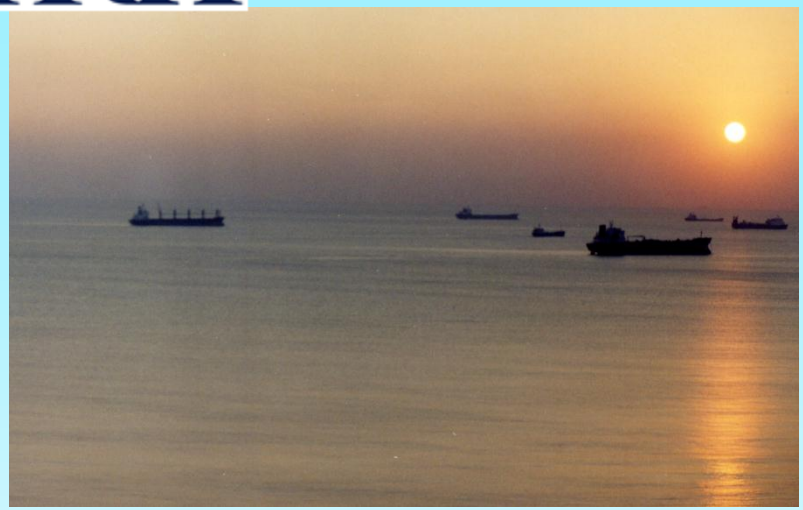
Manifestation of ship wakes in satellite images in periods of intense algae bloom

O. Yu. Lavrova, M. I. Mityagina, T. Yu. Bocharova

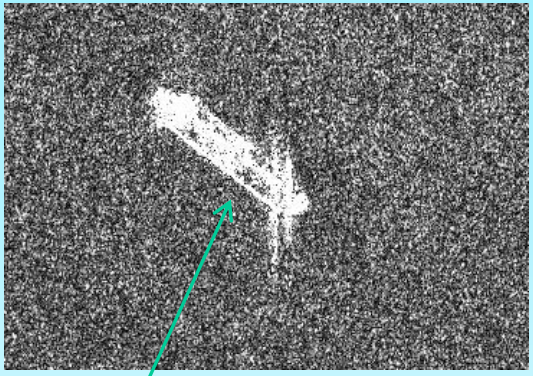
Space Research Institute of Russian Academy of Sciences,
Moscow, Russia

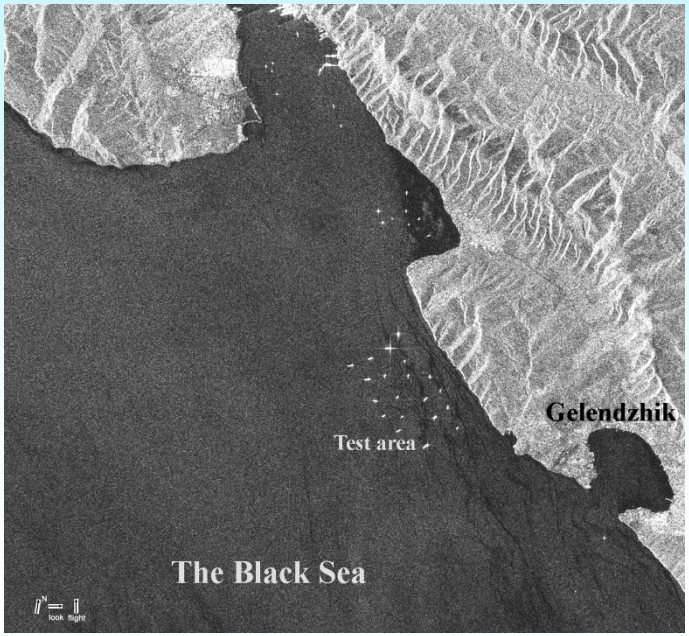
olavrova@iki.rssi.ru

Ship detection on SAR images

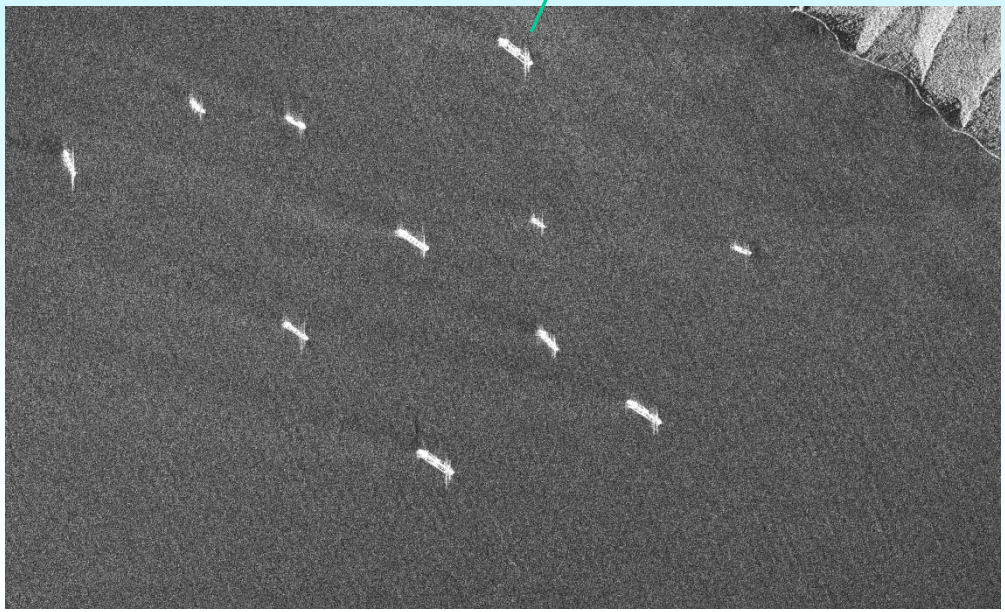


Anchor ship station in the vicinity of cape Doob (Novorossiisk) picked as a test area for our investigations. The typical length of tanker is about 100 m



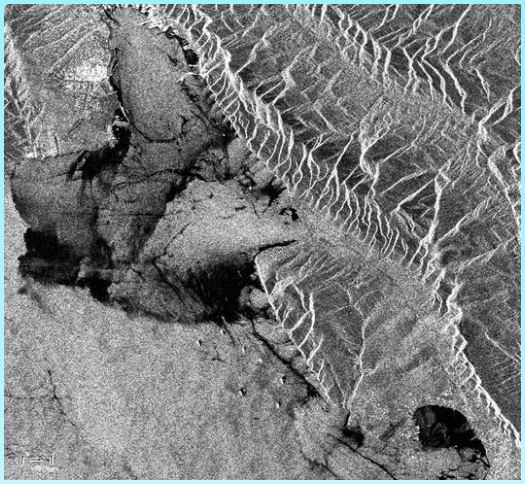


Fragment of ASAR Envisat image of test area. Pixel resolution 12.5 m. (18.05.2006)



Ships on very high resolution Radarsat-2 image. Pixel resolution 1.5 m (11.10.2011)

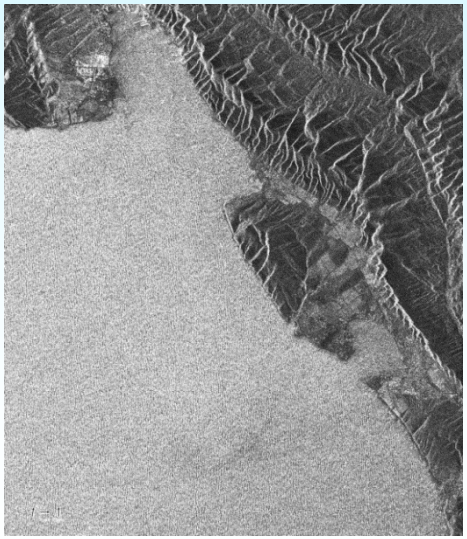
What does ship detection by SAR depend on?



Even against a complex background of various phenomena manifested at the same time ships remain well visible at low and moderate wind speeds and waves.

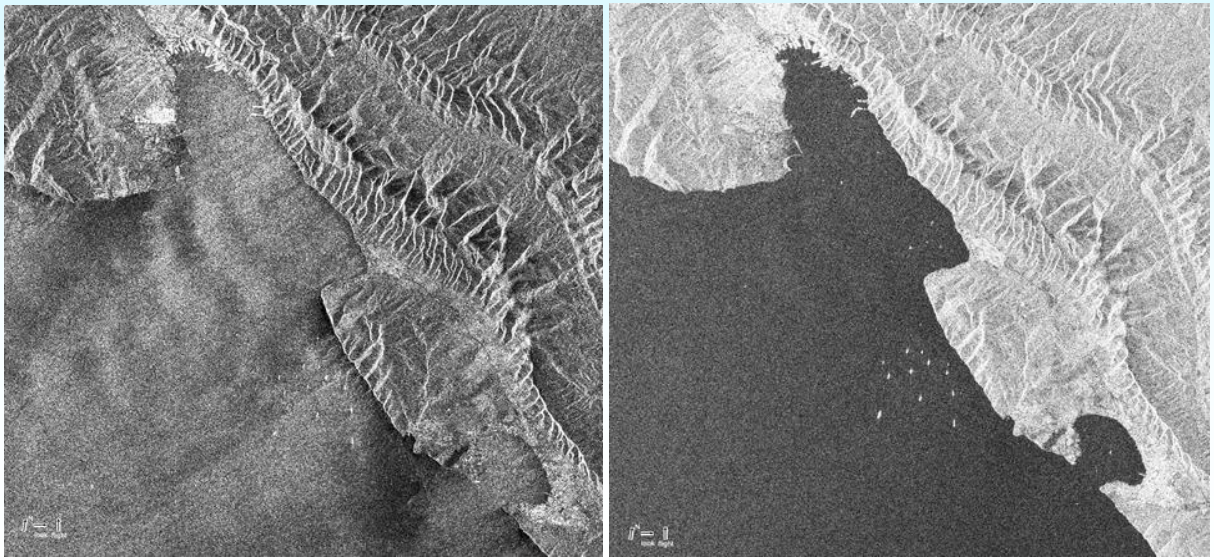
The important factors are divided into two groups.

- The first group includes weather and sea surface conditions. High velocity of the near-surface wind, well-developed high waves and convective structures are the main obstacles for ship detection due to both raised backscatter from the surrounding ocean surface and image synthesizing effects.
- The second one features the characteristics of the radar (SAR/ASAR, polarization, image resolution, swath number etc.). In comparison to mono-polarization (HH, VV) at cross-polarization (HV, VH), the effects of wind and waves are largely attenuated making signals from ships easily detectable.



Wind 17 m/s, waves 3 m.
ERS-2 SAR. 06.06.01

VV-polarization **VH-polarization**



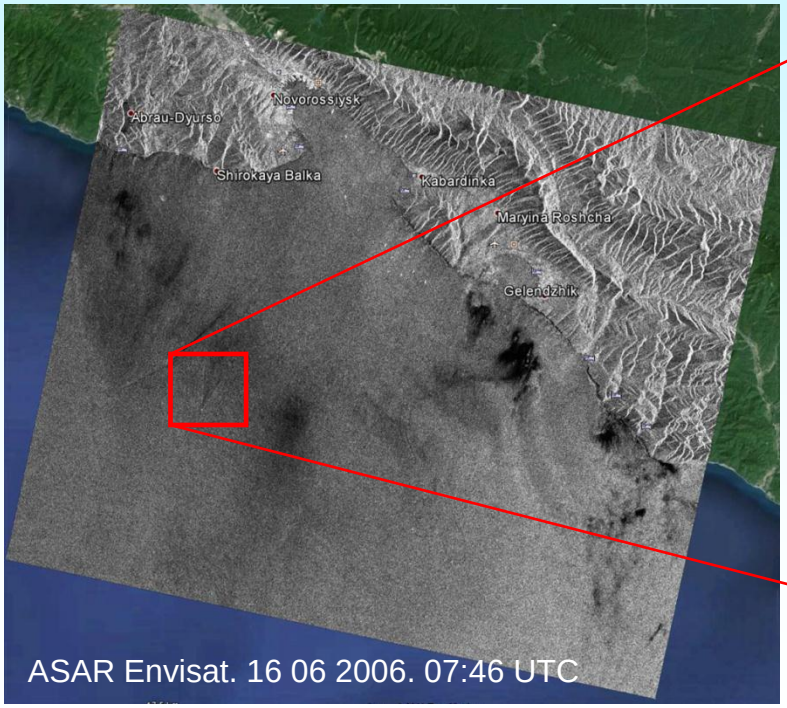
Wind V=14 m/s. Envisat ASAR. 27.08.05

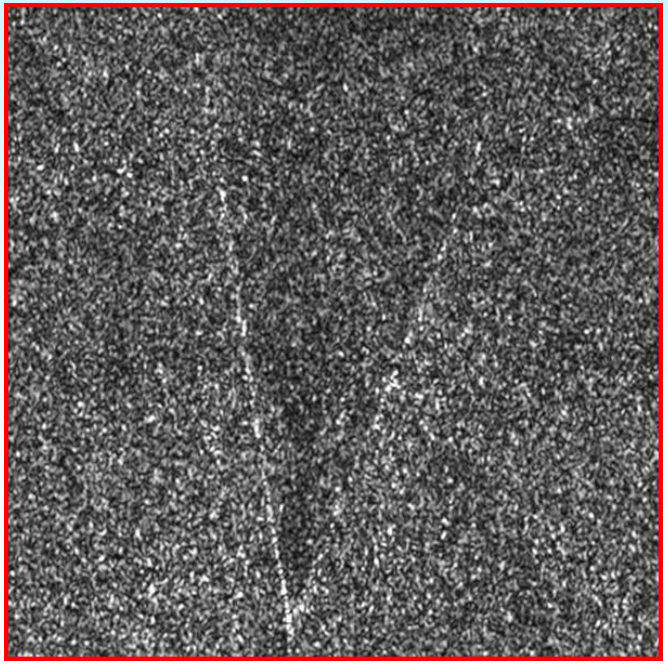
Ship wake

Wake structures fall into four categories:

1. turbulent wakes stretched out directly behind the vessel;
2. the Kelvin wake formed by decameter-scale surface gravity waves generated by the passage of the vessel and propagating outward from the vessel track;
3. narrow-V wakes visible through Bragg scattering from short centimeter-scale waves generated by hydrodynamic processes along the ship's hull;
4. internal wave wakes generated under conditions of shallow stratification

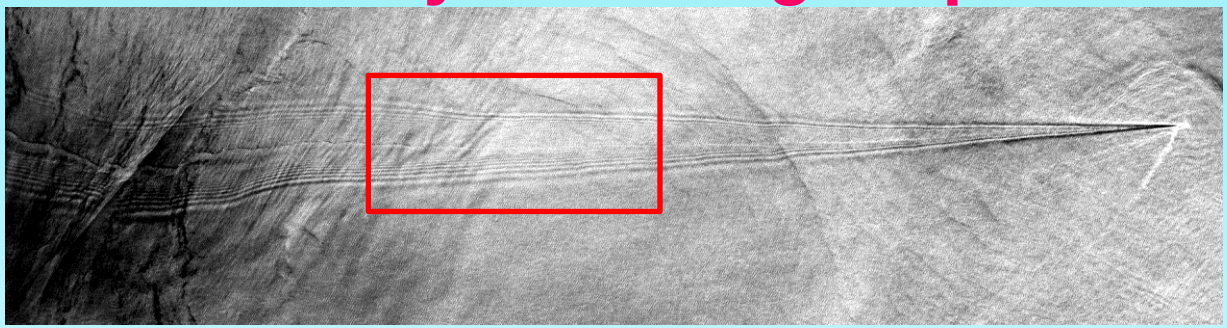
[From Lyden et al., 1988; Shemdin, 1990]

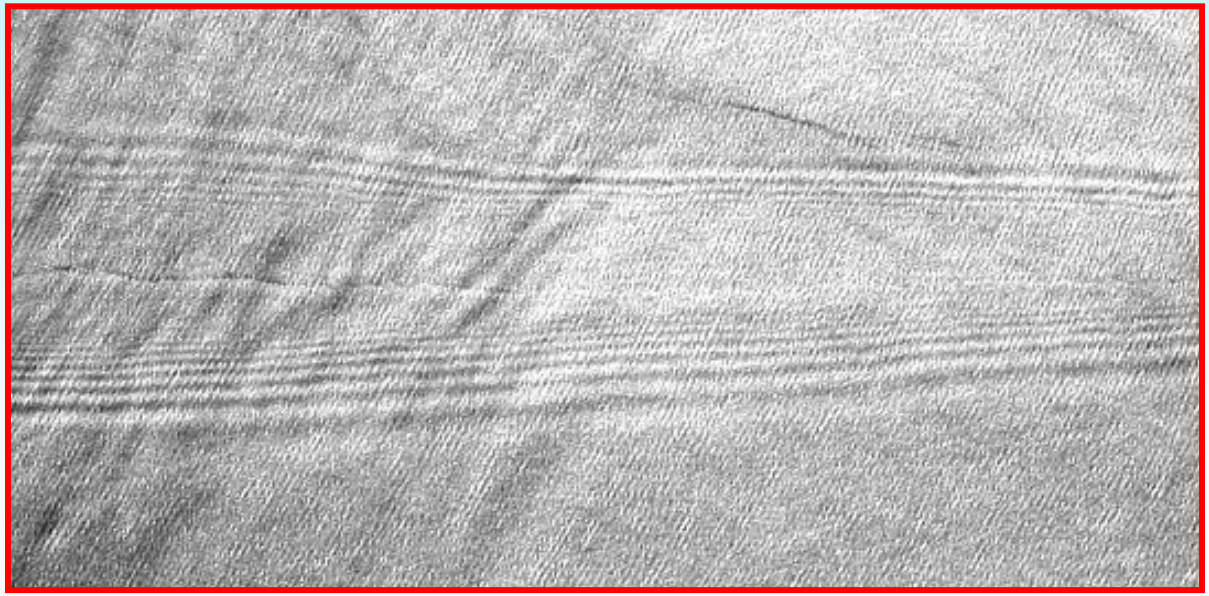




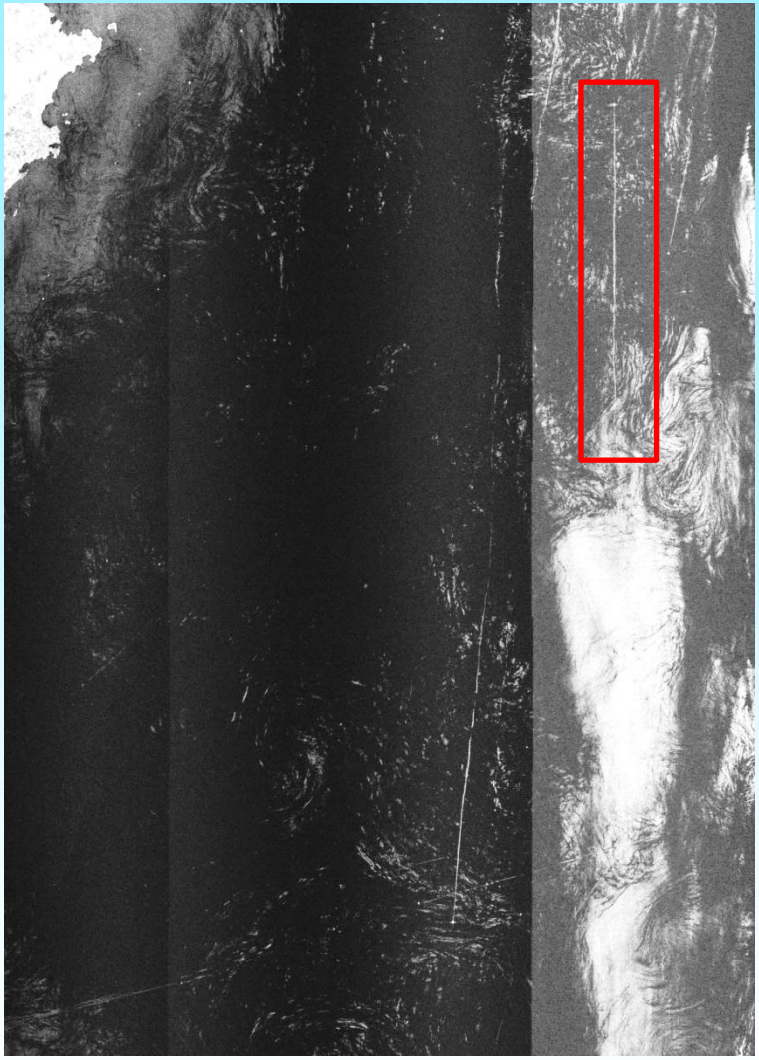
Classic V wake. L= 4 км

Internal waves generated by a moving ship





Fragments of OLI Landasat-8 image of 01.08.2013, Band 8 (pixel resolution 15 m)



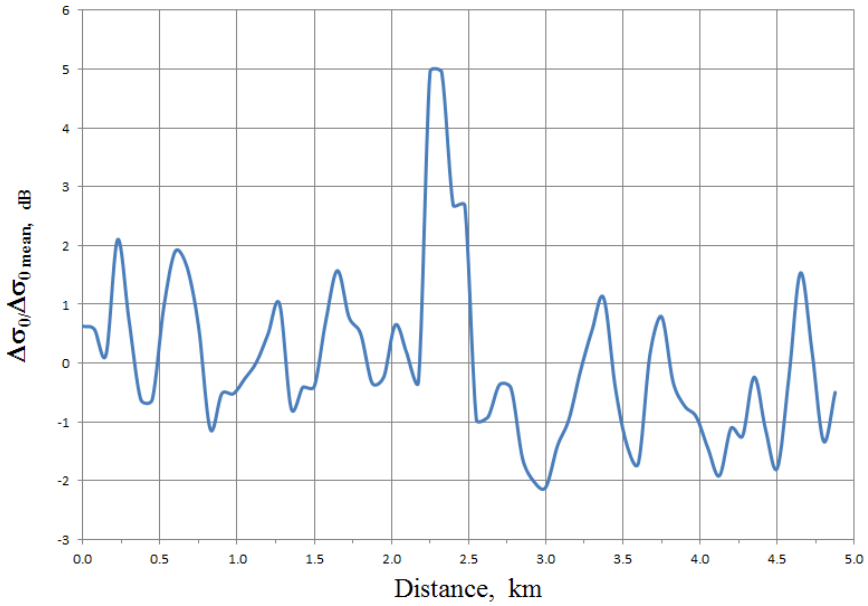
Fragment (126 x 240 km) of Envisat ASAR WSM image. 05.07.2010

Bright long-living ship wakes

Long-living wakes are manifested as bright bands of enhanced backscatter in periods of algae bloom and in regions where it is most intense. The lengths of such wakes sometimes reach 200 km. Given its length and ship mean speed, one can estimate its life time, sometimes it exceeds 6 hours.

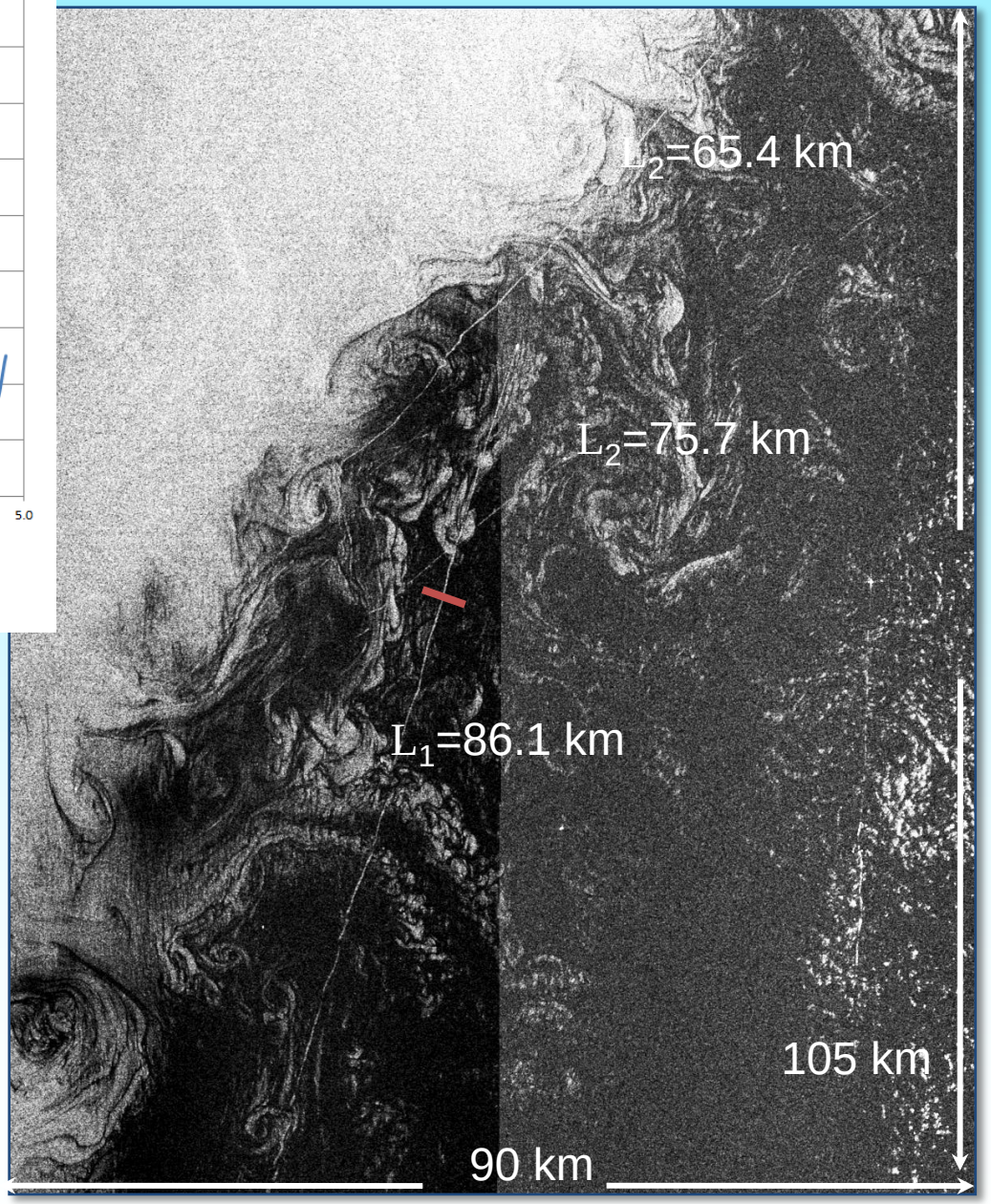
Bright wakes in the Gulf of Finland

Fragment of Envisat ASAR WSM image 13.07.2010



Enhancement of SAR backscatter in a ship wake. The cross-section location is marked by red strip

Width of the wake ≅400 m



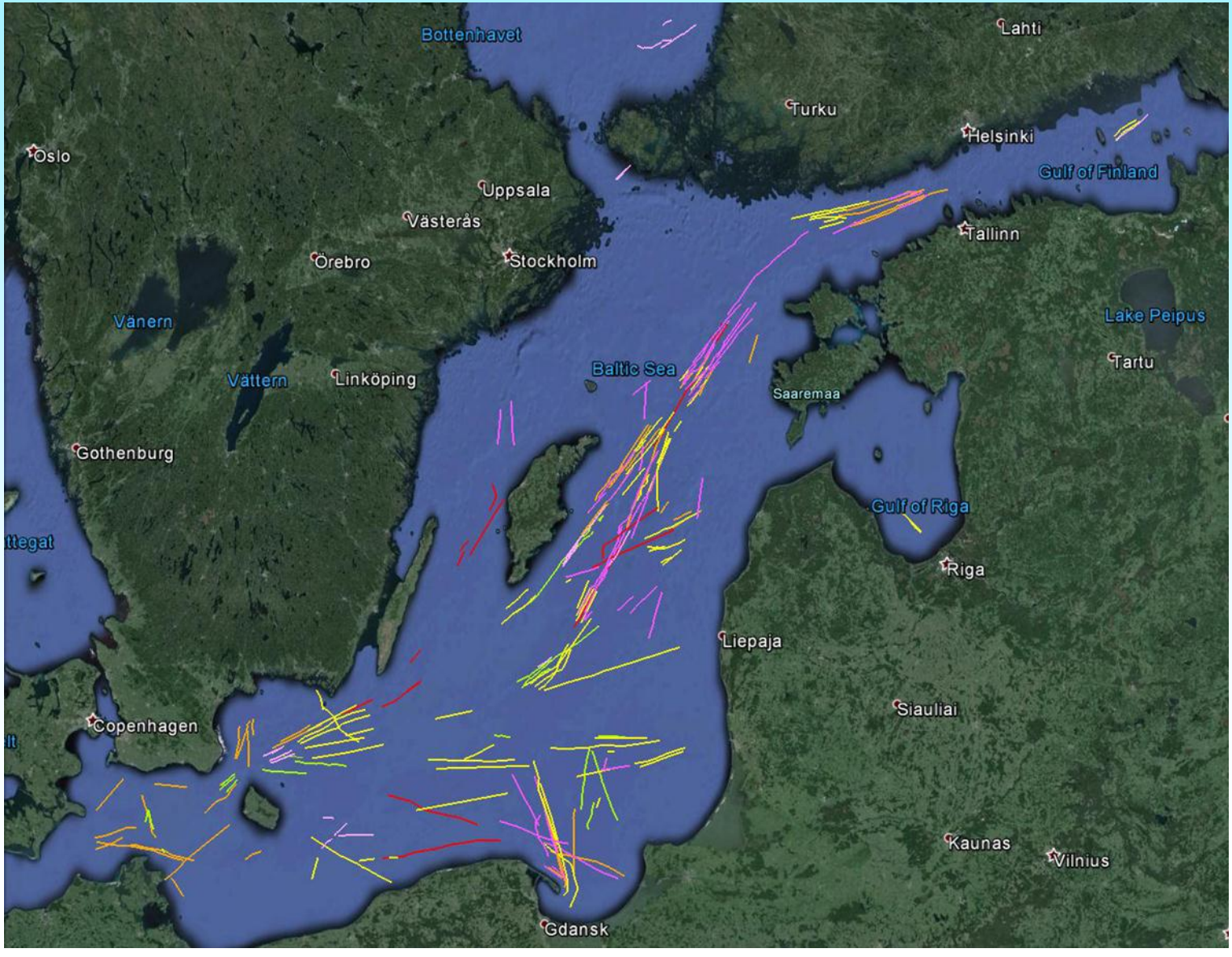
ASAR Envisat.12 09 2009. 09:10 UTC

Blue-green algae near Landsort on 27 July 2008 © SMHI

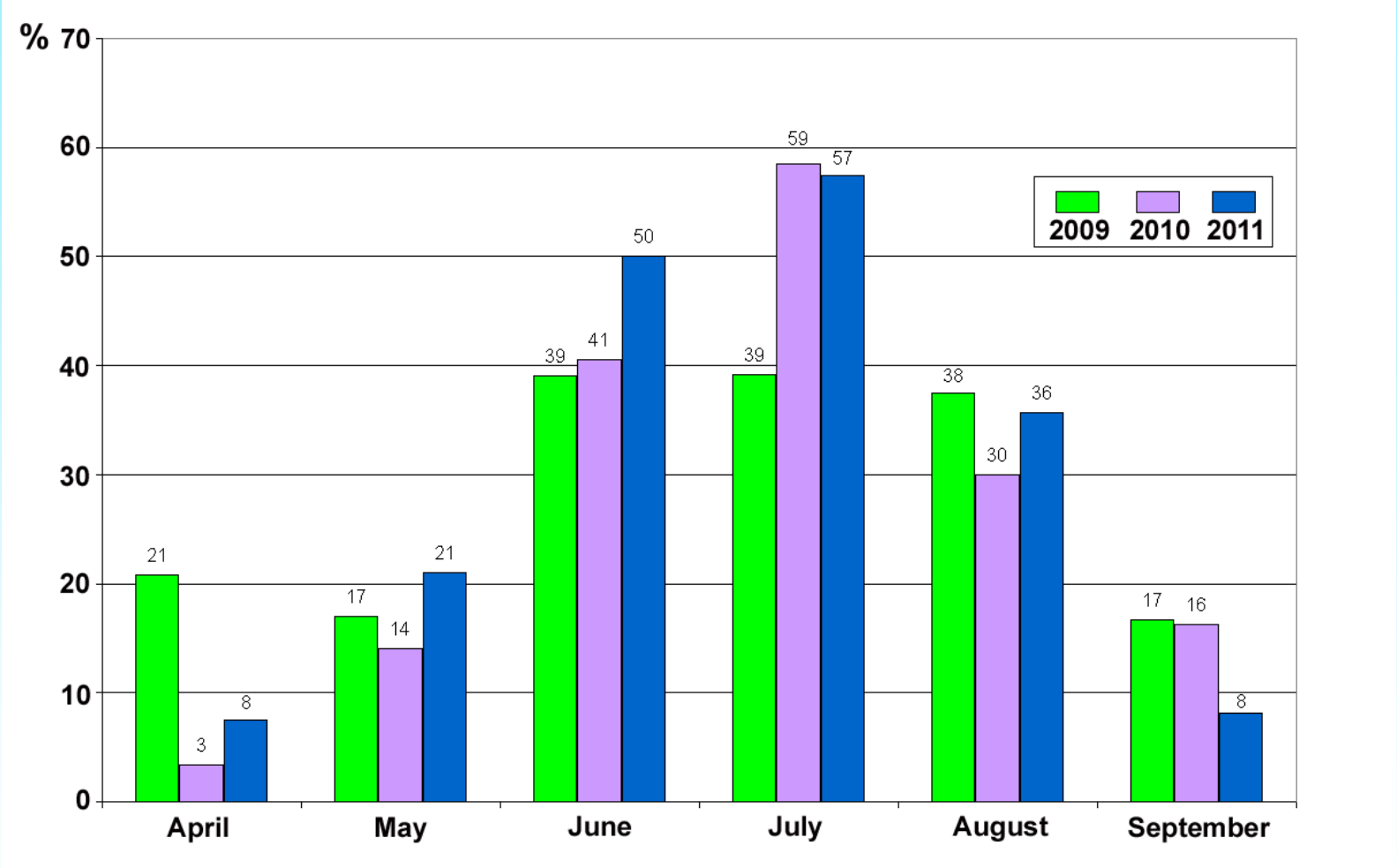
A ship makes way through algae leaves a path of clear water behind. In the region of clear water wind waves responsible for the enhanced SAR backscatter are generated. At moderate wind speeds, a width of such path remains nearly constant

Evolution of wind ripple along the wake in the region of intense algae bloom. Immediately behind the ship - a black wake, than - a bright wake, when water wind waves are already generated. Fragment of Envisat ASAR image of 09.07. 2010

Locations of bright long-living wakes manifestations on SAR images in different months in 2009

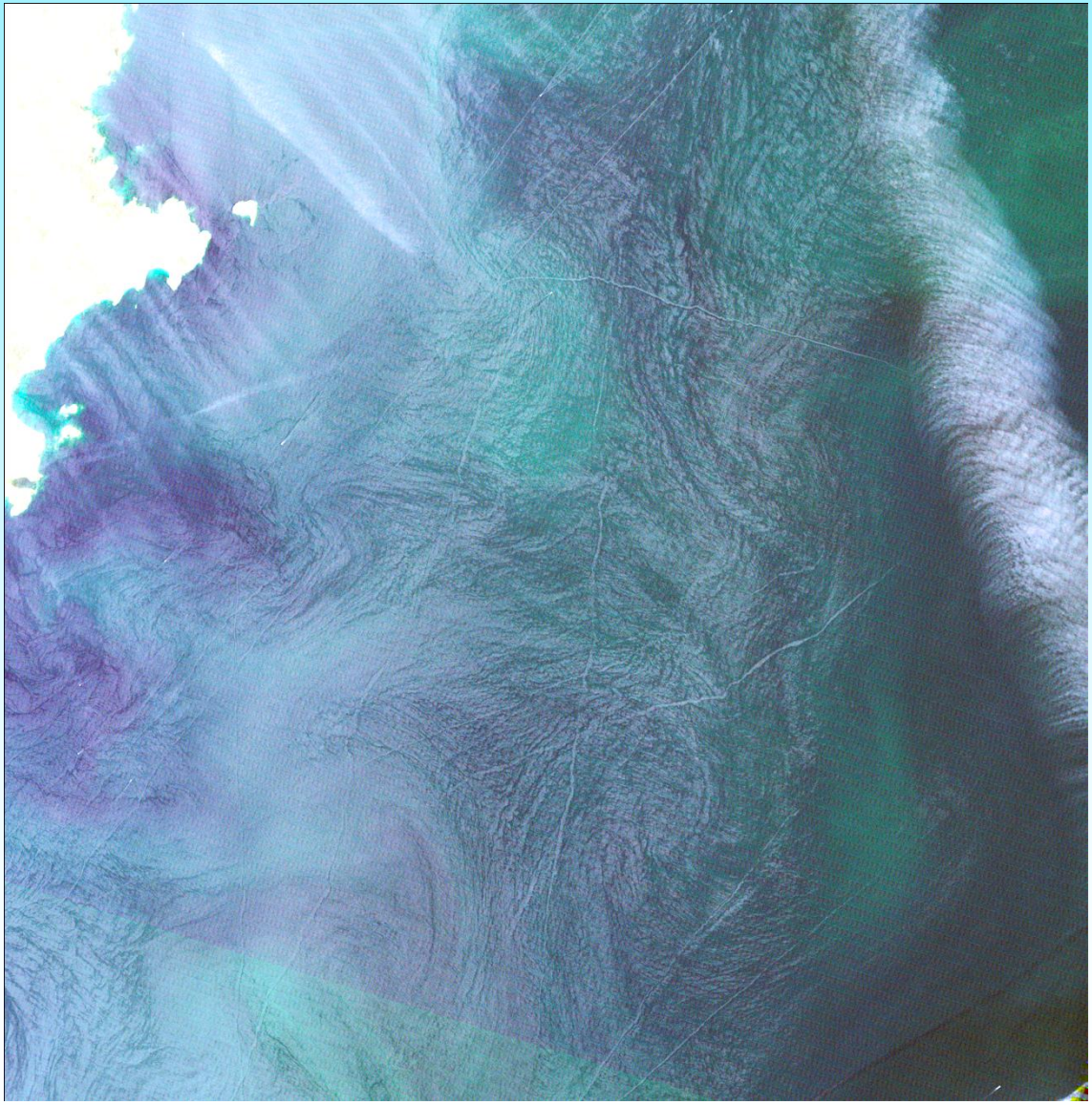


Statistical analysis



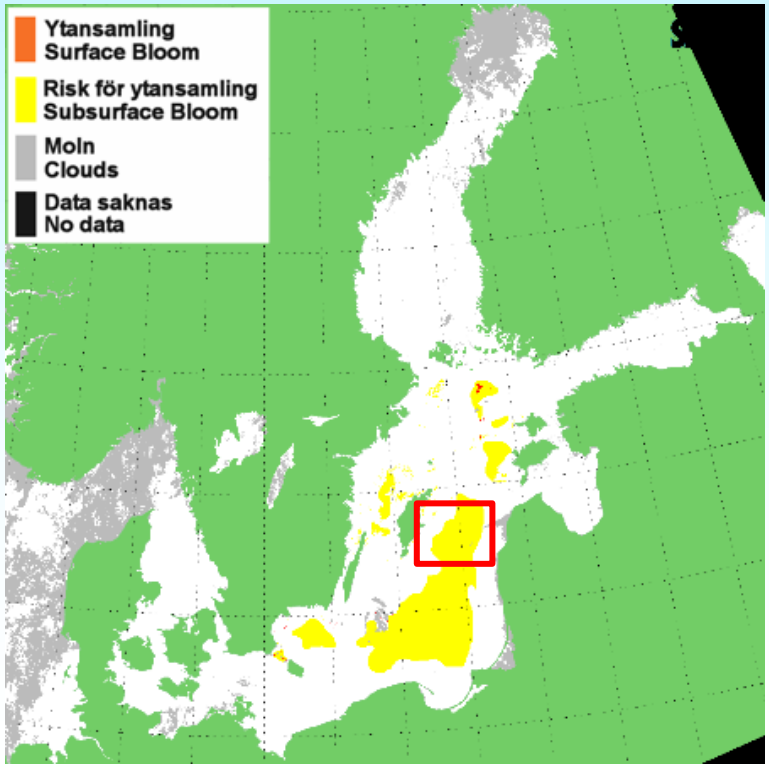
SAR images containing ship wakes of enhanced backscatter, in percentage of total number of SAR images, monthly quantities for 2009 – 2011

Relation between regions of bright wakes and intense algae bloom

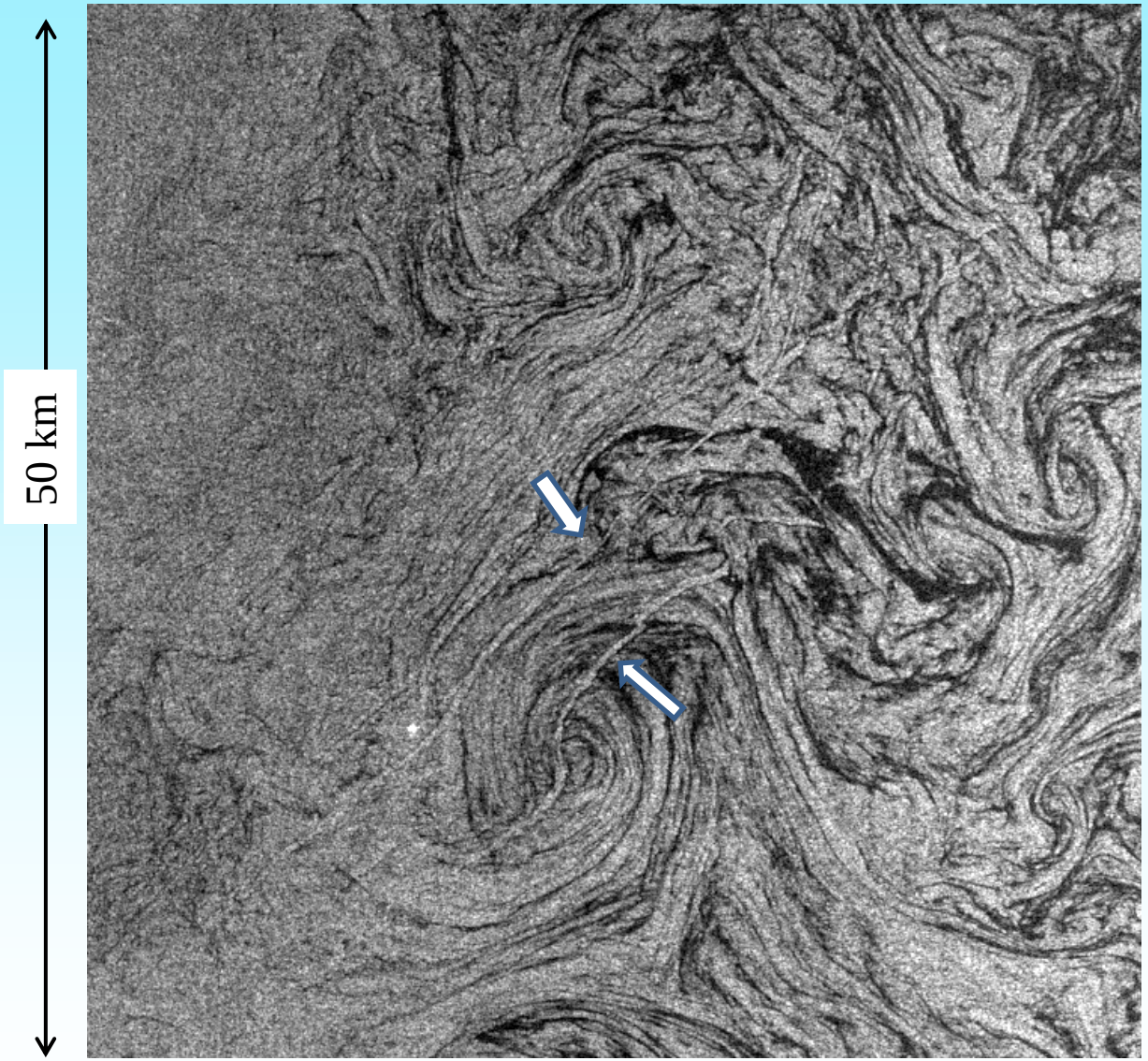


Fragment of TM Landsat -5 image (3; 2; 1 bands)
03 July 2010

Algae bloom map of 03 July 2010 г.
© SMHI

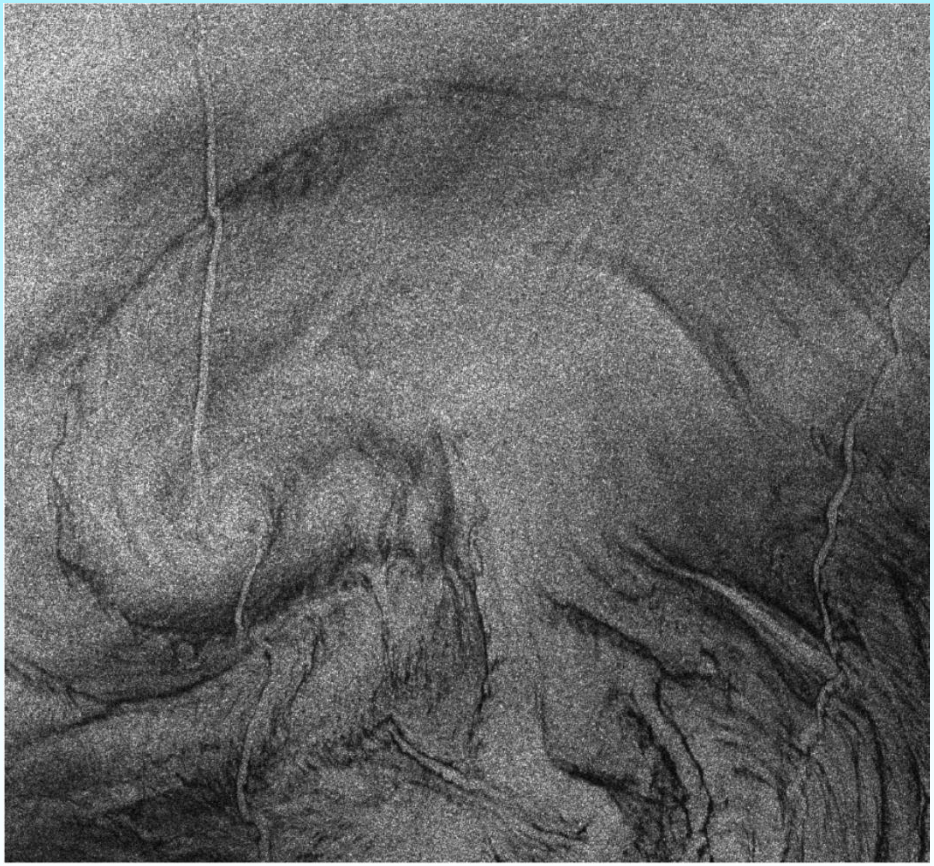


Involvement in eddy motion

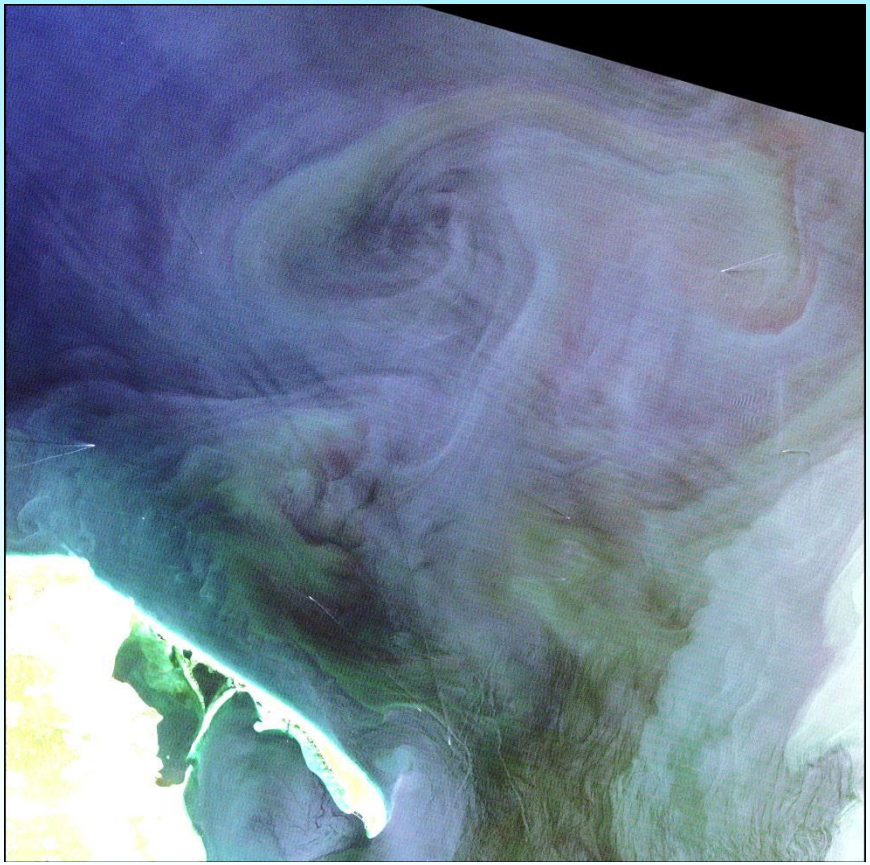


Fragment of ASAR Envisat. 25.04 2009

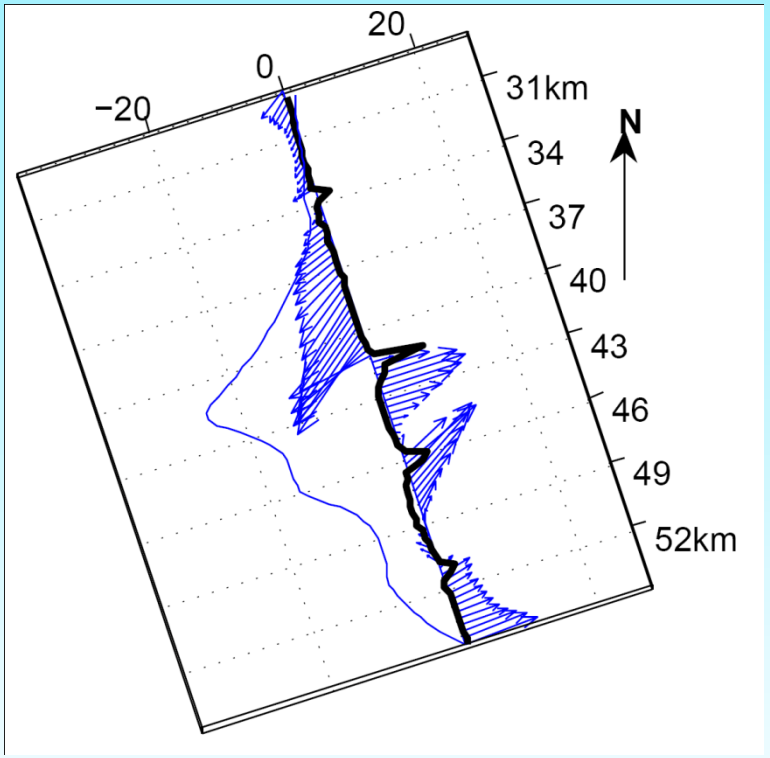
Ship wake distortions as indicator of fine current structure



Fragment of ERS-2 SAR of 23.06.2011
Southeastern part of the Baltic Sea



Fragment of TM Landsat -5
(3; 2; 1 bands) of 29.06.2011



Horizontal and vertical current velocity curve derived from ship wake distortion

Conclusion

- Numerous long-living wakes are manifested both in SAR and VIS data during intense algae bloom period. In SAR images, these persistent wakes are manifested as bright bands of enhanced backscatter.
- Length of a wake can reach more than 100 km.
- Such wake can remain on a sea surface more than 5 hours.
- Bright wakes are well manifested on high resolution images of visible range.
- Possible mechanism of the manifestation of bright wakes – a ship making way through algae leaves a path of clear water behind, where wind waves responsible for the enhanced SAR backscatter emerge
- Long-living ship wakes distortions can be indicators of spatial current fine structure.

ACKNOWLEDGMENTS

- **ERS-2 SAR and Envisat ASAR images were obtained under ESA projects AO Bear 2775 and C1P 1027**
- **RADARSAT-2 and TerraSAR-X data were obtained under international project "SOAR RADARSAT-2/TerraSAR-X Project #5074".**
- **The work was supported by the Russian Foundation for Basic Research (grant #14-05-14-05-00520)**

Thank you

for your attention