the Caspian Sea, their systematization, annotation and integration into STS.

The following tasks were solved on the basis of satellite data.

Using 2022 satellite data, mapping of sea surface oil pollution in earlier detected regions of permanent pollution by oil films was carried out. The maps were compiled in the STS cartographic interface enabling to draw maps of oil pollution in the area of interest for any period of time.

On the basis of the constructed maps, water areas potentially exposed to oil film pollution in various regions were determined: 4037 sq. km in the Neftyaniye Kamni region, 445 sq. km on the Iranian shelf near Cape Sefid Rud and 503 sq. km on the Turkmenian shelf near Cheleken Peninsula.

Area distributions of individual oil occurrences on the sea surface in different test regions were calculated. It was confirmed that the volume of crude oil coming to the sea surface from seafloor seeps is higher in the Turkmen waters near Cheleken Peninsula than on the Iranian shelf near Cape Sefid Rud.

The fact of significant seasonal variability in the number of natural oil occurrences on the sea surface detected in satellite images has been confirmed. This variability is especially pronounced for the data obtained in the visible range.

The characteristics of frequency and intensity of sea surface manifestations of mud volcanism and natural seabed hydrocarbon seeps in the South Caspian Depression were determined. It is shown that the integral area of oil pollution due to mud volcanism identified in 2022 satellite images of the south-western Caspian Sea exceeds one thousand square kilometers.

Variability in the area of the water potentially subject to oil slick pollution in different regions over the entire observation period of 2002-2022 was revealed. It is established that an abrupt increase in the area potentially subject to pollution by natural oil films in some years is associated with intensification of eddy activity in this region.

Special focus was on the identification of anthropogenic pollution due to ship discharges of waters containing oil products. A map of ship oil discharges identified in 2022 was built in the STS. Most ship discharges were detected at the boundary between Middle and South Caspian Sea, between Absheron and Cheleken peninsulas. This is conditioned by the presence of shipping routes connecting the Neftyanye Kamni oil producing region and oil refineries near the Turkmenbashi Gulf and in the south-western Caspian along the transport corridor carrying oil products to Iranian ports Neka and Amirabad.

Analysis of operational information on spatial distribution of chlorophyll-a concentration in different regions of the Caspian Sea was used to map intense phytoplankton bloom, estimate the average monthly values of the parameter for the Middle and South Caspian and assess its seasonal and spatial variability in 2022.

In 2022, operational multi-sensor satellite monitoring of the Caspian Sea ice cover has been conducted. It was found that the duration of the ice cover was 134 days, the maximum ice area was observed in satellite images of 03.02.2022 and made 59,5 thousand sq. km. According to reanalysis data, the sum of negative temperatures during the winter period was - 4430C, which corresponds to a mild winter.

Besides, in the course of the fourth stage of the project all major parameters characterizing the ice cover in the northern Caspian Sea for all winter periods from 1999/2000 to 2021/2022 were refined. The main parameters include: dates of ice formation and ice clearance, ice cover duration, maximum ice cover area in a particular winter (annual maximum ice cover area), sum of negative temperatures over the winter period and winter severity index determined using them. The exiting maps of ice cover for the winters of 1999-2021 were supplemented with the information on the maximum ice area in 2021/2022.

Based on the analysis of satellite radar and optical data, the study of the following hydrodynamic processes was continued: eddy structures, internal waves, storm surges, outflows of the Terek and Sulak rivers.

It has been confirmed that the main eddy hotspots are coastal shelf zones and the continental slope edge, except for the South Caspian, where abundant eddy formation is observed over the entire eastern part, as well as the boundary of the Middle and South Caspian Sea along the Neftyaniye Kamni – Kara-Bogaz-Gol line.

Mapping of surface internal wave occurrences (SIWO) in the Caspian Sea was carried out. Most of the SIWO in satellite images were observed near the eastern coast of the Middle Caspian, being confined to 50-100 m isobaths. During the spring period (end of April - May), the SIWO were observed near the west coast of the South Caspian.

Expeditionary studies of the outflows of the Terek and Sulak rivers were carried out concurrently with satellite imaging near the river estuaries in June 2022 during the period from May 31 to June 12. Based on the analysis of satellite data, the variability of plume boundaries position was determined and it was found that the position of Terek plume boundary is not subject to strong changes, whereas the Sulak plume boundary is quite mobile. Water turbidity in the Terek plume was found significantly higher than in the Sulak plume. The algorithms to determine turbidity and suspended matter concentration were validated for these rivers' plumes based on in situ measurements.

Note that studies of plume parameters based on satellite data and in situ measurements were conducted for the first time in the region.

Storm surge phenomena were studied for shallow areas of the northern Caspian Sea, east of the Ural River delta and in the delta area itself. Nine cases of wave runup and eleven cases of wave rundown were detected.

In order to make forecasts of possible transboundary pollution transfer, the environmental zoning of the Caspian Sea was considered and the results obtained during the project were used to identify the inherent characteristics of different regions due to the presence of various pollution sources and water circulation patterns, to identify factors affecting water exchange between different parts of the Caspian Sea and to determine factors that enhance water exchange and those that inhibit it. Among the identified factors affecting water exchange between different parts of the Caspian Sea, both factors that appear quite regularly and spontaneously occurring atypical situations, such as the emergence of jet currents under the influence of the wind, were identified.

The development of new software tools within the STS was carried out. A system for processing, storage, management and visualization of the data of field measurements received during the expeditions was developed.

The results of the project were presented in 5 publications indexed in SCOPUS and Web of Science. Two articles were published in Q1 journals. 7 reports were made at 2 international conferences.

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 on this project can be found at http://www.iki.rssi.ru/asp/dep_proj/proj_20060.htm.