Use of data from satellite ocean color scanners for bio-ecological monitoring of the seas surrounding the European part of Russia

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- Applications of satellite ocean color data
- Problems of the data processing
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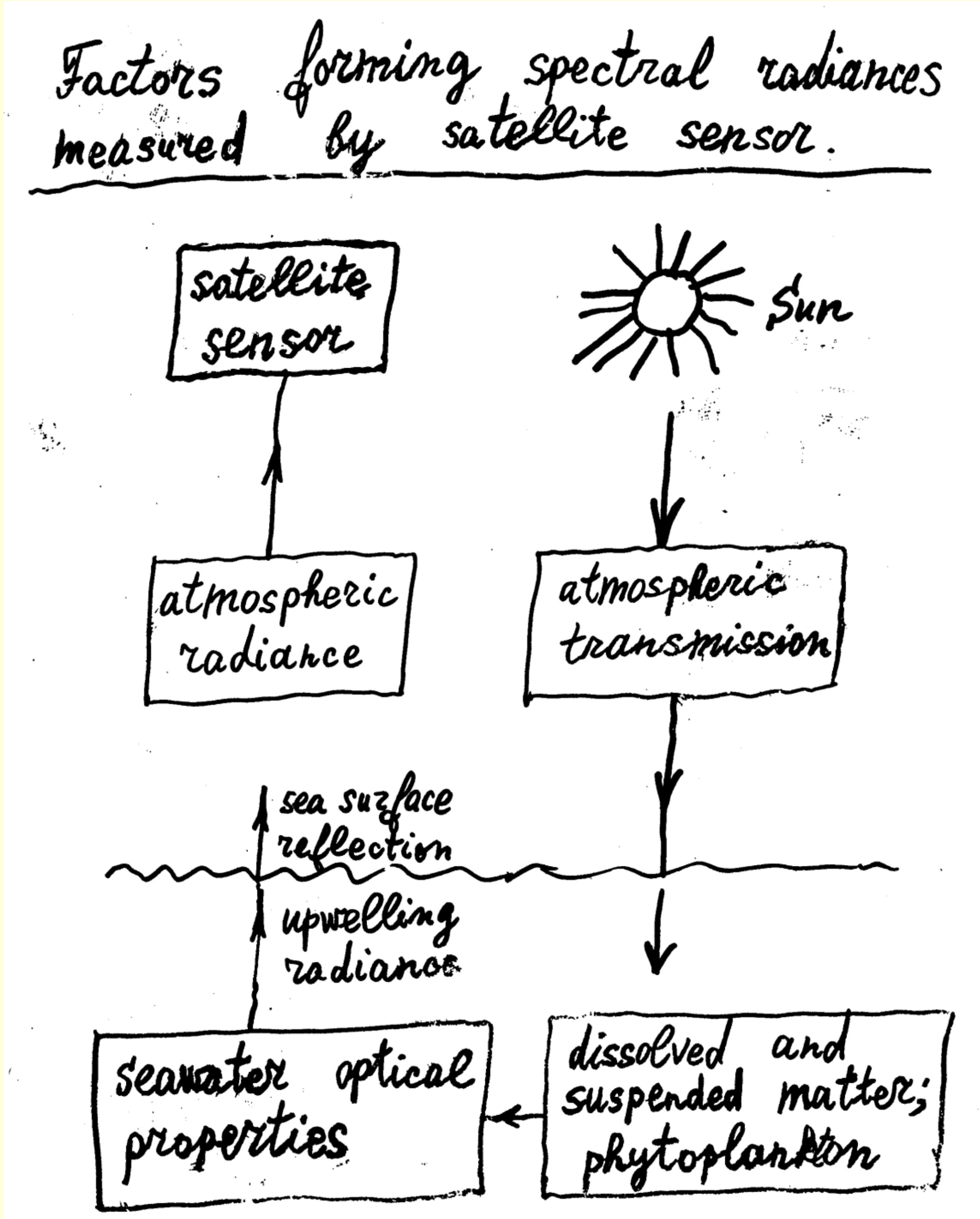
- Conclusion

Bio-optical parameters derived from satellite ocean color data

Parameter	Application
Spectral radiance reflectance	**Spatial and temporal variability of characteristics of the near-surface layer; detection of changes in structure and functioning of the marine ecosystem; harmful blooms**
Chlorophyll concentration	**Phytoplankton biomass; a key characteristics to calculate primary production**
Diffuse attenuation coefficient	**A key characteristics to calculate penetration of solar radiation into water body; ocean albedo; volume absorption**
CDOM absorption coefficient	**CDOM (yellow substance) content; water quality in coastal zone**
Particle backscattering coefficient	**Ocean albedo; total suspended matter; water quality in coastal zone; monitoring of coast erosion and changes in coast line; study of water dynamics including river runoff, mesoscale eddies, frontal zones and others**
Aerosol optical thickness	**Aerosol content in the atmosphere**



$$L_t(\lambda_i) = L_r(\lambda_i) + L_a(\lambda_i) + T(\lambda_i) \cdot L_g(\lambda_i) +$$
$$+ t(\lambda_i) \cdot L_{wc}(\lambda_i) + t(\lambda_i) \cdot L_w(\lambda_i),$$

$L_R(\lambda)$ and $L_a(\lambda)$ are the contributions from Rayleigh scattering and aerosol multiple scattering with the interaction between Rayleigh and aerosol scattering;

$L_g(\lambda)$ is the sun glint radiance,
$L_f(\lambda)$ is the radiance from foam (whitecaps),
$L_w(\lambda)$ is the water-leaving radiance;
$T(\lambda)$ and $t(\lambda)$ are the direct and diffuse transmittances of the atmosphere.

All radiances and transmittances are functions of the wavelength λ, the solar θ_o and viewing θ zenith angles and the azimuthal angles φ_0 , φ .

Two main stages of processing of satellite ocean color data

1. Atmospheric correction

The problem of the atmospheric correction is to derive the water-leaving reflectance $\rho_w(\lambda_i)$ from the spectral top-of-the atmosphere (TOA) radiance $\rho_t(\lambda_i)$ measured by a satellite detector. The TOA radiance reflectance $\rho_t(\lambda_i)$ in a spectral band centered at a wavelength λ_i can be represented as a sum of the following components:

$$\rho_t(\lambda_i) = \rho_r(\lambda_i) + \rho_a(\lambda_i) + T(\lambda_i)\rho_g(\lambda_i) + t(\lambda_i)\rho_{wc}(\lambda_i) + t(\lambda_i)\,\rho_w(\lambda_i)\,,$$

$$\rho = \pi L / Fo \cos\theta_o\,,$$

where $F_o \cdot \cos\theta_o$ is the irradiance produced by solar radiation at the top-of-the-atmosphere; $\rho_r(\lambda_i)$ is Rayleigh scattering; $\rho_a(\lambda_i)$ is the aerosol contribution, including the multiple scattering by aerosols, and interaction between Rayleigh and aerosol scattering; $\rho_g(\lambda_i)$ is the contribution from sun glints; $\rho_{wc}(\lambda_i)$ is the contribution from whitecaps on the sea surface; $T(\lambda_i)$ and $t(\lambda_i)$ are the direct and diffuse transmittance of the atmosphere.

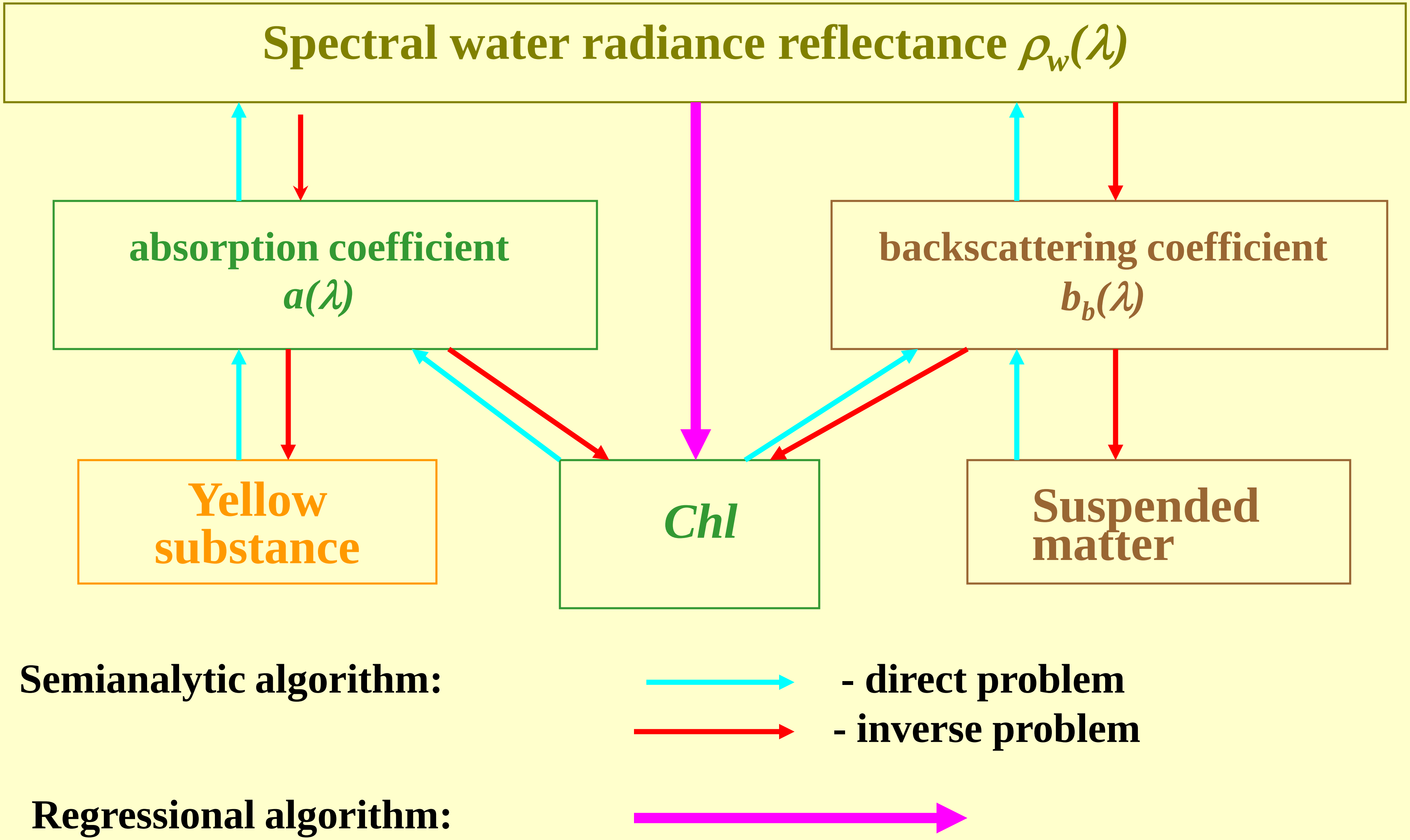
2. Bio-optical algorithms

Their purpose is to retrieve the seawater bio-optical characteristics from the water-leaving reflectance $\rho_w(\lambda_i)$.

Spectral bands of satellite ocean color scanners SeaWiFS and MODIS

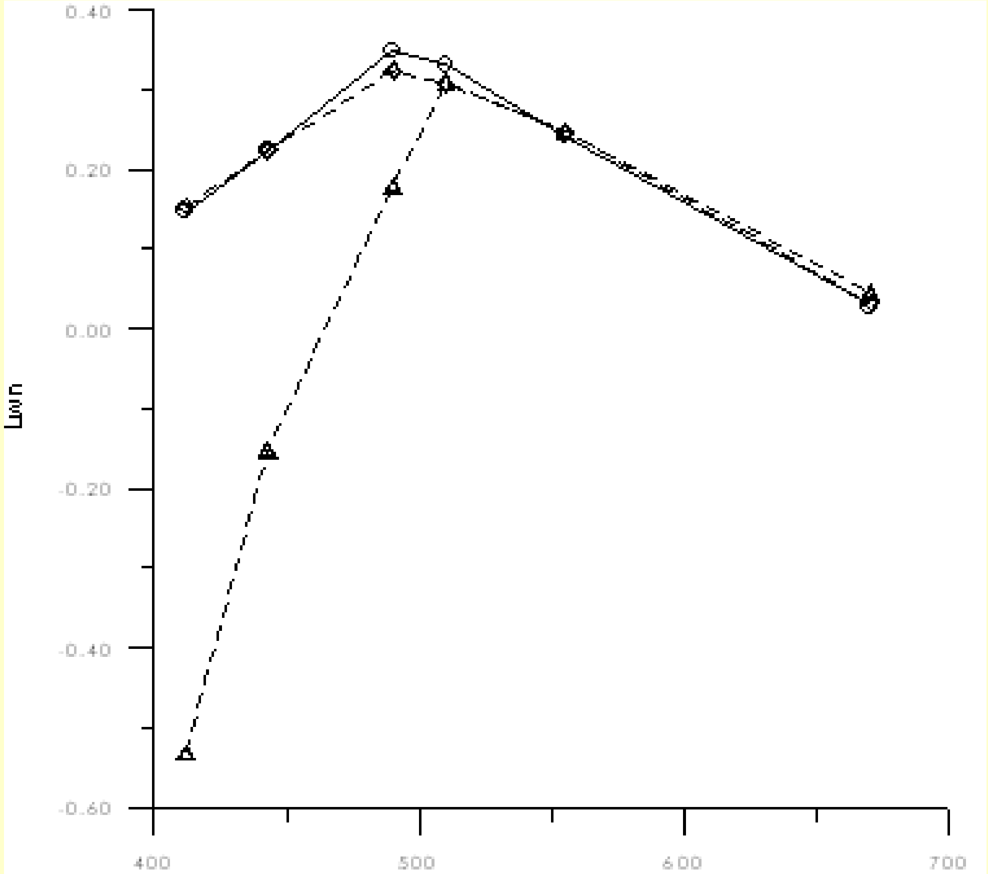
SeaWiFS		MODIS-Aqua	
Bands	**Spectral interval, nm**	Bands	**Spectral interval, nm**
1	402-422	8	405-420
2	433-453	9	438-448
3	480-500	10	483-493
4	500-520	11	526-536
5	545-565	12	546-556
6	660-680	13	662-672
7	745-765	14	673-683
8	845-885	15	743-753
		16	862-877

Bio-optical algorithms



Comparison between spectral values of the water radiance reflectance $\rho_w(\lambda)$, measured *in situ* (circles), derived with the standard SeaWiFS algorithm (triangles) and by SIO RAS algorithm (diamonds)

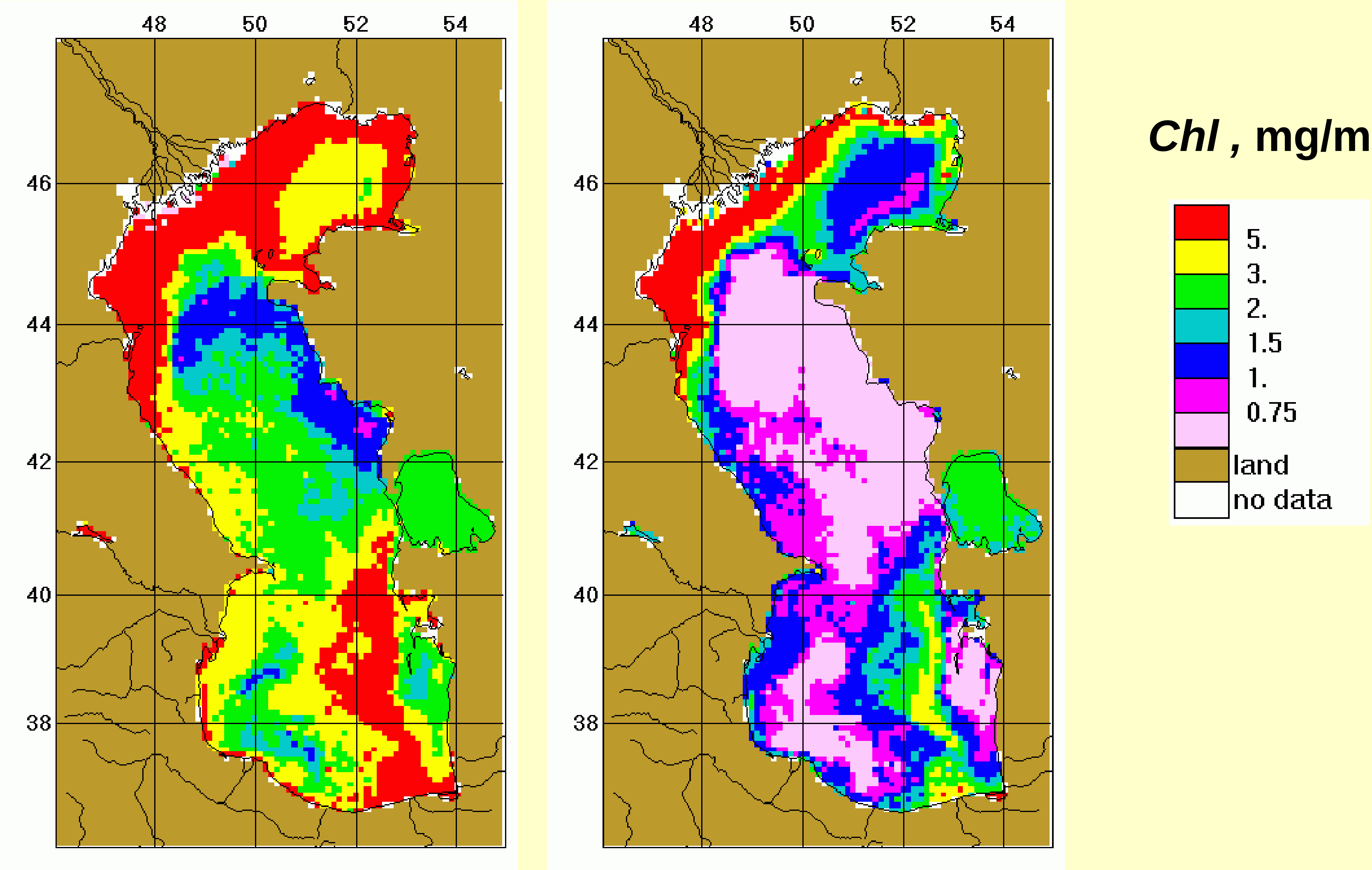
The SIO RAS algorithm is based on *in situ* data measured in the Barents Sea.



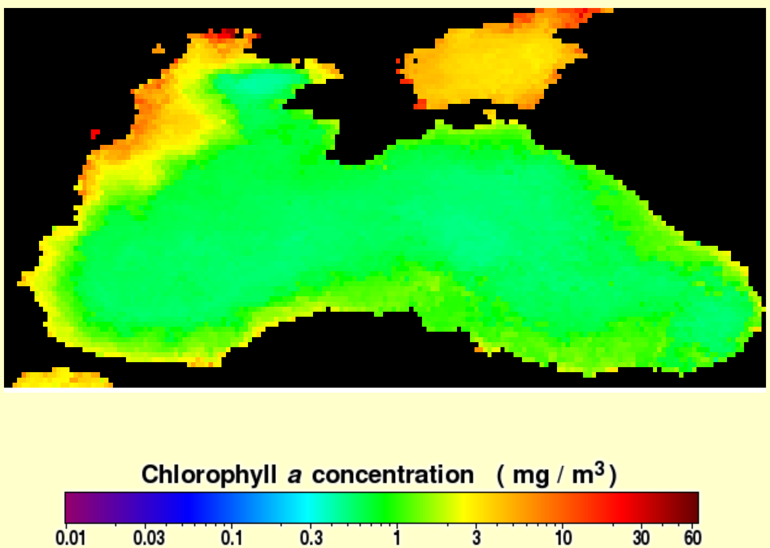
wavelength, nm

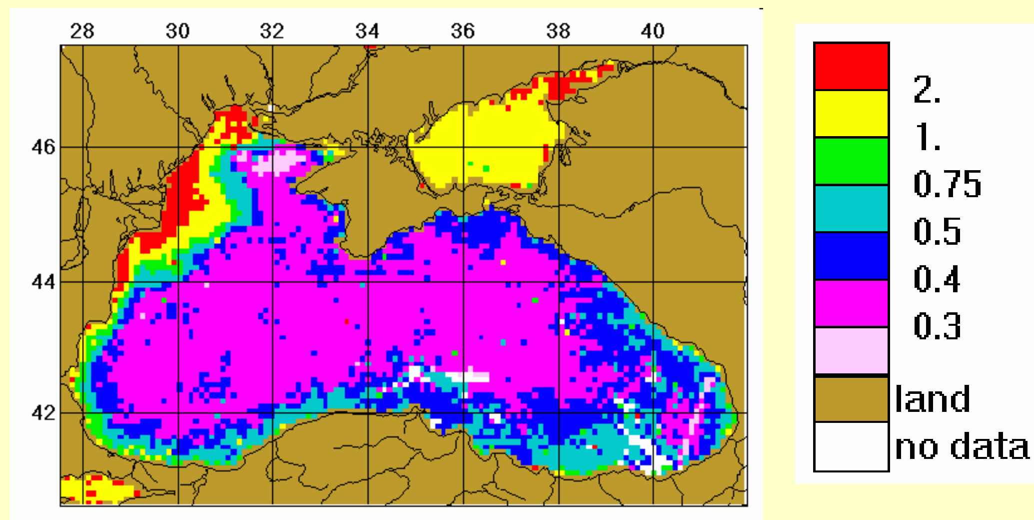
St.1131 in the Barents Sea, 69.77N, 56.28E.

Comparison between spatial distributions of chlorophyll concentration derived from SeaWiFS satellite ocean color data by the standard (left) and the regional (right) algorithms (August 2006)



Comparison between the monthly mean distributions of chlorophyll concentration in April 2006 derived from SeaWiFS data with the SeaWiFS standard algorithm (left) and the SIORAS algorithm (right)

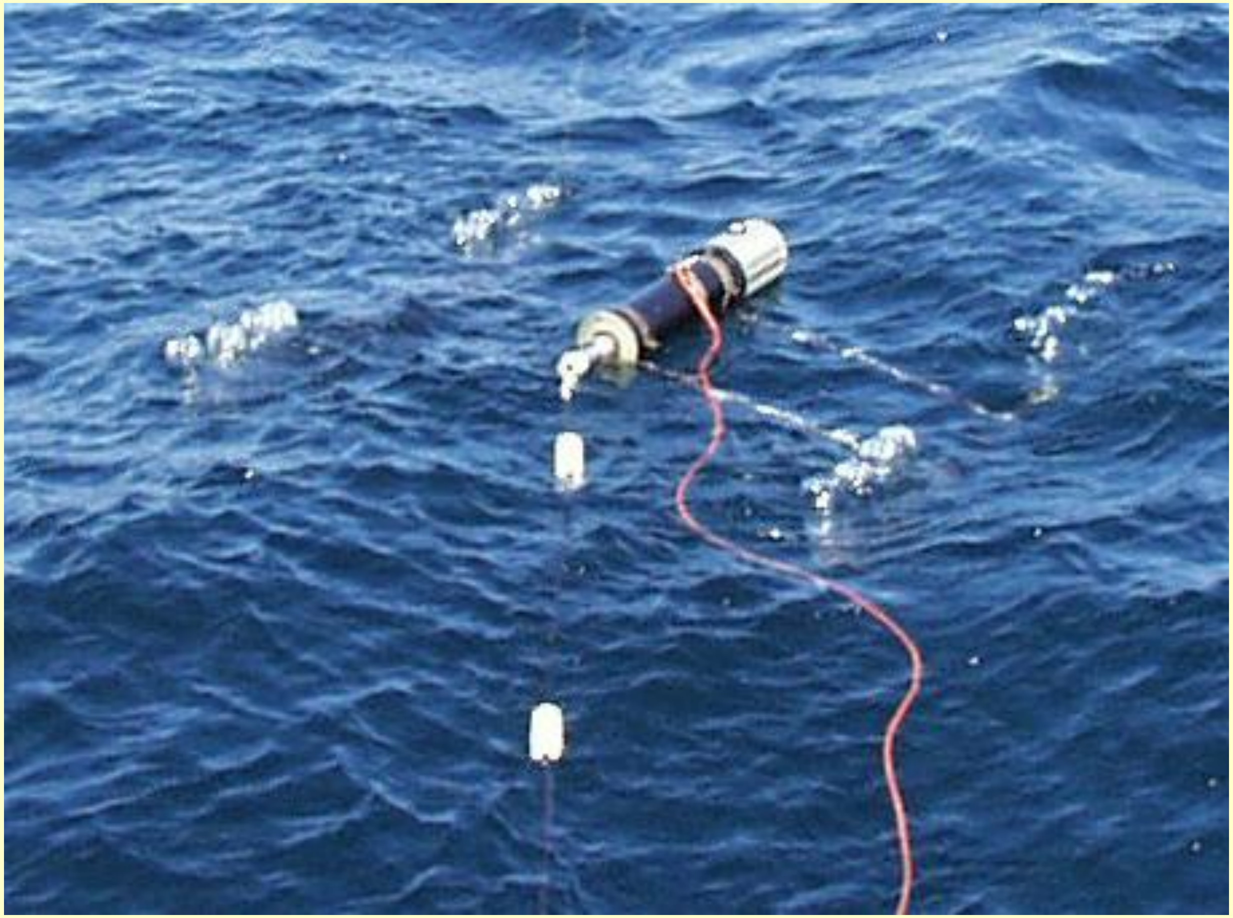




SeaWiFS standard algorithm (http://seadas.gsfc.nasa.gov/)

SIORAS algorithm

Floating spectroradiometer



It measures spectral values of the surface irradiance just above the sea surface and the upwelling radiance just below the sea surface to avoid sun glints.

The spectral range is 390-700 nm; s pectral resolution - 2.5 nm;
an accuracy is about 5%.

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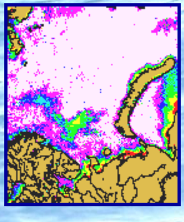
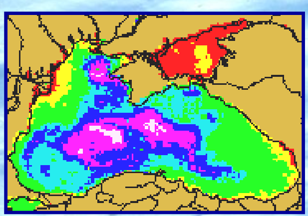
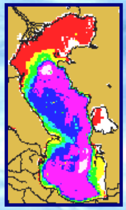

BIO-OPTICAL CHARACTERISTICS OF THE BARENTS, WHITE, BLACK, and CASPIAN SEAS FROM DATA OF SATELLITE OCEAN COLOR SCANNERS

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Moscow 2009

This CD-ROM presents the mean monthly distributions of chlorophyll "a" concentration, the particle backscattering coefficient, suspended matter concentration, and the yellow substance absorption coefficient in the Barents, White, Black and Caspian Seas derived from data of satellite ocean color scanners SeaWiFS and MODIS-Aqua from 1998 to 2008.

A brief analysis of the obtained results is given.

CD-ROM viewing

Internet Explorer or other Internet Browser is needed to view this CD-ROM. It is opened automatically; if not so, please click index.html.

Attention!!!

All maps are given with two scales. To look at a map with better resolution, please click this map by the left mouse button.

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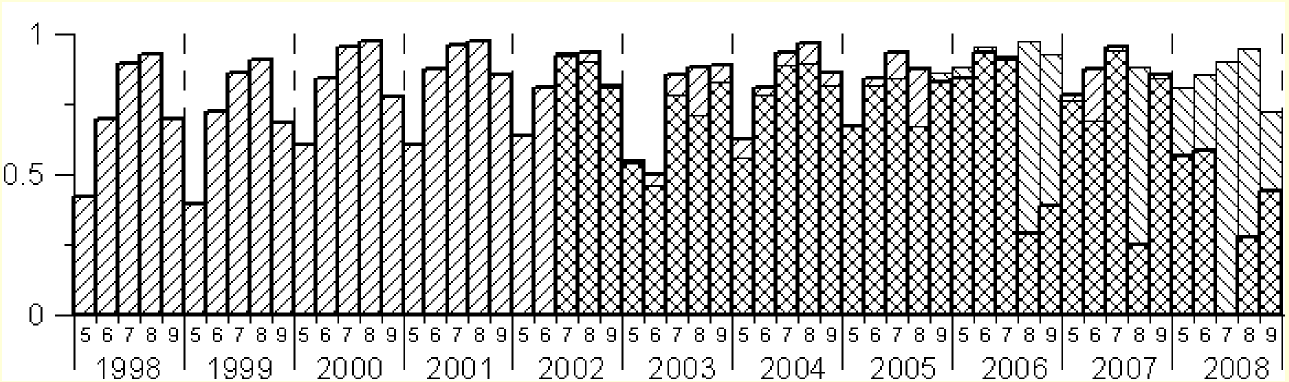
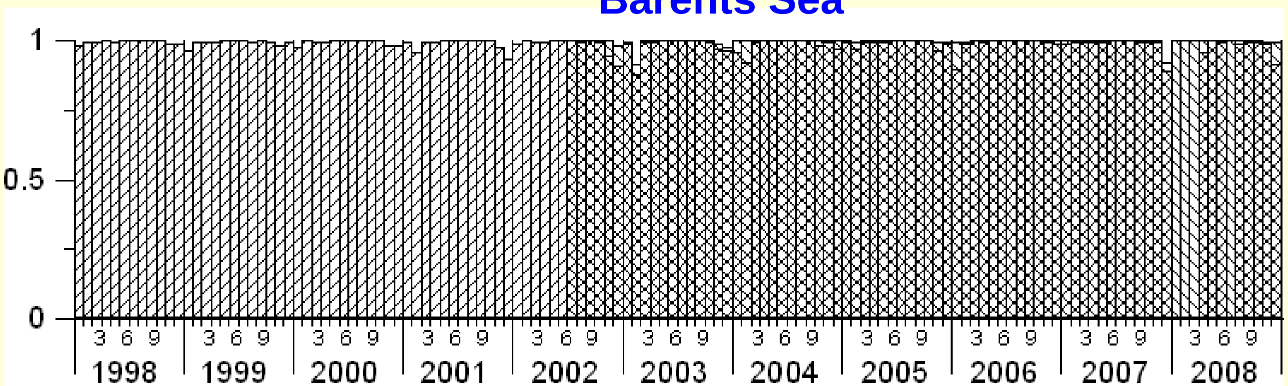
The software package was developed for Microsoft Windows *(Sheberstov S.V., Lukyanova E.A.* A system for acquisition, processing, and storage of satellite and field biooptical data // Proceedings of IV international conference "Current problems in optics of natural waters", Nizhny Novgorod. P. 179 – 183. 2007).

Since 2007 the package has been refined and now provides a full support for processing the Level-1 - Level-3 SeaWiFS and MODIS files generated by SeaDAS [http://seadas.gsfc.nasa.gov/]. The daily Level-3 values were generated by averaging the Level-2 values within a given bin of 9 x 9 km (for the Barents Sea the size of a bin was 6 x 6 km, for the White Sea from MODIS-Aqua data a bin was 2 x 2 km). The monthly or other Level-3 files were created by averaging the daily Level-3 values over the corresponding period.

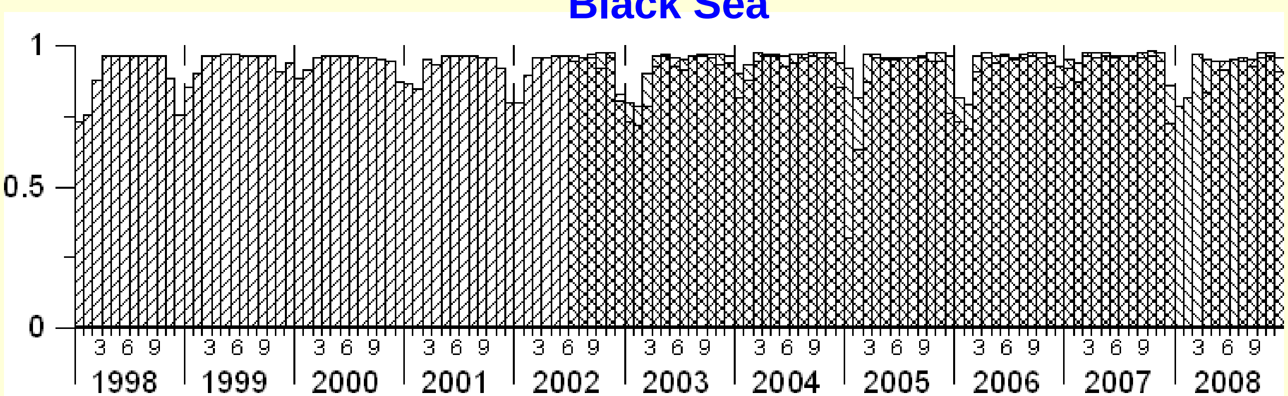
Monthly coverage of the Barents, Black, and Caspian seas by SeaWiFS and MODIS satellite data



Barents Sea



Black Sea



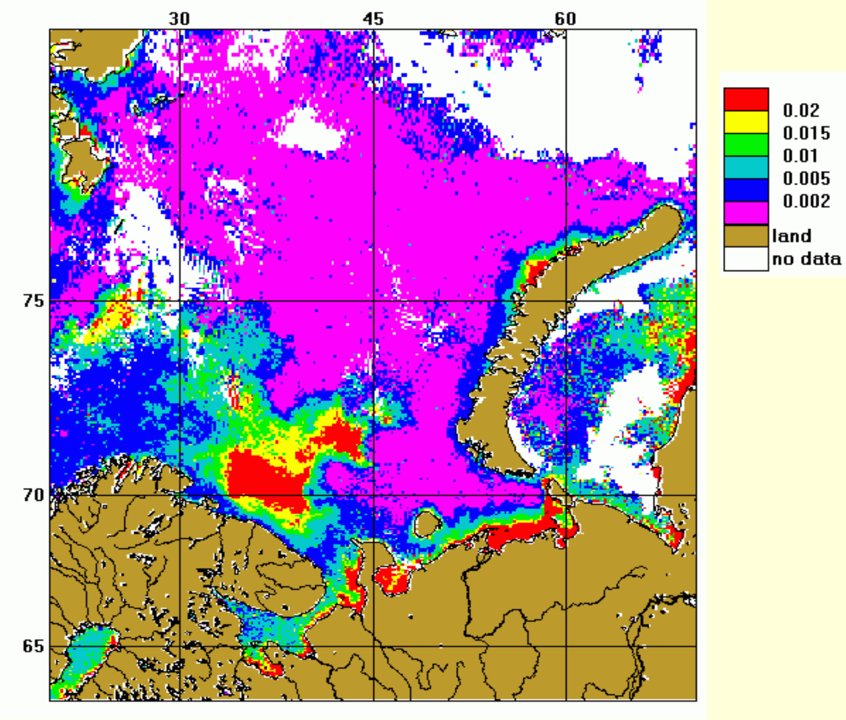
Caspian Sea

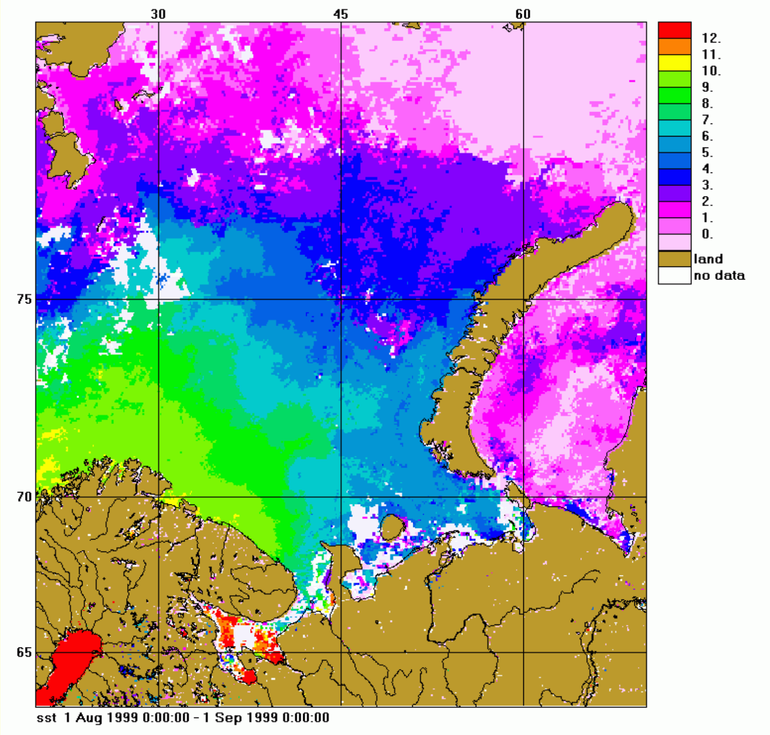
In 2008 a difficulty with SeaWiFS data, used before for construction of the long-term series since 1998, has arisen.
The SeaWiFS instrument was powered off in January – March and then in July 2008 due to the loss of GPS and attitude data in the space telemetry.

The gaps in coverage by SeaWiFS data in 2008 are seen on Figures whereas MODIS-Aqua provides the reasonable coverage.

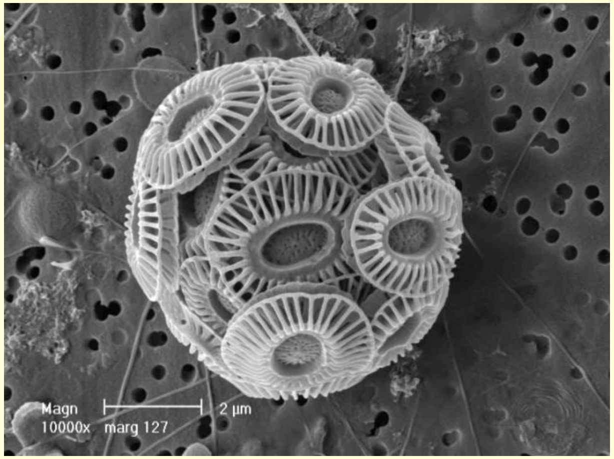
A special procedure of joining SeaWiFS to MODIS-Aqua has been developed.

Barents Sea



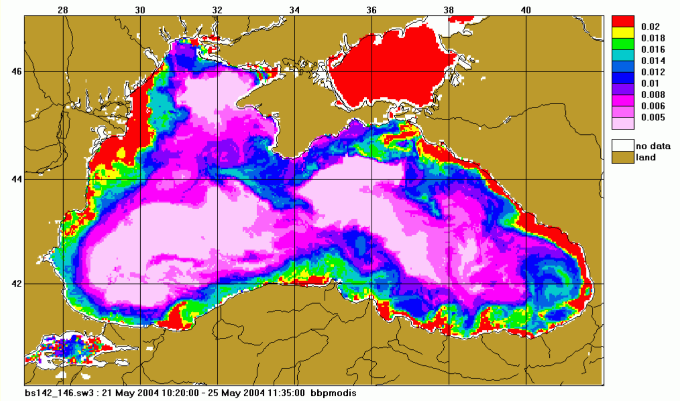


Spatial distributions of the particle backscattering coefficient (left) and sea surface temperature (right) in August 1999.

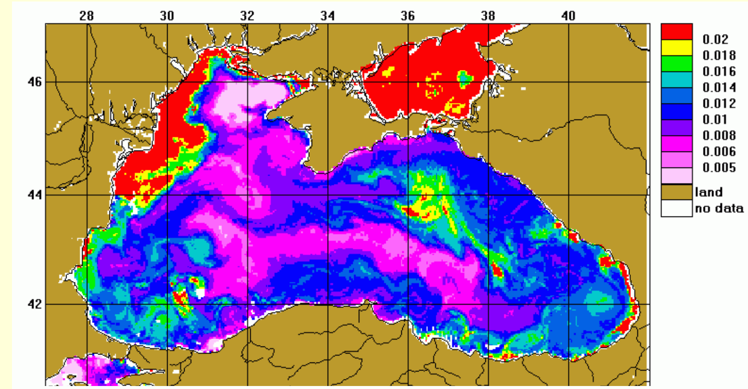


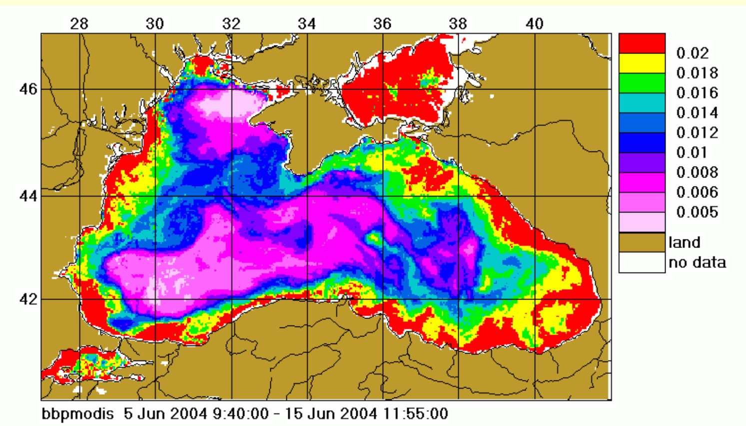
Emiliania huxleyi **(Ehux)**

Changes in the spatial distribution of the particle backscattering coefficient b_{bp}, m^{-1} in May-June 2004 (left) and 2006 (right)



21-25.05





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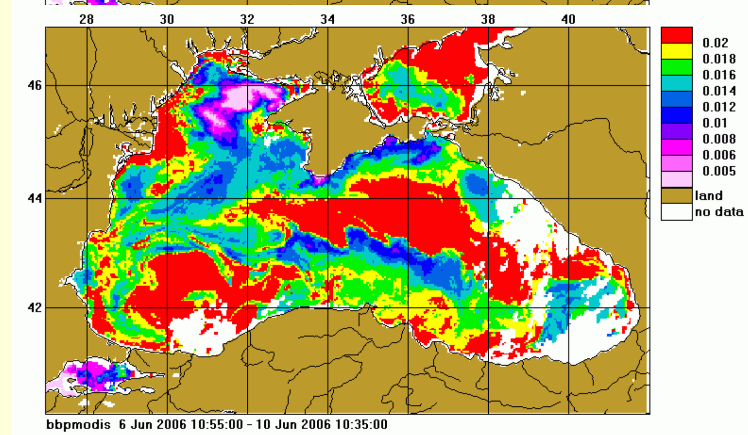
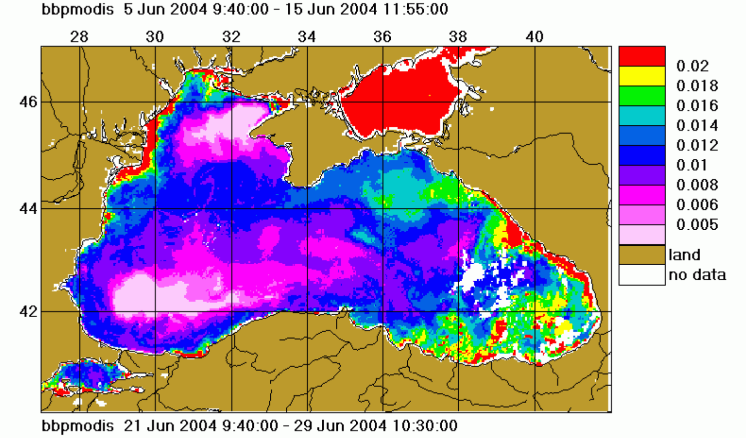
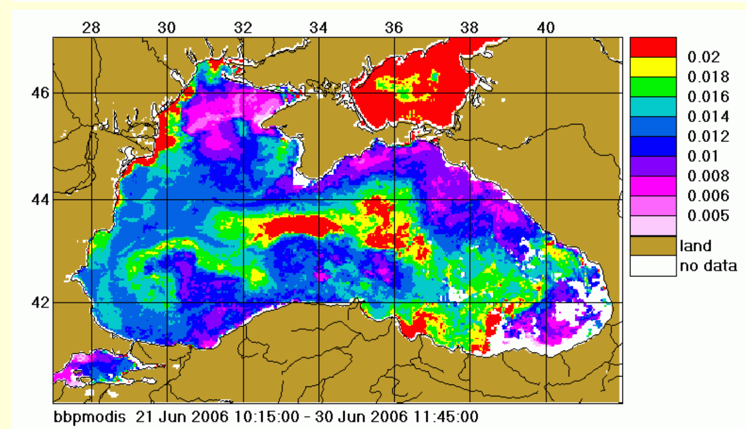
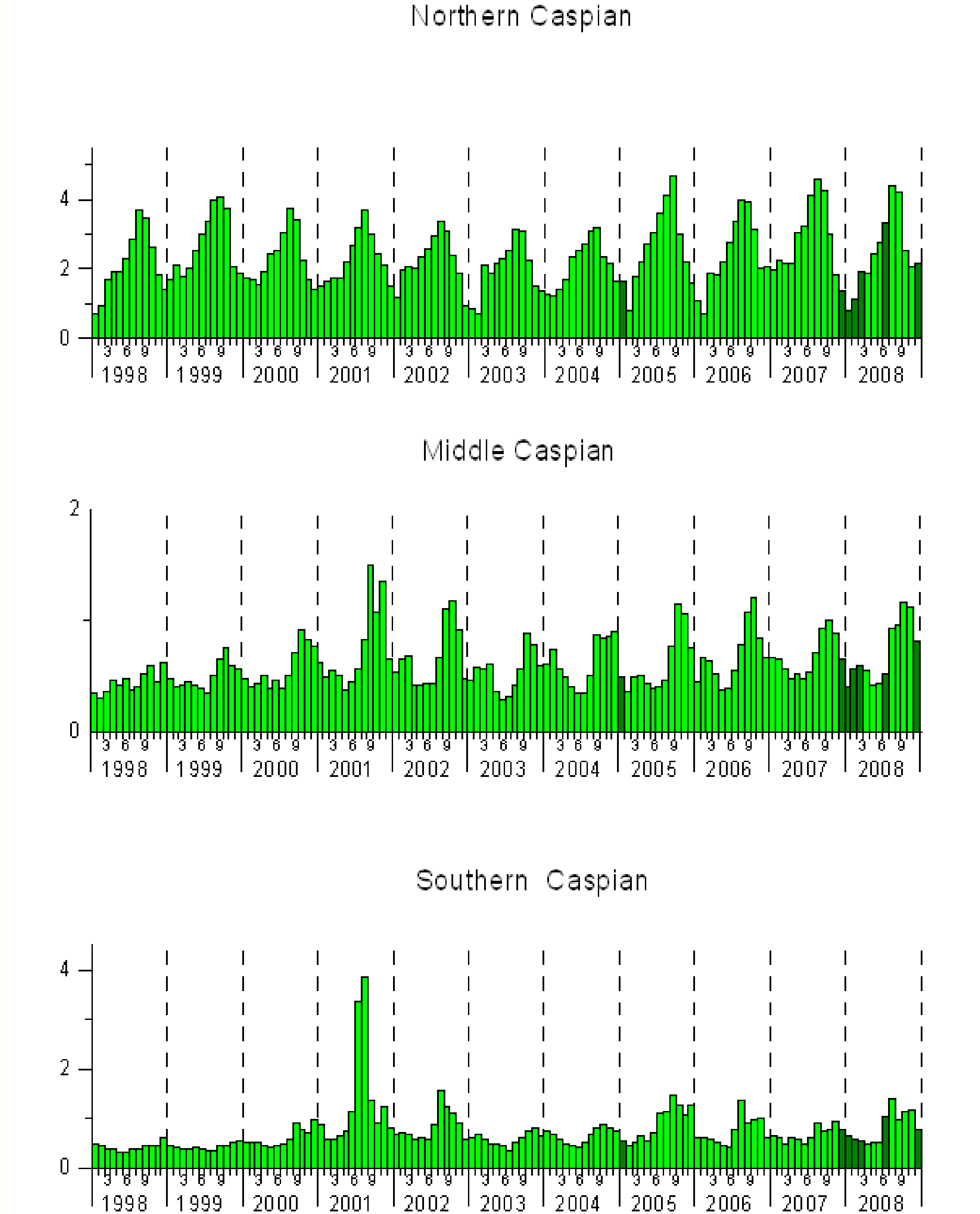




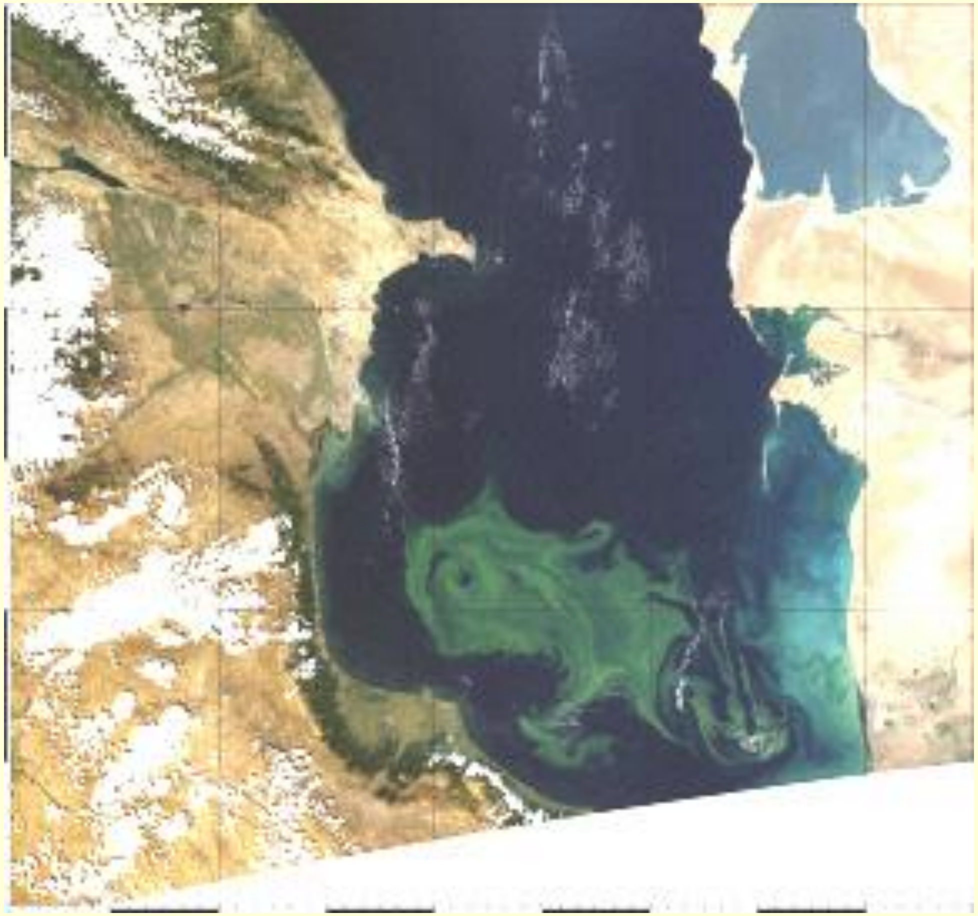
21-30.06



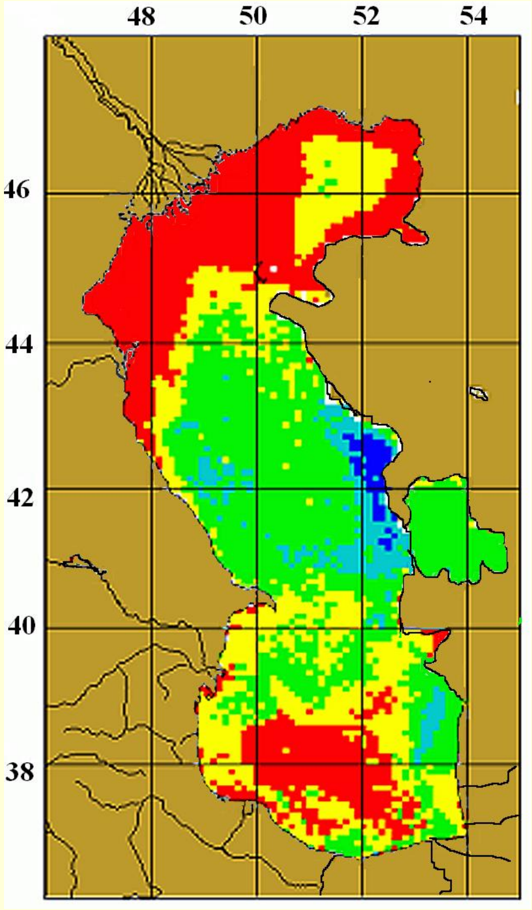


Variability of the monthly means of chlorophyll concentration (mg/m^3) in the Northern, Middle and Southern Caspian from 1998 to 2008.

Anomalous Algal Bloom in the Southern Caspian in 2005



SeaWiFS image in true color
on 1 September 2005.



The mean monthly distribution
of chlorophyll concentration
in September 2005 derived
from SeaWiFS data.

Conclusion

- **Satellite ocean color data provide us with a variety of useful applications including the bio-ecological monitoring of marine environment.**
- **Processing of satellite ocean color data includes two main stages: atmospheric correction and retrieval of bio-optical seawater constituents. The most seas need regional algorithms based on *in situ* measurements to correctly process satellite data.**
- **Long-term series of satellite ocean color data give opportunities to study seasonal and interannual changeability of seawater bio-optical parameters and to reveal some interesting phenomena such as coccolithophore and harmful blooms, changes in marine ecosystems.**

Thank you for your attention