Determining zones of persistent ecological risk in the Baltic Sea

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Abstract

Results of multiyear research on determining zones of persistent ecological risk in the Baltic Sea are presented. They are areas most affected by oil pollution, harmful algae bloom and raised concentration of suspended particulate matter.

The research was based on satellite remote sensing data obtained over the Baltic Sea in the period from 2004 to 2015. Data from radar sensors ERS-2 SAR, Envisat ASAR, Sentinel-1, Radarsat 1,2, as well as Ocean Color and infrared data from Envisat Meris, Landsat-5 TM, Landsat-7 ETM+, Landsat-8 OLI, and Terra/Aqua Modis were used.

Analysis of radar data indicated areas worst affected by ship spills of bilge waters. The area sizes were estimated. Our maps of oil pollution for different years were compared with data of other researchers. Interactive numerical model Seatrack Web (SMHI) was used for a 48 hours forecast of an oil spill drift and for revealing the regions of persistent ecological risk. It should be noted that in recent years, a significant decrease of anthropogenic pollution associated with ship spills of oil and oil products has been observed. Apparently, this is the result of dedicated satellite monitoring campaigns conducted by various international organizations, for instance, in the framework of the CleanSeaNet initiative.

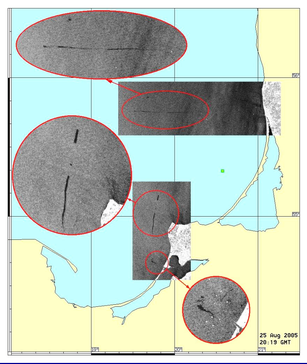
Meanwhile, eutrophication has recently become a very important problem worldwide. It is especially true for the Baltic Sea as blooming cyanobacteria (blue-green algae) can be observed almost in any part of it. As a rule, intense algae bloom is detected using satellite data in visible range and chlorophyll-a maps.

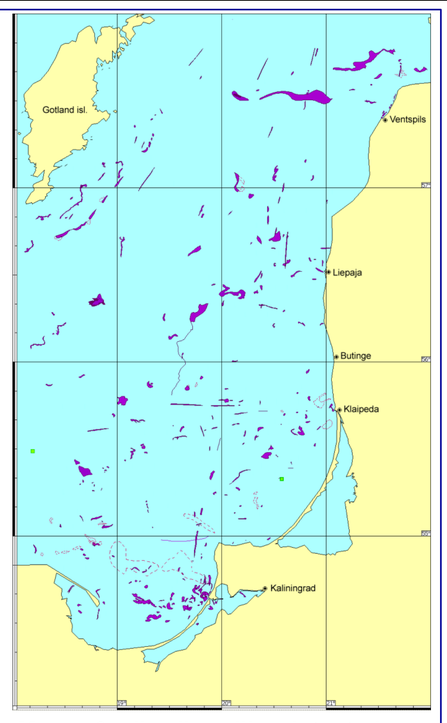
Areas characterized by increased concentration of suspended particulate matter were revealed using maps compiled from Envisat MERIS data, Modis Aqua and Landsat color composites. Among the most remarkable ones are certain regions of the Gulf of Finland and various river plume zones, first of all, those of the Vistula and Neva Rivers.

Oil pollution from ships in the Baltic Sea

The real-time monitoring of oil pollution was based on processing and analysis of the Synthetic Aperture Radar (SAR) images acquired from all passes of ENVISAT, ERS-2 satellites (2004-2012) and Sentinel-1 A satellite (2014 - nowadays). The majority of anthropogenic pollution of the sea surface, identified during satellite monitoring were leaks and discharges of oil and oil-containing liquids from ships. The main sources of pollution releasing from ships are washing, ballast, and bilge waters. The long-term monitoring revealed the regions of most frequent discharges:

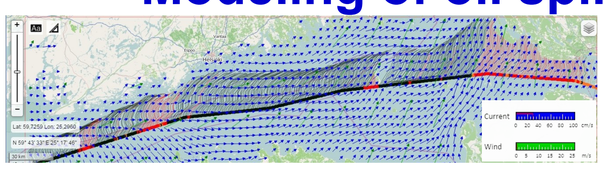
- **the major shipping routes eastward of Gotland Isl.;**
- **shipping routes to the ports of Klaipeda, Liepaja and Kaliningrad (Baltiysk);**
- **along the Hel Spit (Poland);**
- **the part of the Gdansk Bay in the vicinity of the entrance to the gate of Kaliningrad Canal;**
- **the entrance to the Gulf of Finland and Neva Bay;**
- **along the ship route northward of Hiiumaa Isl (Estonia).**



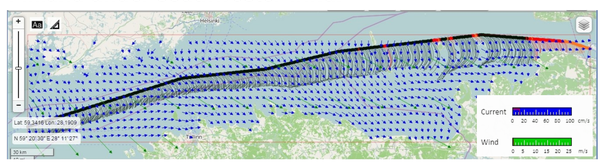


Map of all oil spills detected on radar imagery in 2004 – 2005

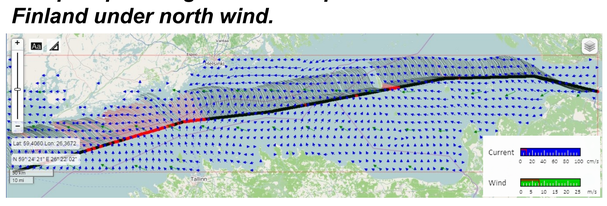
Modeling of oil spill drift in the Gulf of Finland



Oil spill spreading from the ship route in the Gulf of Finland under southwester wind.

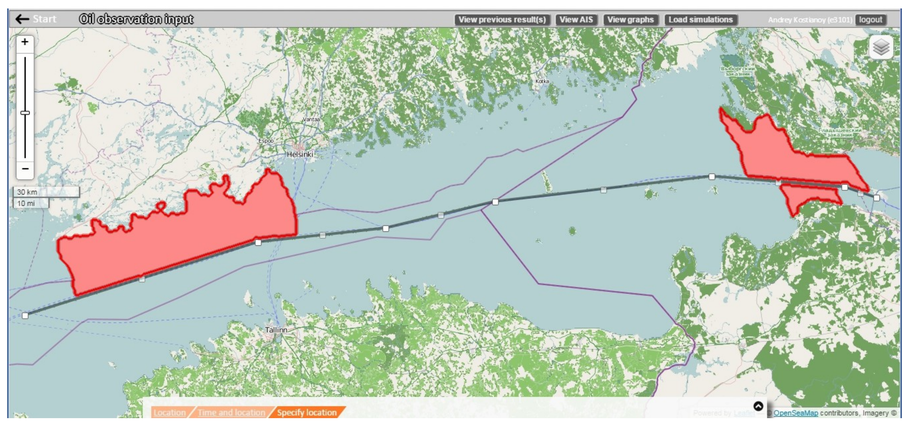


Oil spill spreading from the ship route in the Gulf of Finland under north wind.



Oil spill spreading from the ship route in the Gulf of Finland under southeaster wind.

Red hatching marks the area where pollutants would reach the coast



Zones of ecological risk (red) revealed by modeling the spreading of oil spills due to illegal discharges from ships along the main ship route in the Gulf of Finland. Ship route in the Gulf of Finland used in model oil spills (black line).

A new, very effective technology for the quantitative environmental risk assessment, was elaborated based on the Seatrack Web model. For every kilometer of the coastline, as well as for any part of the sea surface it allows to calculate a probability to be polluted by oil, resulted from shipping activities (main ship routes) in the Baltic Sea.

The modeling of oil spill spreading was made for the period of 48 hours after the spill. Every 3 hours new forecast hydrometeorological parameters, such as wind speed and direction, current velocity and direction, etc., were input into the model.

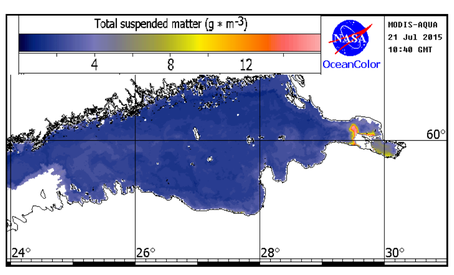
High water turbidity in Neva Bay

The east end of the Gulf of Finland – Neva Bay – is one of the most polluted areas of the gulf and the Baltic Sea. The Neva River flowing through the multi-million city of Saint Petersburg is heavily polluted by industrial discharges of hundreds of enterprises. The river is a busy oil and petroleum products transportation way. Moreover, due to the city's low sewage capacity part of the sewage is discharged untreated to the river. Over 80 thousand tons of pollutants are spewed every year into the Neva. Flood prevention facilities built to protect Saint Petersburg significantly contributed to pollution of the Gulf of Finland. The dam diminished water exchange between Neva Bay and the gulf by 20%. Shallow waters between the dam and the city got extremely eutrophicated because storms could not any more clear well enough the bay.

The ecology of the area was further damaged by the construction of an avanport in Bronka (south end of the dam) where a nature sanctuary called *Plavni Kronkolonii*, part of the *South Coast of Neva Bay* nature reserve, is situated. Summer 2015 enormous dredging and sluicing works had a negative impact on water quality and fauna of the area. Moreover, a town of Lomonosov situated just to the east of the construction site has no sewage facilities and all industrial, port and municipal waste go untreated into the bay. After the construction of the dam, it is not long to wait for the confined coastal aquatic area to turn into stinking waste marsh.

Manifestations of high water turbidity on ETM+ Landsat-7 and MODIS data

High water turbidity caused by the construction works, as demonstrated by Terra/Aqua MODIS, Landsat-8 OLI and Landsat -7 ETM+ data, was observed throughout the year and propagated over nearly the whole eastern Gulf of Finland.



TSM concentration map from MODIS Aqua image of July 21, 2015

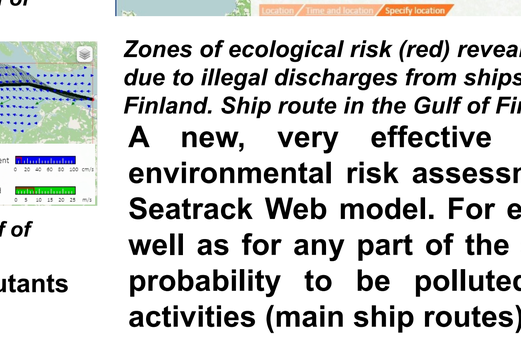
The volume of suspended matter in seawater was so high that the "plume" zone of the works (highest suspended matter concentration) was marked white in Total Suspended Matter (TSM) maps, meaning absence of data or inability of the NASA algorithm even to recognize it as a water zone.

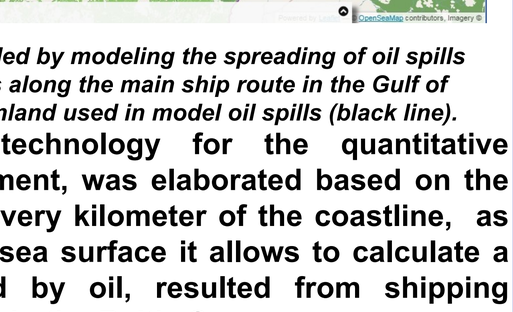
Forecast for oil spill drift from D-6 platform

We accumulated daily forecasts for oil spill drift from the platform during 48 hours for the time period from 1 July to 31 December 2004 (184 maps) and obtained a statistical map of the area of oil distribution and a probability in % of an oil location in any point of the investigated marine area and a coastal zone. Results: (1) oil spill may drift in any direction but with different probability; (2) the most probable direction is to north-east; (3) the coast of Sambia Peninsula will not be affected by the pollution; (4) any point of the Curonian Spit may be polluted, but with different calculated probability; (5) any point within the 15 km long zone at the Curonian Spit coast has a maximum probability (10%) to be polluted; (6) during 48 hours oil spill may reach even the coast of Lithuania northward of Klaipeda, but with a probability less than 3%.

Lukoil D-6 platform

Map of all oil spills detected by the analysis of ASAR Envisat and RADARSAT-1,2 imagery from July 2004 to December 2015. There is no pollution in the vicinity of the D-6 oil platform.



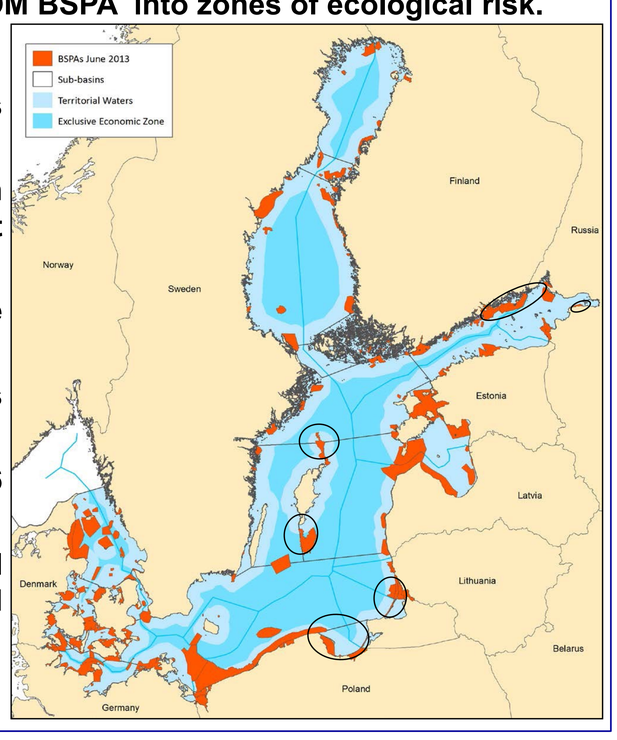


Probability (%) of propagation of potential oil pollution from the Lukoil D-6 platform during 48 hours after a release of 10 m³ of oil

Conclusions

The main goal of the HELCOM Baltic Sea Protected Areas (BSPAs) is to protect valuable marine and coastal habitats in the Baltic Sea. This is done by designating suitable areas which have particular nature values as protected areas and by managing human activities within those areas (HELCOM 2003). Today the number of established areas is 163. The BSPAs cover both marine and coastal areas, including islands. The studies we conducted on the basis of multiyear satellite observations of the Baltic Sea showed that various negative factors turned a number of HELCOM BSPA into zones of ecological risk.

- ***Northwest end of the Gulf of Finland*: high risk of oil spills from ships and intense algae blooming;**
- ***Southeast end of the Gulf of Finland*: vast polluted areas in consequence of an avanport construction and poor treatment of sewage being discharged directly into the sea;**
- ***Area near the north end of Gotland Isl., and Lagoons*: intense algae blooming every year;**
- ***Area to the south off Gotland Isl.*: regular oil spills from ships along main ship routes;**
- ***Curonian Spit*: risk of oil pollution in case of emergency on D6 oil platform;**
- ***Gulf of Gdansk, Hel Peninsula and Vistula Spit*: high risk of oil spills from ships, outflows from the Vistula River and Kaliningrad Canal.**



Areas included in BSPA by June 2013 are marked by orange color on the map (HELCOM 2003). Zones of ecological risk are in black ovals

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