Assessing the ecological state of the Barents and Kara Seas from satellite remote sensing data

Olga Y. Lavrova, Marina I. Mityagina,
Tatiana Y. Bocharova, Alexey Y. Strochkov
Space Research Institute of Russian Academy of Sciences
Moscow, Russia

Abstract

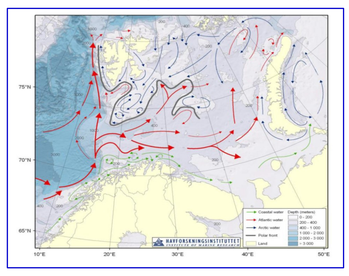
The Barents and Kara Seas are on the west of the Russian part of the Arctic region. In recent years, the region has been affected by a growing activity of man, especially in the Barents Sea. Since 2014, the development of an oil deposit in the eastern Barents Sea has been going on at the first Russian platform in the Arctic named Prirazlomnaya. The paper presents the results of satellite monitoring of sea surface in some test regions of the Barents and Kara Seas. As test regions we selected those that were worst affected by the anthropogenic pressure. In the Barents Sea, they are: (a) western Russian coastal part of the sea traversed by the main shipping routes; (b); Kola Gulf with the ice-free port of Murmansk, one of the largest Russian ports; (c) the mouth of the White Sea – the only water connection to the Barents Sea; and (d) the region around Prirazlomnaya. The ecosystem of the Kara Sea is affected by multiple river inflows. Dissolved and suspended sediments are transported by the largest Arctic rivers Yenisei and Ob'. Hence as test regions in the Kara Sea, we selected the Yenisei and Ob' outflow zones and the ship traffic area. Satellite radar observations revealed no oil films around Prirazlomnaya before the start of platform operations. Another ecological problem is abrupt increase in blooming algae. The paper discusses the results of detection of the sites of intense algae blooming in the Barents Sea. Based on Ocean Color data, we attempted to distinguish between the alga types (diatoms, and coccolithophores). Seasonal, interannual and spatial variations of blooming intensity of coccolithophores bloom were estimated. The sites of surface oil and biogenic films locations and zones of intense phytoplankton blooming were revealed based on radar data of Sentinel-1, Envisat, ERS-2 satellites and optical data of high spatial resolution: Landsat series and MSI Sentinel-2A.

Study area

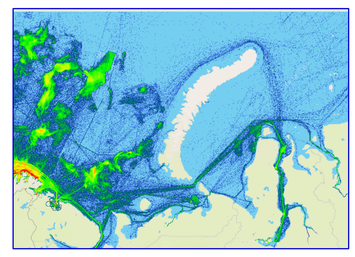
The Barents Sea **is a high-latitude large marine ecosystem that is bordered by Norway and Russia. It is influenced by Atlantic Water to the south and west and by Arctic or mixed (Atlantic and Arctic) water to the north and east. It is the largest and deepest of the Continental Shelf seas surrounding the Arctic Ocean. Ice conditions in the Barents Sea are influenced by both Atlantic and Arctic Oceans, and by atmospheric conditions. Currently, the impacts of pollution by oil spills and radioactive wastes remain slight. However, due to the expansion of the oil and gas industry in the region, as well as increased shipments of oil and gas *through the Barents Sea, the risk of accidental oil spills is likely to increase in the near future.***

The Kara Sea, **an extension of the Arctic Ocean, is located off the coastline of Siberia in far northwestern Russia. It's separated from the Barents Sea (in the west) by the Kara Strait and Novaya Zemlya - and the Laptev Sea (in the east) by the Taymyr Peninsula and Severnaya Zemlya. Ice-bound for most of the year, the sea is generally navigable only during August and September.**

The main ports are Dickson and Novy Port, and they are heavily used during the two-month fishing season. They will also be distribution points when the petroleum and natural gas discovered here is brought to the surface.



Main currents

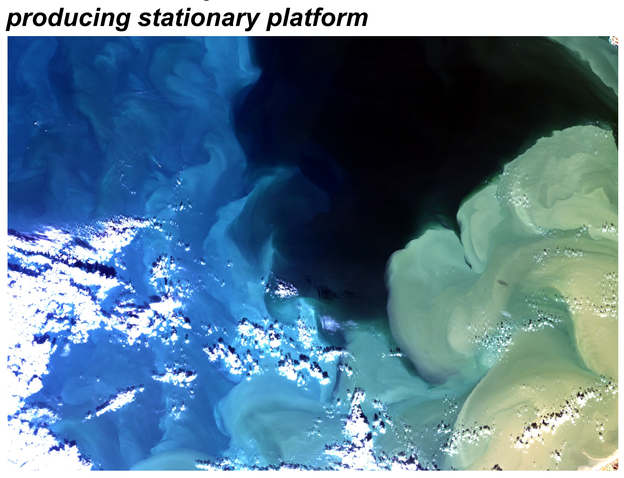


Main ship routes

Satellite monitoring of the Prirazlomnaya region

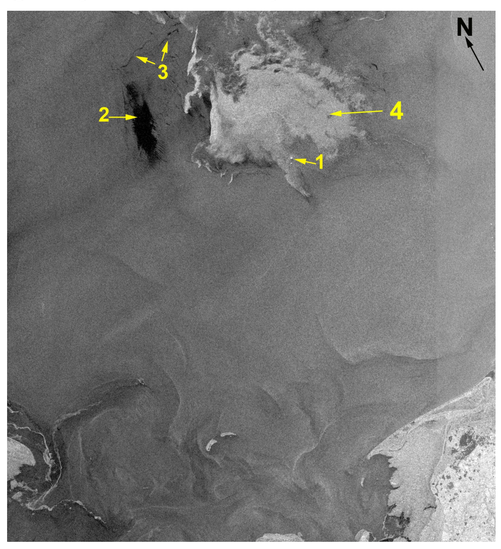
The Prirazlomnoye oil field was discovered in 1989. It is located on the Pechora Sea shelf 60 kilometers off the shore (Varandey settlement) at a water depth of 19 to 20 meters. The Prirazlomnoye oil field is currently the only Russian hydrocarbon production project on the Arctic shelf. The Prirazlomnaya offshore ice-resistant oil-producing stationary platform was built specifically for the Prirazlomnoye oil field. The platform is used for all production operations, namely well drilling, oil extraction, storage, treatment and offloading. As it was designed for the Arctic region, the platform can be used in extreme weather conditions; it is compliant with the most stringent safety requirements and resistant to maximum ice loads. The wellheads of all wells to be drilled at the field are located within the platform, while its foundation serves as a buffer zone between the well and the open sea. In addition, the equipment installed at the wells is meant to prevent blowouts of oil or gas. The offloading line used for transferring oil to tankers is provided with an emergency shutdown system that can be activated instantly.

The Prirazlomnaya offshore ice-resistant oil-producing stationary platform

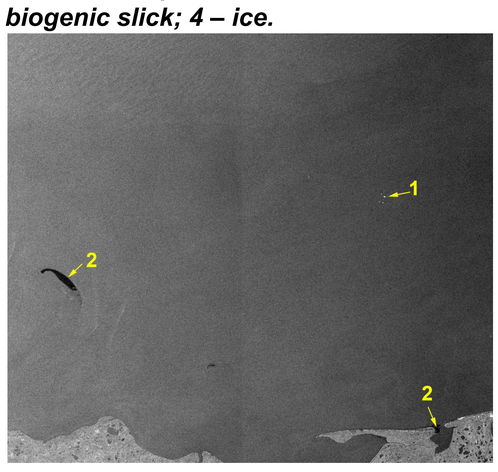


Manifestation of river muddy water on OLI Landsat-8 of Prirazlomnaya oil field, obtained on August, 31, 2016. 1 – platform.

Our satellite monitoring, based on SAR-C Sentinel-1 data, conducted on June-September 2015-2016 showed that no oil spills has been detected in the platform area!

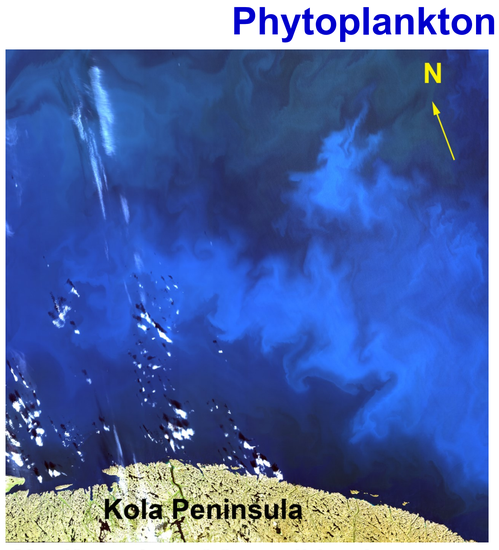


SAR-C Sentinel-1A image of Prirazlomnaya oil field, obtained on May, 26, 2016. 1 – platform; 2 – bloom area; 3 – biogenic slick; 4 – ice.

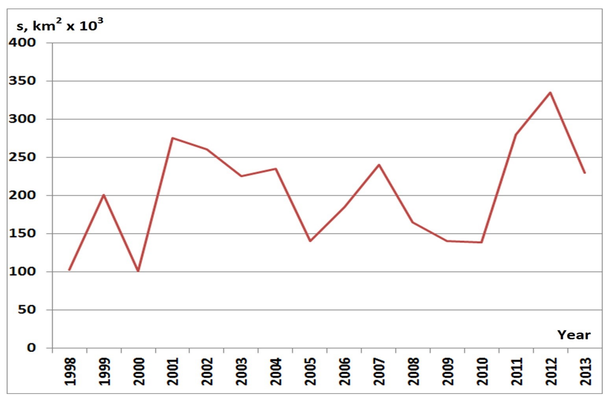


SAR-C Sentinel-1A image of Prirazlomnaya oil field, obtained on September, 17, 2016. 1 – platform; 2 –young ice.

Phytoplankton bloom in the Barents Sea

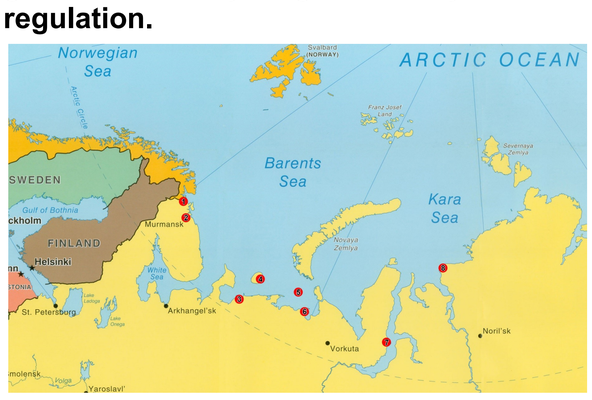


Manifestation of Coccolithophores boom in OLI Landsat-8 image, 31.08.15



Interannual dynamics of E. huxleyi bloom in the Barents Sea

Satellite observations based on Ocean Color data allowed us estimate the spatial scale of areas occupied by phytoplankton bloom. The milky-blue color that dominates the bloom suggests that it contains large numbers of coccolithophores. The spring bloom of phytoplankton can start quite early close to the ice edge, because the fresh water from the melting ice makes up a stable water layer on top of the sea water. Emiliania huxleyi (E. huxleyi) is the most prominent coccolithophore in the Barents Sea. Because of E. huxleyiits ecological success and its ability to fix inorganic carbon into both photosynthetic and biomineralized product, it has significantly impacted the biogeochemistry of the earth directing carbonate chemistry in surface oceans and exporting large amounts of C to deep water sediments and it plays an important role in global carbon cycling. E. huxleyi also contributes to global sulfur cycling and climate regulation.



Red dots indicate the location of oil terminals: 1- the Bøkfjorden and Kirkenes; 2 - the Kola Bay and Murmansk; 3 – Indiga; 4 - Kolguyev Island; 5 - the Prirazlomnoye oil field;6 - Varandei; 7 - Novy Port; 8 - Dickson

The main sources of pollution in the Barents and Kara Seas waters are:

- **illegal discharge from ships;**
- **continental runoff;**
- **extraction of mineral resources on the continental shelf;**
- **long-range transport of pollutants by ocean currents;**
- **transport of contaminants by atmospheric currents;**
- **Novaya Zemlya test site;**
- **the disposal of radioactive waste and nuclear reactors.**

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