Main results of project RSF 14-17-00555 in 2017

The goal of the project is to develop and improve the techniques for the retrieval of parameters of sea surface pollution, investigate the impact of dynamic and circulation processes on pollution propagation and assess the ecological state of Russia's seas based on a combined analysis of satellite data. Nowadays, the relevance of estimating the ecological state of Russia's bordering seas not only persists but continuously rises. There are many reasons for that. The risk of oil pollution, including the Arctic region, increases with the expansion of oil and gas industry, construction of new underwater pipelines and growth of ship traffic. Increased concentration of suspended matter in water leads to higher water turbidity and lower biological productivity. Year-to-year, anomalous algae blooming lasts longer and covers greater areas and occurs in regions never affected before. Expanding domestic tourism and marine recreation industries increase risk of anthropogenic pollution of coastal waters.

Consequently, we acknowledge the growing topicality of satellite oceanography and ocean environment problems of assessing the influence of water dynamics and circulation processes on propagation of pollutants and determining overall ecological state of Russia's seas.

Over the past three years, new satellites have been launched that are equipped with the most advanced sensors enabling remote diagnostics of processes on the Earth's surface. These sensors provide continuous flow of high resolution data (down to units of meters) in various wave ranges of the electromagnetic spectrum that help dramatically improve the quality of remote studies of marine processes.

The 2017 studies conducted in the framework of the project were based on data of the newly launched Sentinel satellites of the European Space Agency and processing and analysis tools of the See the Sea geoportal (STS) developed and operated by the Space Research Institute RAS. In the course of the project, a number of STS functionals were created and tested intended for automatic receipt and integration of the new sensor data, including: Sentinel-2 MSI (MultiSpectral Instrument), Sentinel-3 OLCI (Ocean and Land Color Instrument) and SLSTR (Sea and Land Surface Temperature Radiometer). Also, a special STS toolkit for processing and analysis of those data was developed.

On the basis of the retrospective analysis and consolidation of information on pollution sources and propagation mechanisms in the Baltic, Black and Caspian Seas performed in the course of Project-2014, the following test sites were selected: the environs of the Danube Delta, northeastern, northern and southeastern parts of the Black Sea, and the Kerch Strait; Middle and South Caspian Sea; southeast Baltic; and the Gulf of Lion of the Mediterranean Sea. For the Arctic region, we selected the region of the Kola Peninsula, the Kola Strait, the Sea of Pechora (the site of Prirazlomnaya oil platform) and regions of the Ob' Gulf and Baidartskaya Bay in the Kara Sea where no substantial ecological assessments have ever been conducted and where tanker traffic linked to the Vorota Arktiki oil terminal has intensified over the past two years. All selected test regions are remarkable for the diversity of hydrodynamic processes and exposed to various types of pollution.

Using the STS toolkit, we conducted thematic processing of satellite data obtained in different ranges of the electromagnetic spectrum: Sentinel-1A, -B radar data; Sentinel-2A, -2B MSI,

Landsat-8 OLI/TIRS, and Sentinel-3A OLCI visible and IR data. The aim of thematic data processing was to recognize manifestations of hydrodynamic processes and phenomena that can be responsible for spreading and drift of various types of marine pollutants. High spatial resolution of the data allowed us to focus on submesoscale structures and internal waves.

A dataset was compiled and thematic processing of satellite data featuring manifestations of pollution typical of the selected test regions was performed. The results were incorporated into the STS database of processes and phenomena associated with the studied regions. Regional mapping of pollution by types was performed. For the first time, a map of 2009-2017 oil pollution of the sea surface of the shelf of Turkey in southeast Black Sea was compiled. It was established that the area of high risk of oil pollution due to natural seafloor seepages amounts to about 360 sq.km.

Maps of high water turbidities for the test regions of the Black Sea, southeast Baltic and the Gulf of Lion close to the Rhone River mouth were updated with 2017 data. Based on carefully selected sets of data obtained by different satellite sensors at small time intervals, we endeavored to retrieve the main parameters of small-scale hydrodynamic processes with high spatial and temporal accuracy. The focus was on submesoscale eddies and short-period internal waves. For the first time we succeeded to track the formation, evolution and degradation of an eddy dipole from analysis of satellite images obtained in August 2015 to the northwest of Cape Taran in the Baltic. The lifetime of the eddy dipole was 8 days.

Today's constellation of orbiting satellites carrying sensors with high spatial and temporal resolution made it possible to study in detail processes in large sea areas, in particular, oil spreading and drift. For example, three consecutive satellite images obtained on 19 June 2017 over the Gulf of Lion in the Mediterranean with intervals of 5 and 7 hours and 10 m resolution, enabled us to retrieve spreading and drift details of oil patches due to a discharge of polluted water from a ship. The effect of wind on the evolution of the patches was investigated. In the vicinity of the discharge location, close to the coast, the wind had no influence on oil drift, only spreading of the oil was observed. We proved that the effect of the wind was compensated for by that of a coastal current with opposite direction. Farther off the coast, without the influence of the coastal current and under the south-southeast wind, the oil patches drifted northwest at an average velocity of 15-19 cm/s.

In January – February 2017, we conducted day-to-day satellite monitoring of the Kerch Strait, including the region of the Crimean Bridge under construction. Alongside with oil pollution at ship anchorage sites south of the Kerch Strait, we investigated with high spatial and temporal accuracy the properties of ice formation and drift through the strait as well as its interaction with the piers of the main and technological bridges. From analysis of a series of satellite images, we found that even under strong northeast winds, ice could not overpass the construction site, including the wide shipway. The technological bridge appears to be a giant dike hampering southward drift of ice. A retrospective study of ice condition in the Kerch Strait was performed using radar and optical satellite data of 1999-2017. Before the construction of the Crimean Bridge, ice could freely drift south past the west end of Tuzla Island, cover the whole distance of the strait and even reach the Black Sea.

In 2017, two series of ground measurements were conducted concurrently with satellite observations: in the region of the Rhone Delta in the Gulf of Lion in northwest Mediterranean from 25 January to 1 February and near the Sambia Peninsula in the Baltic from 18 to 30 August. The scope of the expedition works in the Gulf of Lion was directly related to the project tasks and included investigation of hydrological parameters and properties (concentration, size, composition, form and effective density) of suspended matter in the area of Rhone waters intrusion.

The expedition works in the Baltic coastal area near the Sambia Peninsula included measurements of current parameters using ADCP acoustic profiler mounted on a small boat. These were accompanied by CTD, turbidity and fluorimeter probing. In total, 9 sections were completed Also, 5 Lagrangian drifters were launched. Their drift was calculated using the interactive Seatrack Web HELCOM model with varying wind factor. The calculations were compared with the observed drifter trajectories. An interesting result was that over 70% of the drifters launched in open sea in different atmospheric and hydrodynamic conditions were driven ashore near the settlement Yantarnyi. The beach of the settlement is the first in Russia to be awarded with the Goluboi Flag (Blue Flag) honor title, it is one of the most popular tourist sites. Our study, however, shows that it is also the region of high pollution risk in case of oil spills or other accidents.

The results of our work under the project were published in 12 papers indexed in Web of Science Core Collection, SCOPUS and RSCI. We made 16 presentations at 9 international and Russian conferences.

For more detailed information on the materials of project implementation, please refer to http://www.iki.rssi.ru/asp/dep_proj/proj_555.htm.