Seasonal and diurnal distributions of the phytoplankton bloom, organic and suspended matter contents indicators in the Amur Bay and adjacent area (Japan/East Sea) according to satellite data

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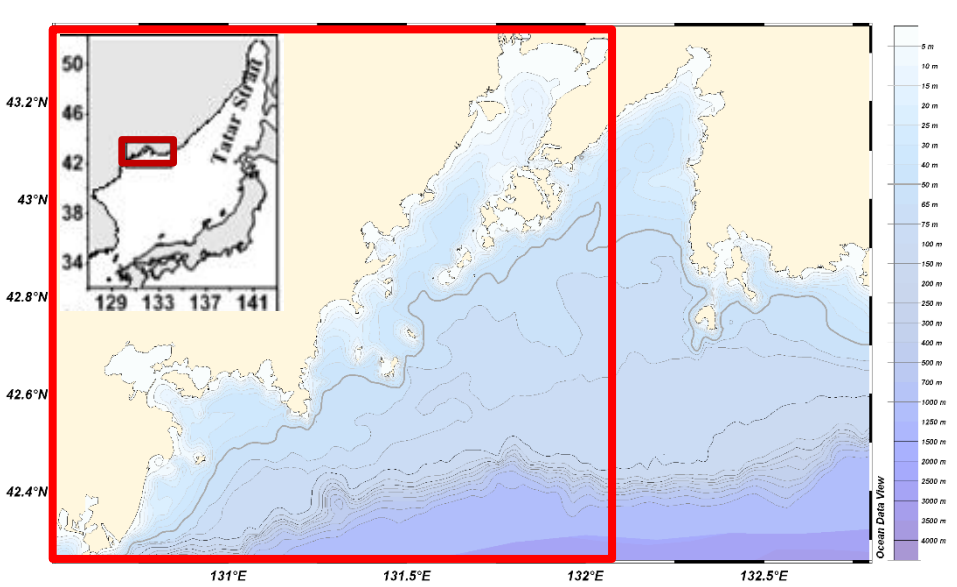
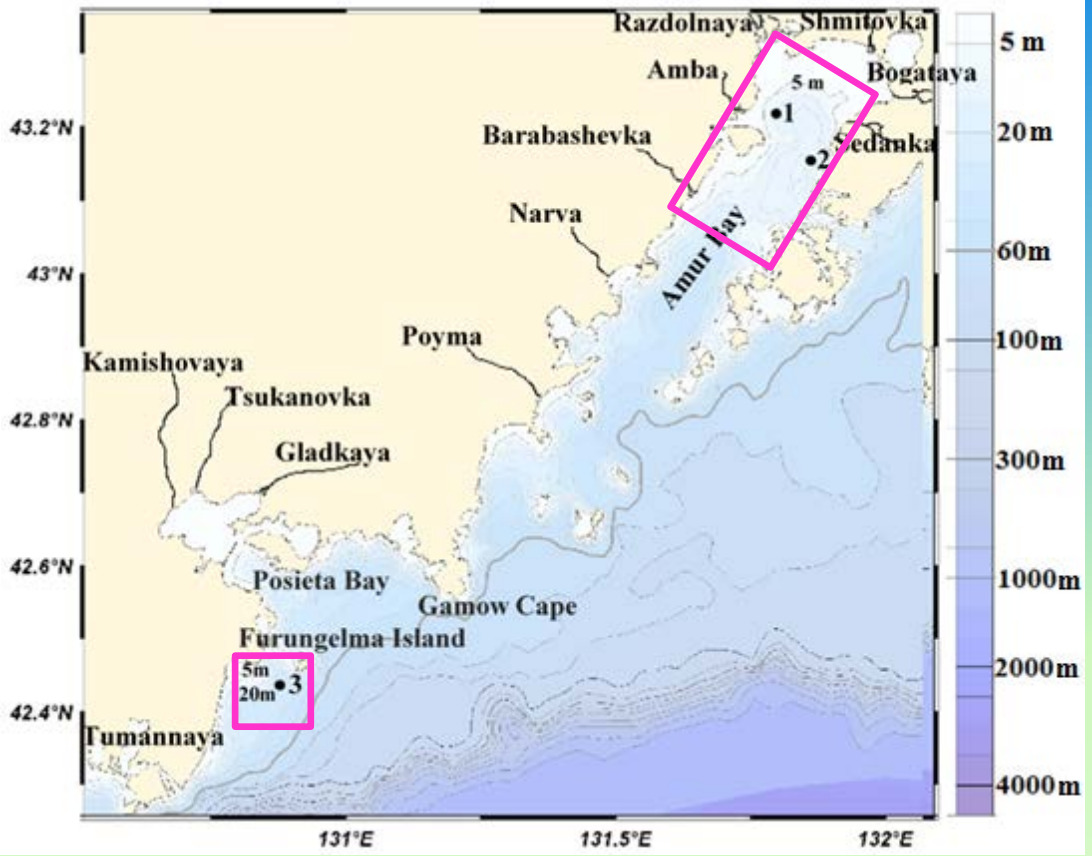
Phytoplankton blooms, streams of organic and suspended matter affect the formation of near-bottom hypoxia during conditions of water stratification. Their variability in the surface layer can be characterized by means of the water color characteristics (concentration and fluorescence of chlorophyll-*a*, coefficients of light absorption by detritus and yellow substance, light backscattering by suspended particles), which were obtained using the satellite data.

According to in situ observations of hydrochemical properties the cases of near-bottom water hypoxia in Amur Bay and area of marine State Reserve toward south-western from the Furungelma Island during late summer - early autumn were identified by the researchers of our institute. Main reason of the hypoxia formation is associated with the eutrophication of the water after floods on the rivers. Also the hypoxia formation in Amur Bay is associated with the southern winds leading to the downwelling of waters, and its breakdown – with northern winds.

Region of study

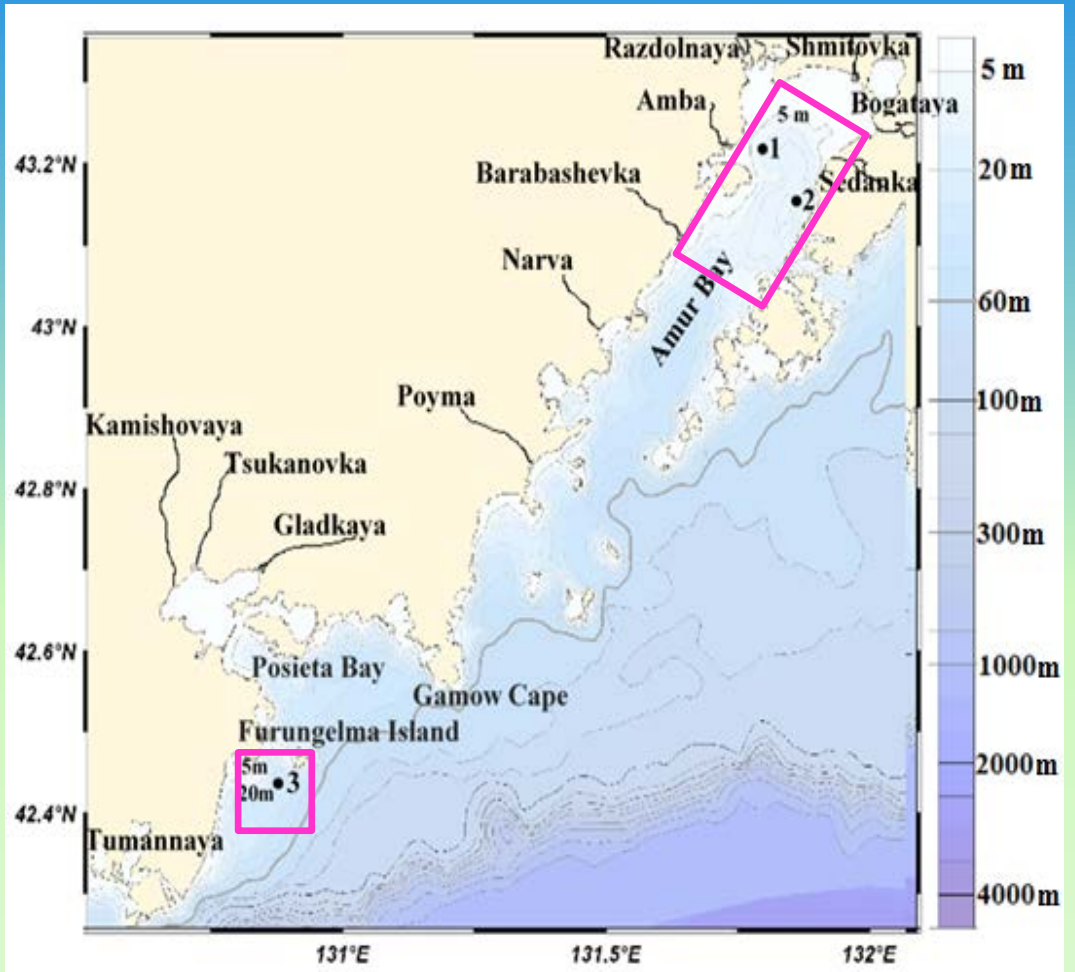




Location of the study region (red rectangle) in Peter the Great Bay and in Japan/East Sea is shown. Also locations of areas (pink rectangles), where the cases of near-bottom water hypoxia were identified by the researchers of our institute, are shown. Points 1, 2, 3 show the areas, where we considered the time series of water color characteristics according to the satellite data. Locations of the larger rivers confluence in sea are shown. On the Bogataya and Sedanka Rivers the reservoirs are located. Bathymetric map was taken from the site – pacificinfo.ru/data/cdrom/11/img/3_1_2/pgb_bathy.png. Scale to the right shows the depths.

The aim of this work is:

according to satellite data 1) to identify the features of seasonal course for the phytoplankton bloom, organic and suspended matter contents indicators at comparison of these variables to change of the water temperature, the wind and the precipitation quantity in points 1, 2, 3 for period of 2013-2014; 2) to analyze spatial distributions of the above-mentioned water color indicators having the increased values under certain hydrometeorological conditions and to note the situations that contribute to the formation of water hypoxia.



Data

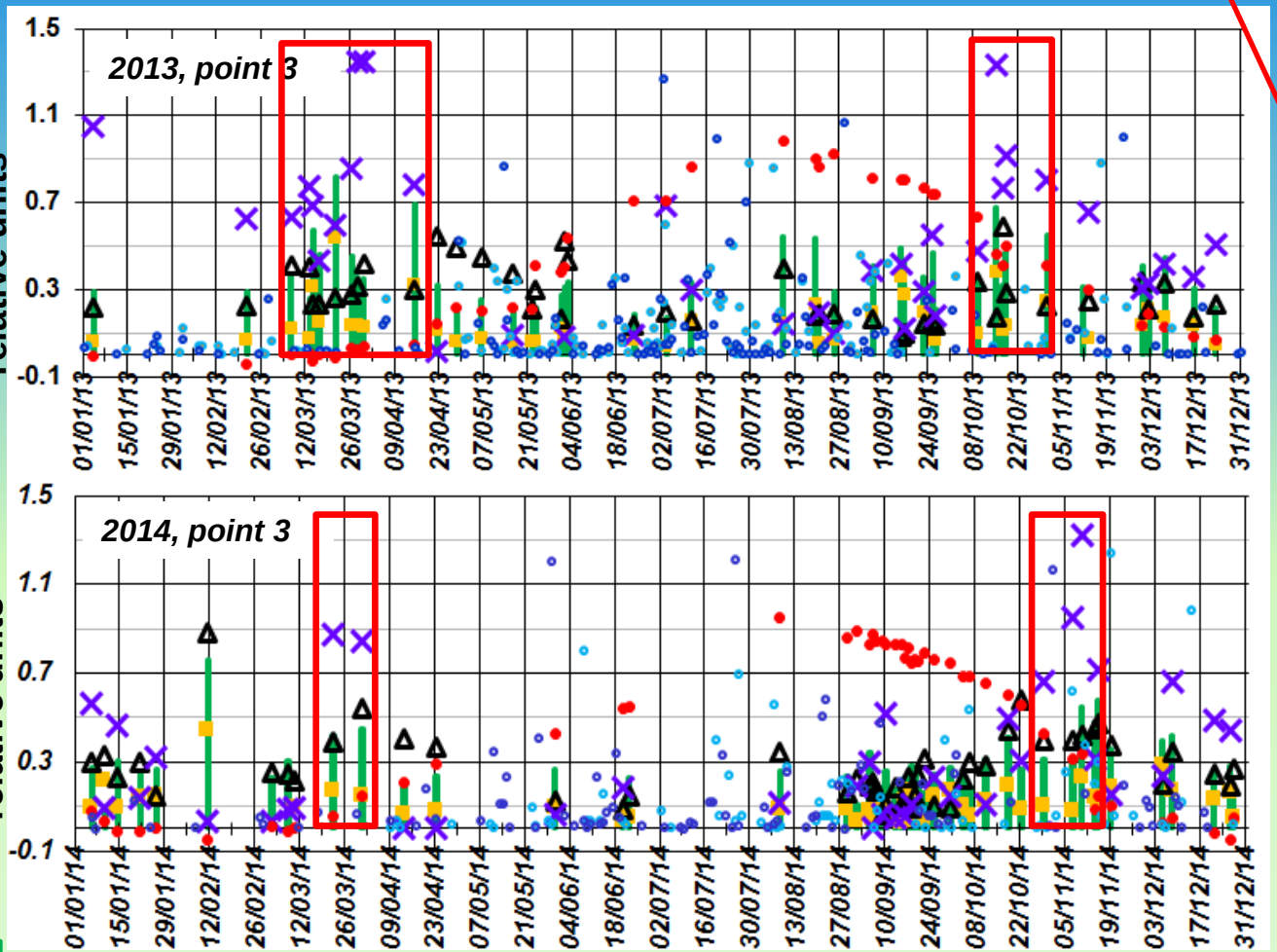
Satellite data

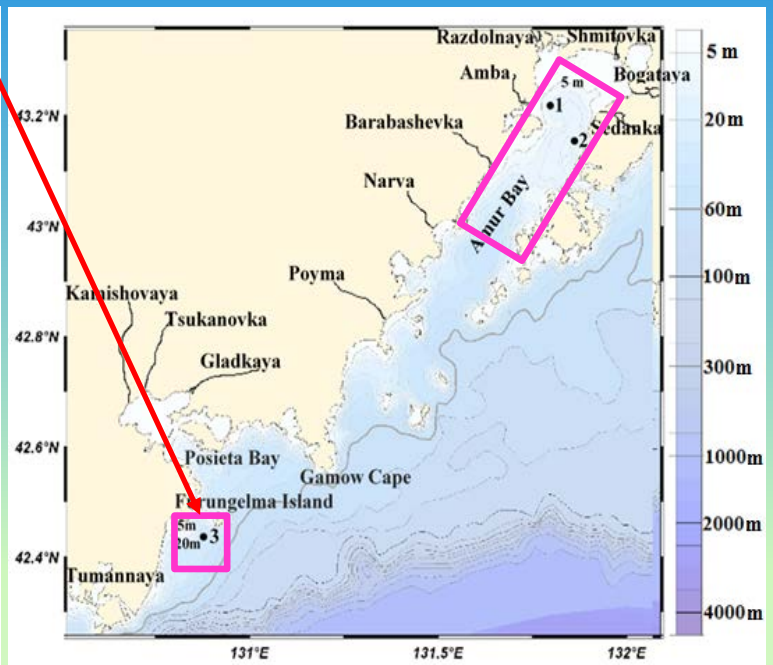
MODIS-Aqua and GOCI-COMS (2013-2014, January - December)
The data of level 1 were obtained via the NASA's Ocean Color Web-site and were processed by means of the software SeaDAS of versions 6.4 and 7.3
Chlorophyll-*a* concentration (Chl) (1-day data of level 2),
Fluorescence Line Height, normalized on radiance downloaded to sea surface (Fchl) at a wavelength of 678 nm,
Coefficient of light absorption by detritus and yellow substance (characteristic of Colored Dissolved Organic Matter, CDOM), calculated according to algorithm QAA (Quasi-Analytical Algorithm) at a wavelength of 443 nm (a_{dg}),
Coefficient of light backscattering by suspended particles, calculated according to QAA at a wavelength of 443 nm (b_{bp}).

Hydrometeorological characteristics

Sea Surface Temperature (SST) from MODIS-Aqua
Wind Speed and Direction from the hydrometeorological station Vladivostok (data obtained via the Weather Schedule Web-site)
Quantity of Atmospheric Precipitation (Q_{ap}) from the TRMM satellite obtained by means of Giovanni online data system (the NASA's Ocean Color Web-site), and from the hydrometeorological station Vladivostok (data obtained via the Weather Schedule Web-site)

Features of seasonal course of the phytoplankton bloom (Chl, Fchl), organic and suspended matter contents (a_{dg}, b_{bp}) indicators in point 3 (near the Furungelma Island)



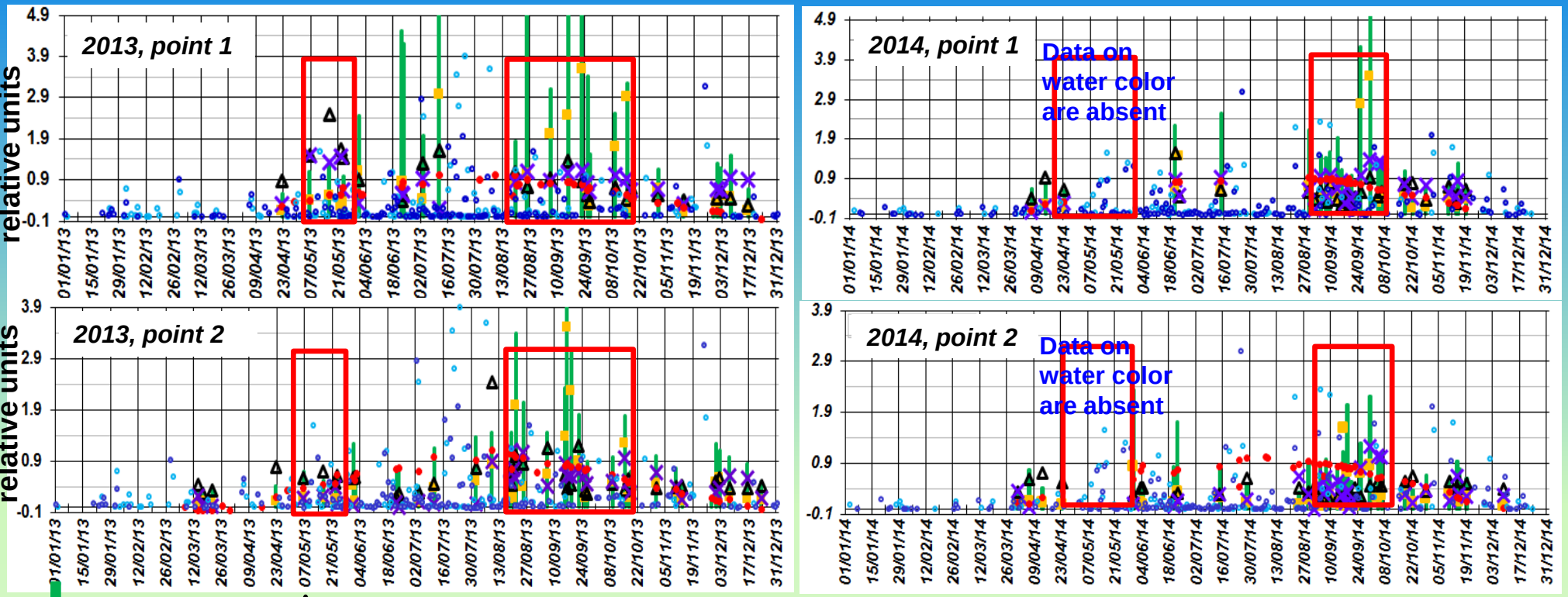


– Spring phytoplankton bloom (Fchl, Chl) in 2013 is from early-middle March to middle April, and in 2014 – from late March to early April; autumn phytoplankton bloom (Fchl, Chl) in 2013 is from middle to late October, and in 2014 – from early November to middle November.

- Chl, - a_{dg} , Δ - b_{bp} , × - Fchl, - SST, - Q_{ap} (HMS "Vladivostok"), - Q_{ap} (TRMM)

Coefficients of recalculation for *Chl* is 3 mg/m^3, a_{dg} is 0.5 m^{-1}, b_{bp} is 0.05 m^{-1}, *Fchl* is 0.03 mW /(cm^2 × μm × sr), *SST* is 25ºC, Q_{ap} is 50 mm/day at points 3.

Features of seasonal course of the phytoplankton bloom (Chl, Fchl), organic and suspended matter contents (a_{dg} , b_{bp}) indicators in points 1, 2 (Amur Bay)



■- Chl, ■ - a_{dg} ,Δ - b_{bp} , × - Fchl, ●- SST, ○- Q_{ap} (HMS "Vladivostok"), ○- Q_{ap} (TRMM)

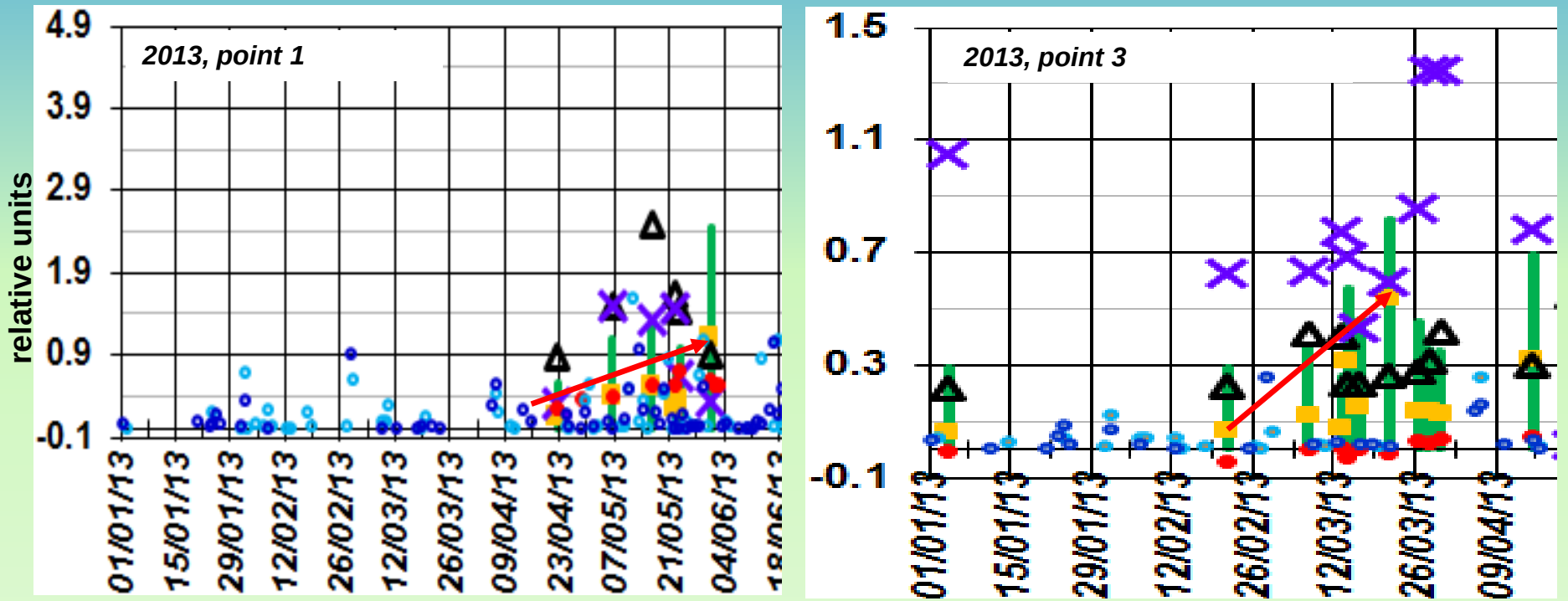
Coefficients of recalculation for *Chl is 3 mg/m³* , *a_{dg} is 0.5 m^{-1},b_{bp} is 0.05 m^{-1},*

Fchl is 0.03 mW /(cm² × μm × sr), SST is 25ºC, Q_{ap} is 20 mm/day at points 1, 2.

- Spring phytoplankton bloom (Fchl) in 2013 is in may, and in 2014 the data for this period are absent; autumn phytoplankton bloom in 2013 is from middle-late August to middle October, and in 2014 - from early September to early October.
- Relatively high values of a_{dg} , $b_{bp,}$ and therefore the strong influence of organic and suspended matter contents on the satellite Chl estimates were noted. The Chl estimates are calculated by means of empirical algorithms containing the reflectance coefficient (Rrs, $R_{rs} = R_{rs}(a, b_b, \lambda)$). (At the relatively high content of colored dissolved organic matter the satellite chl estimates are strongly increased).

Features of seasonal course of the phytoplankton bloom (Chl, Fchl), organic and suspended matter contents (a_{dg} , b_{bp}) indicators in Amur Bay and near the Furungelma Island

Increase of the organic matter content indicator (a_{dg})
due to the accumulation of phytoplankton vital activity products during its bloom



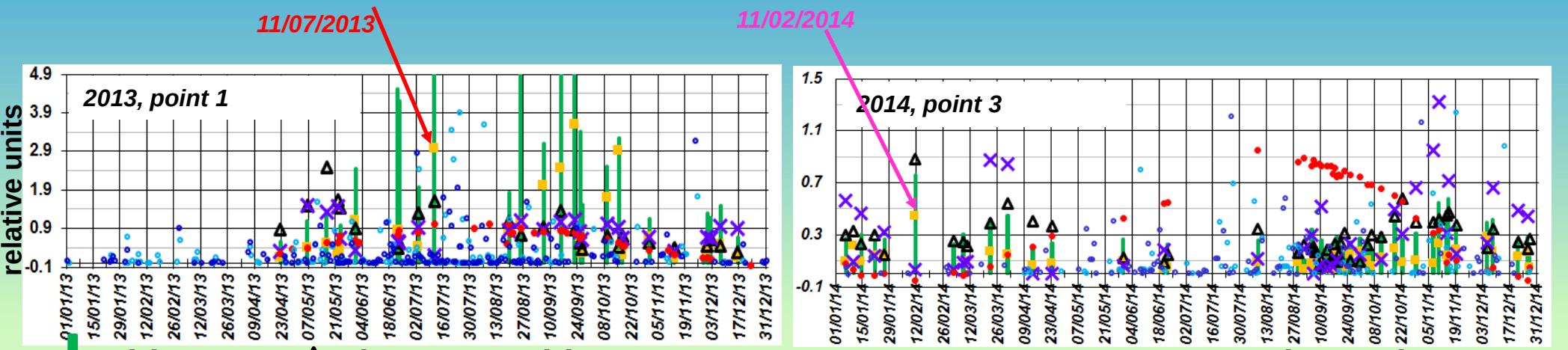
- Chl, - a_{dg} , Δ - b_{bp} , × - Fchl, ● - SST, ○ - Q_{ap} (HMS "Vladivostok"), ○ - Q_{ap} (TRMM)

Coefficients of recalculation for *Chl* is 3 mg/m³, a_{dg} is 0.5 m^{-1}, b_{bp} is 0.05 m^{-1}, *Fchl* is 0.03 mW /(cm^2 × μm × sr), *SST* is 25ºC, Q_{ap} is 20 mm/day at points 1, 2, and 50 mm/day at points 3.

Features of seasonal course of the phytoplankton bloom (Chl, Fchl), organic and suspended matter (a_{dg} , b_{bp}) contents indicators in Amur Bay and near the Furungelma Island

Increase of the organic matter content indicator (a_{dg})

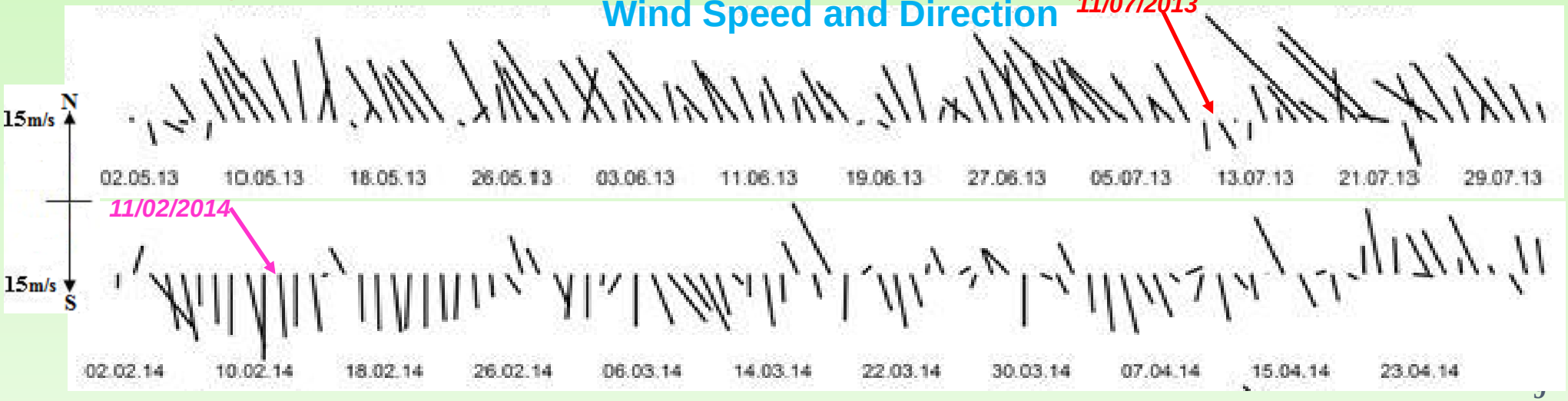
because of influence of northern winds from about 3-7 m/s depending on the depth of the water layer having an increased content of organic matter



- Chl, - a_{dg} , - b_{bp} , - Fchl, - SST, - Q_{ap} (HMS "Vladivostok"), - Q_{ap} (TRMM)

Coefficients of recalculation for *Chl is 3 mg/m³* , *a_{dg} is 0.5 m^{-1}*, *b_{bp} is 0.05 m^{-1}*, *Fchl is 0.03 mW /(cm² × μm × sr)*, *SST is 25ºC*, *Q_{ap}* is 20 mm/day at points 1, 2, and 50 mm/day at points 3.

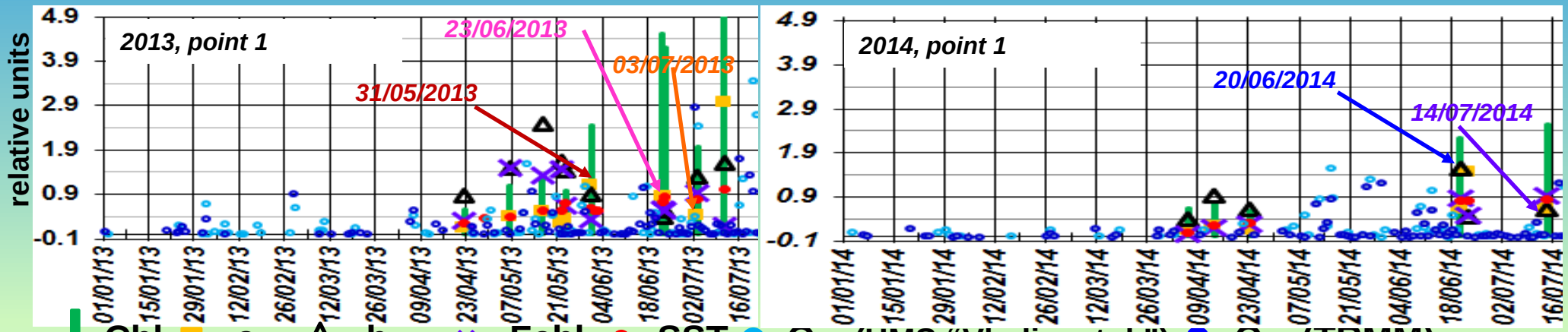
Wind Speed and Direction



Features of seasonal course of the phytoplankton bloom(Chl, Fchl), organic and suspended matter (a_{dg} , b_{bp}) contents indicators in point 1

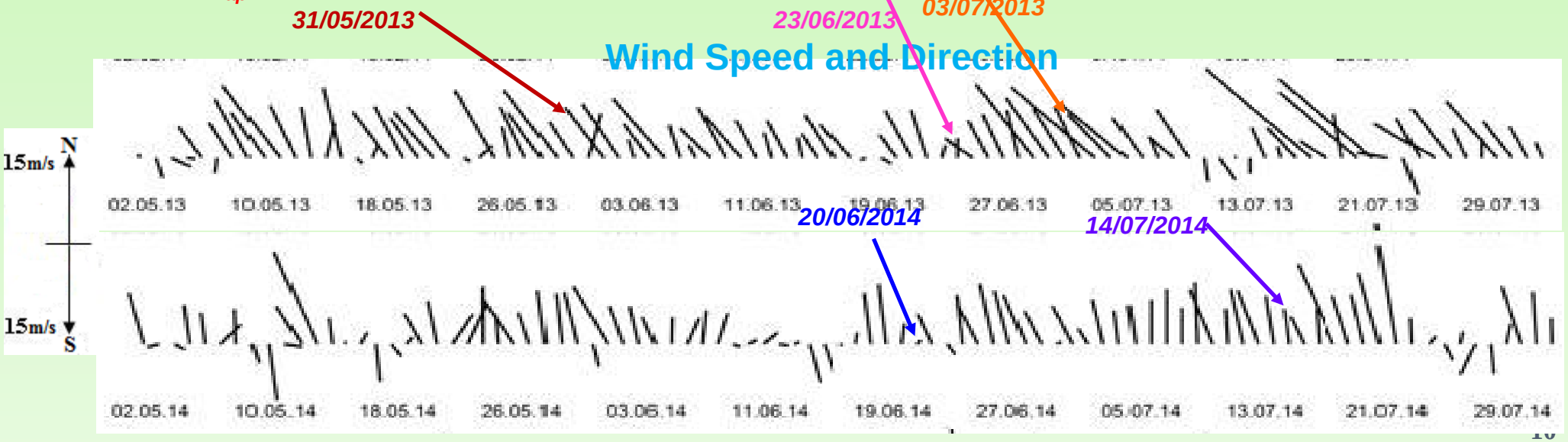
Increase of the organic matter content indicator (a_{dg})

after long-term winds of southern directions from about 5-7 m/s depending on the runoff of the Razdolnaya River



- Chl, - a_{dg} , Δ - b_{bp} , × - Fchl, ● - SST, ○ - Q_{ap} (HMS "Vladivostok"), ○ - Q_{ap} (TRMM)

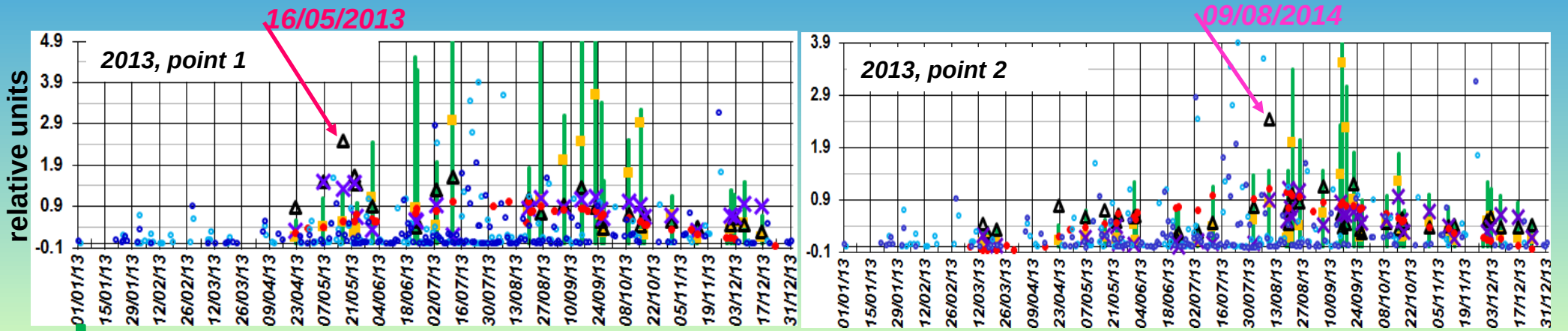
Coefficients of recalculation for *Chl is 3 mg/m³* , *a_{dg} is 0.5 m^{-1}*, *b_{bp} is 0.05 m^{-1}*, *Fchl is 0.03 mW /(cm² × μm × sr)*, *SST is 25ºC*, *Q_{ap}* is 20 mm/day at points 1, 2, and 50 mm/day at points 3.



Features of seasonal course of the phytoplankton bloom (Chl, Fchl), organic and suspended matter (a_{dg} , b_{bp}) contents indicators in points 1, 2 (Amur Bay)

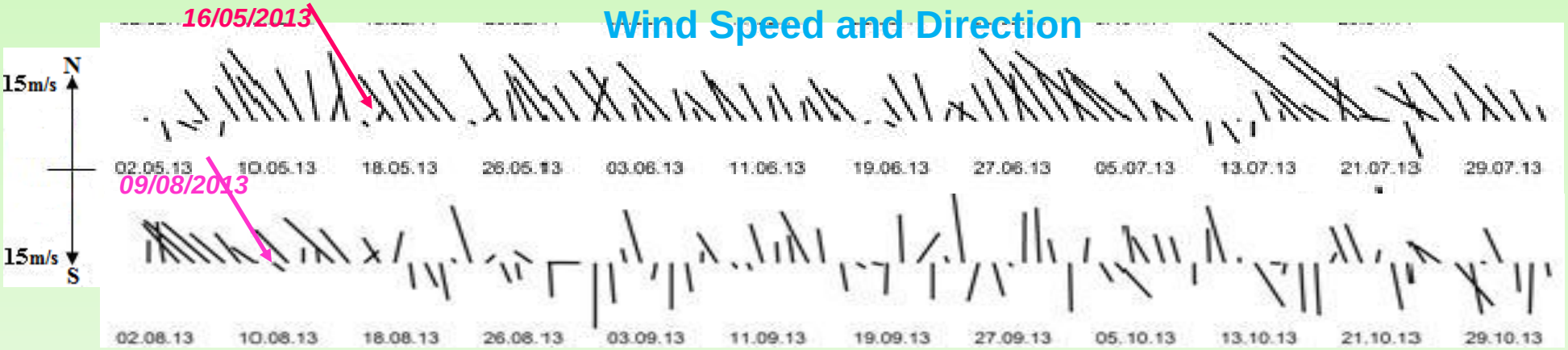
Maximum of the suspended matter content indicator (b_{bp})

at continental runoff (during spring flood on Razdolnaya River; runoff from eastern coast of the Amur Bay on the 9-th of August 2013)



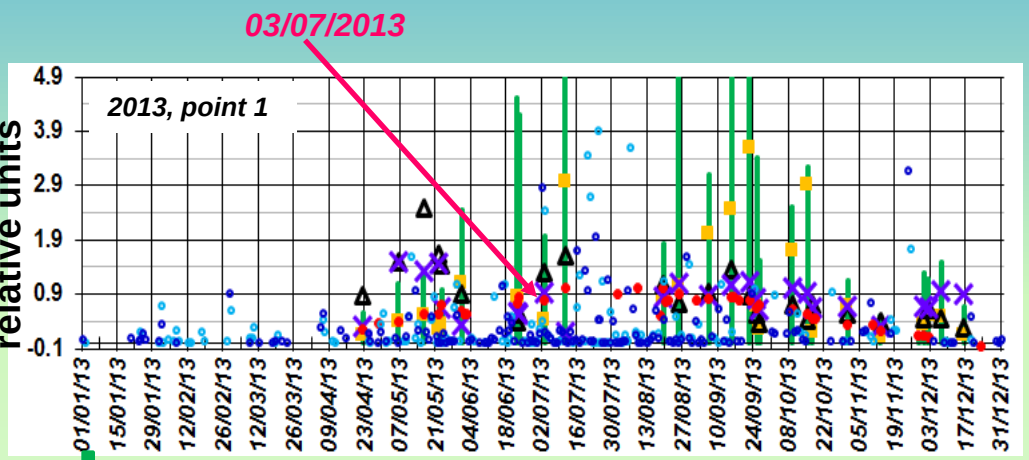
- Chl, - a_{dg} , Δ - b_{bp} , × - Fchl, ● - SST, ⊙ - Q_{ap} (HMS "Vladivostok"), ⊙ - Q_{ap} (TRMM)

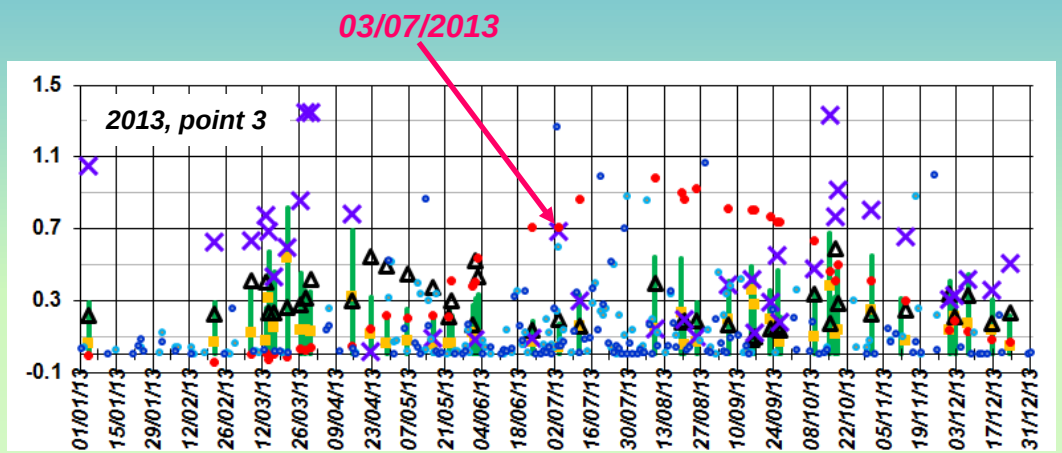
Coefficients of recalculation for *Chl is 3 mg/m³* , *a_{dg} is 0.5 m^{-1}*, *b_{bp} is 0.05 m^{-1}*, *Fchl is 0.03 mW /(cm² × μm × sr)*, *SST is 25ºC*, *Q_{ap}* is 20 mm/day at points 1, 2, and 50 mm/day at points 3.



Features of seasonal course of the phytoplankton bloom (Chl, Fchl), organic and suspended matter (a_{dg}, b_{bp}) contents indicators in Amur Bay and near the Furungelma Island

Increase of Fchl parameter during the summer phytoplankton development minimum due to the influence of runoff from the Razdolnaya River and the Tumannaya River after a large quantity of precipitation (about 50 mm/day) and at that strong south-eastern wind (about 10 m/s) in area near the Furungelma Island.



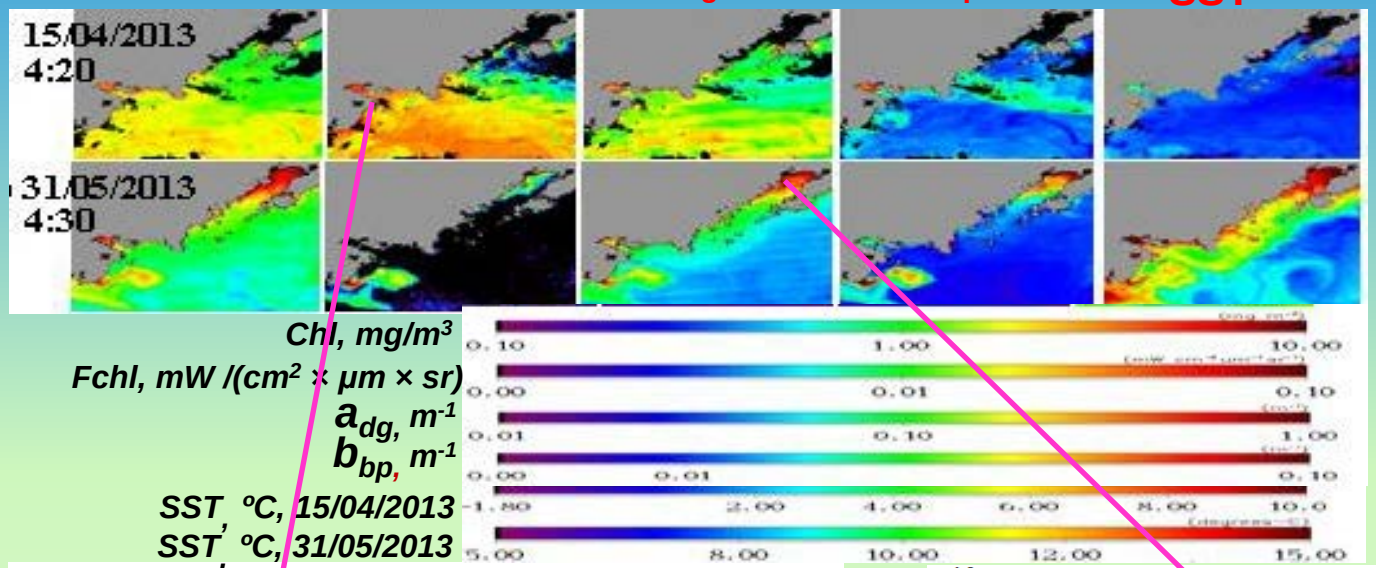


- Chl, - a_{dg} , Δ - b_{bp} , × - Fchl, ● - SST, ○ - Q_{ap} (HMS "Vladivostok"), ○ - Q_{ap} (TRMM)

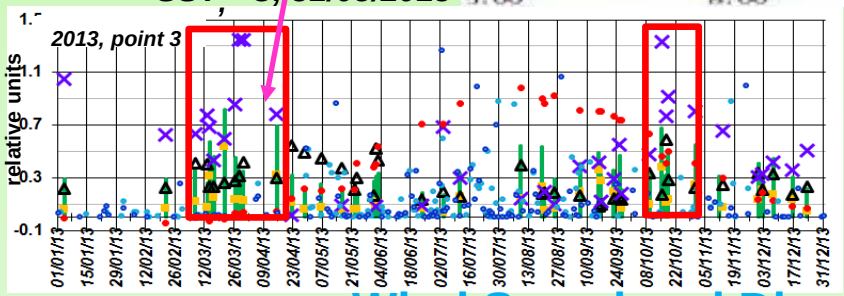
Coefficients of recalculation for *Chl is 3 mg/m³* , *a_{dg} is 0.5 m^{-1}*, *b_{bp} is 0.05 m^{-1}*, *Fchl is 0.03 mW /(cm^2 × μm × sr)*, *SST is 25°C*, *Q_{ap}* is 20 mm/day at points 1, 2, and 50 mm/day at points 3.

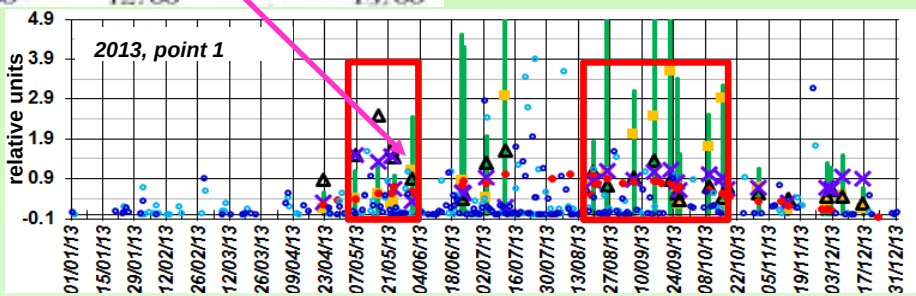
Situations contributing the water hypoxia formation in the Amur Bay and area toward south-western from the Furungelma Island

Spring phytoplankton bloom at the stable formation of water layer stratification, the decrease of exchange processes between the surface and the bottom; phytoplankton bloom because of the spring flood on Razdolnaya River



Distributions of the Chl, Fchl, a_{dg} , b_{bp} , SST parameters reflecting situations that contribute the near-bottom water hypoxia formation (according to MODIS-Aqua data). Time of the satellite information receipt is indicated by Greenwich Mean Time. Black color means that the data are absent.

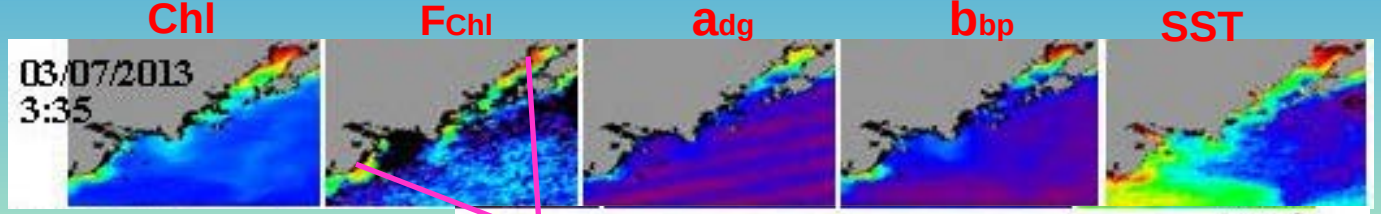




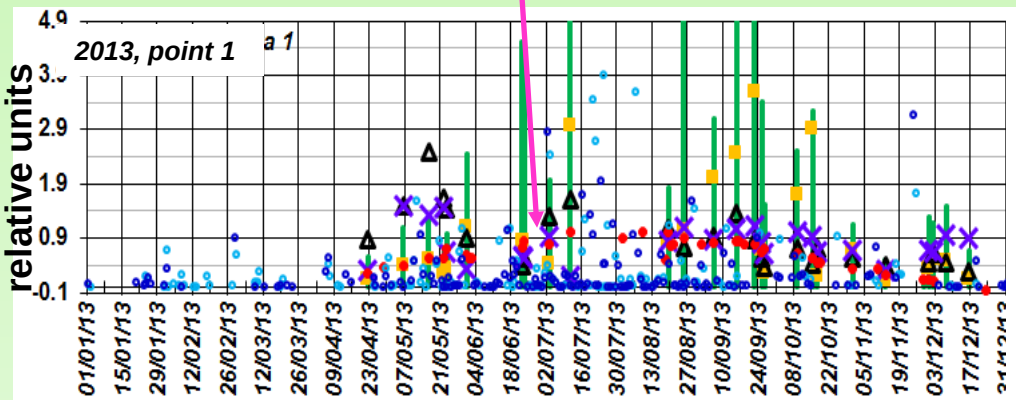
Wind Speed and Direction

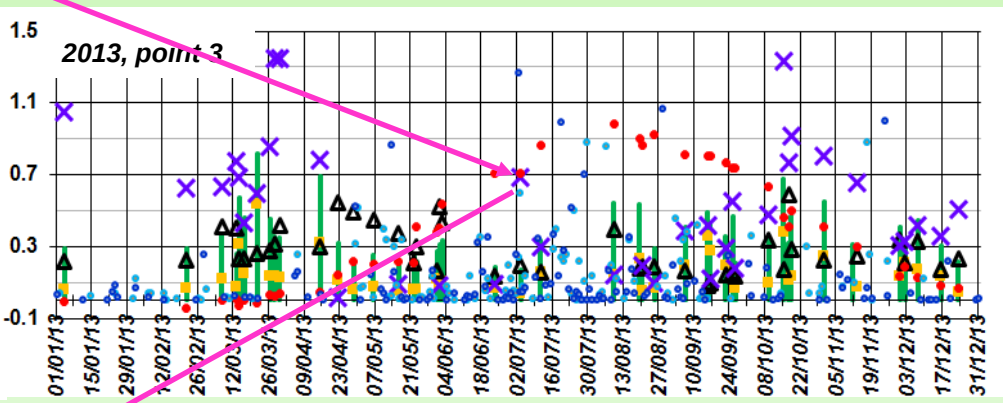
Situations contributing the water hypoxia formation in the Amur Bay and area toward south-western from the Furungelma Island

In Amur Bay and area near the Furungelma Island continental runoff after a significant quantity of atmospheric precipitation (about 50 mm/day) and at that strong south-eastern wind (about 10 m/s) in area near the Furungelma Island.



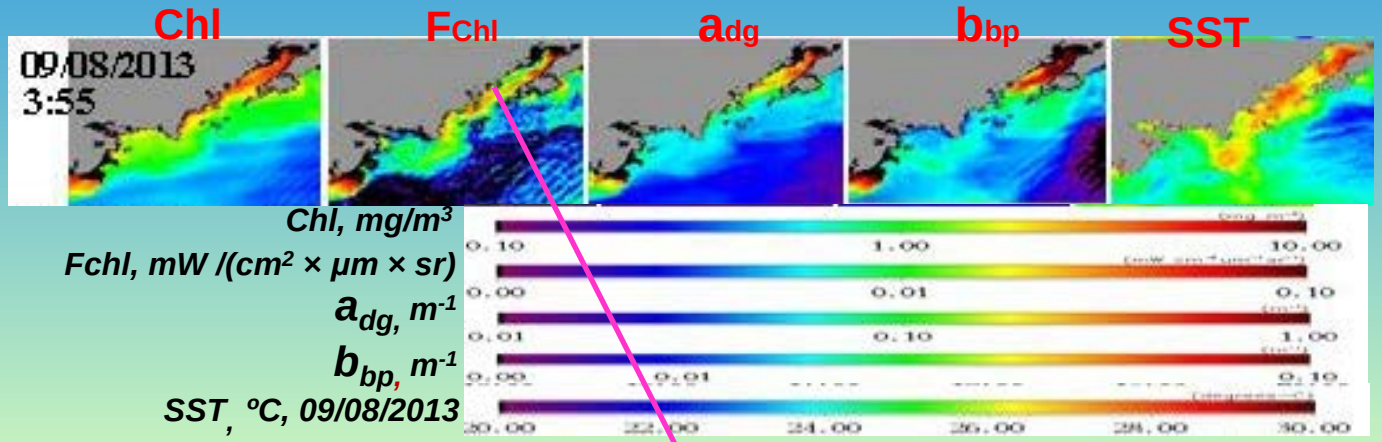
Distributions of the Chl, Fchl, a_{dg} , b_{bp} , SST parameters reflecting situations that contribute the near-bottom water hypoxia formation (according to MODIS-Aqua data). Time of the satellite information receipt is indicated by Greenwich Mean Time. Black color means that the data are absent.



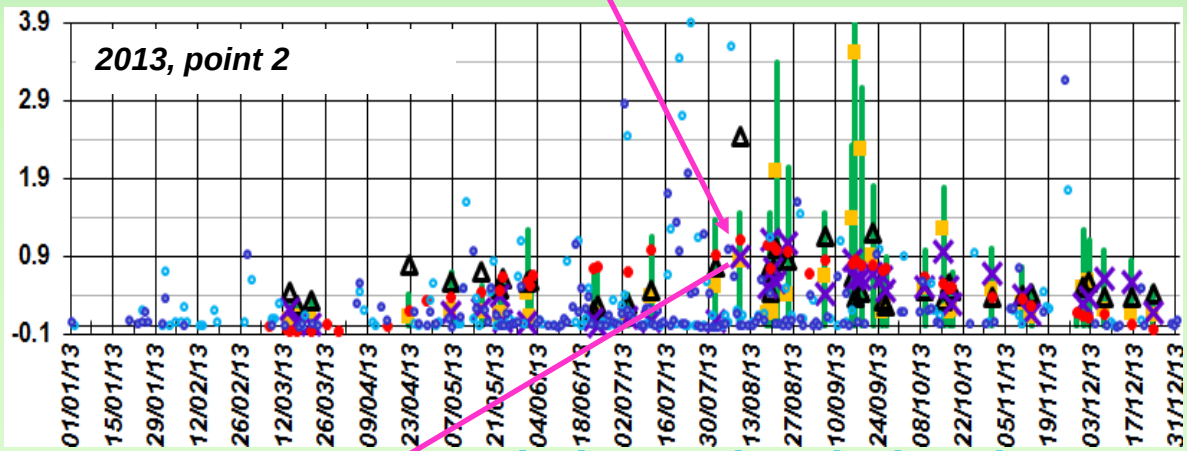


Situations contributing the water hypoxia formation in the Amur Bay and area toward south-western from the Furungelma Island

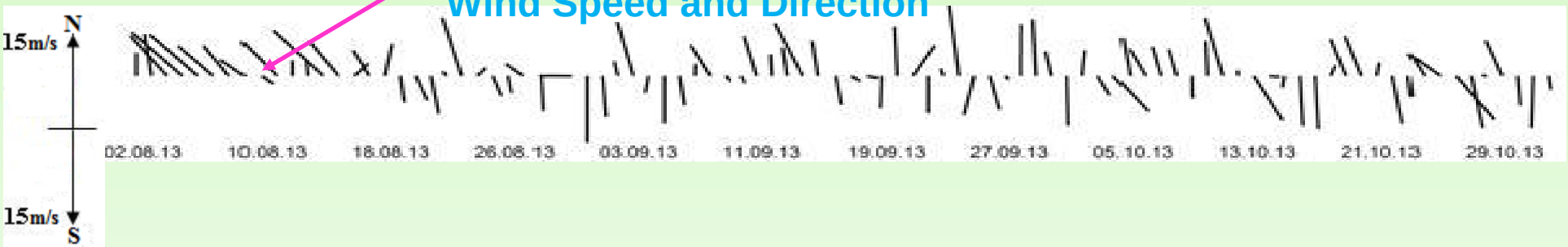
Continental runoff at the overflow of reservoirs located on the Sedanka and Bogataya Rivers after the accumulation of a large quantity of precipitation



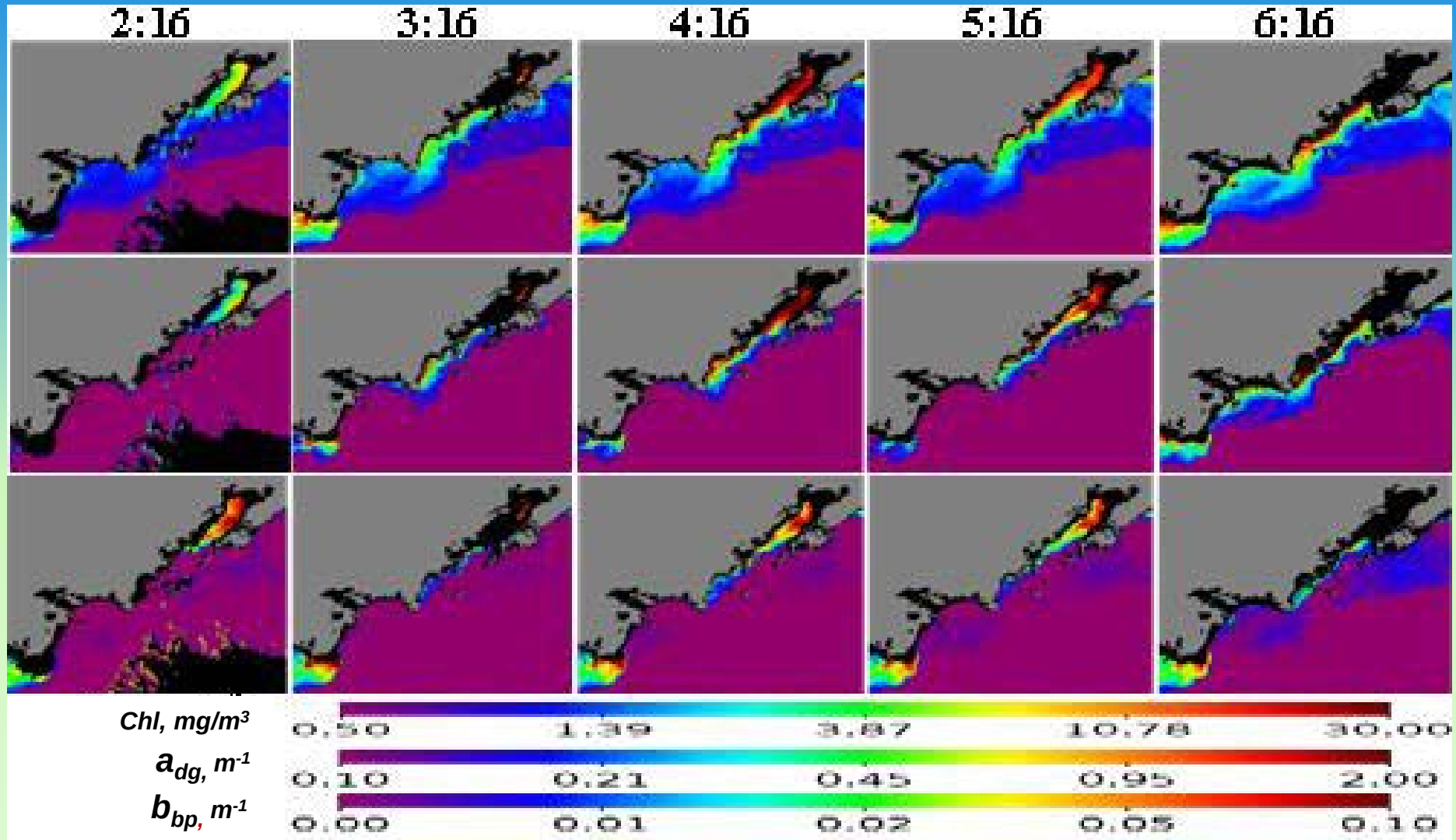
Distributions of the Chl, Fchl, a_{dg} , b_{bp}, SST parameters reflecting situations that contribute the near-bottom water hypoxia formation (according to MODIS-Aqua data). Time of the satellite information receipt is indicated by Greenwich Mean Time. Black color means that the data are absent.



Wind Speed and Direction



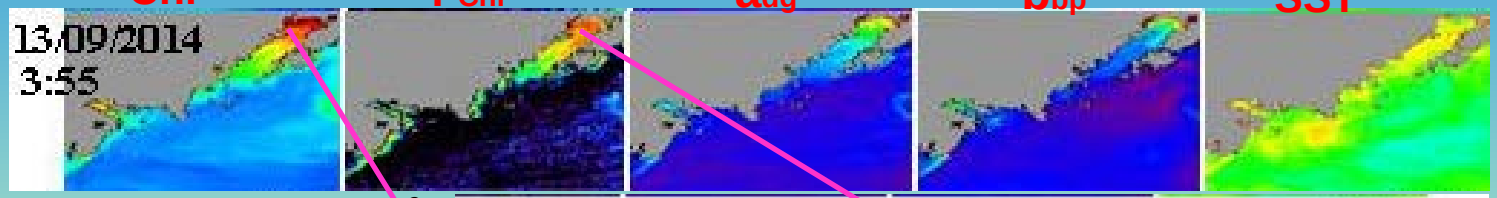
Diurnal distributions of the water color characteristics



The Chl, a_{dg} , b_{bp} parameters distribution reflecting the water flow spreading from the east to the west coast of the Amur Bay and further toward south from the Gamow Cape on the 9-th of August 2013 (according to GOCI-COMS data). Time of the satellite information receipt is indicated by Greenwich Mean Time. Black color means that the data are absent.

Situations contributing the water hypoxia formation in the Amur Bay and area toward south-western from the Furungelma Island

Single cases of the northern wind leading to the water mixing in the summer, which lead to move of nutrients in the surface layers together with water flows;
the early of the autumn phytoplankton development



Chl, mg/m^3

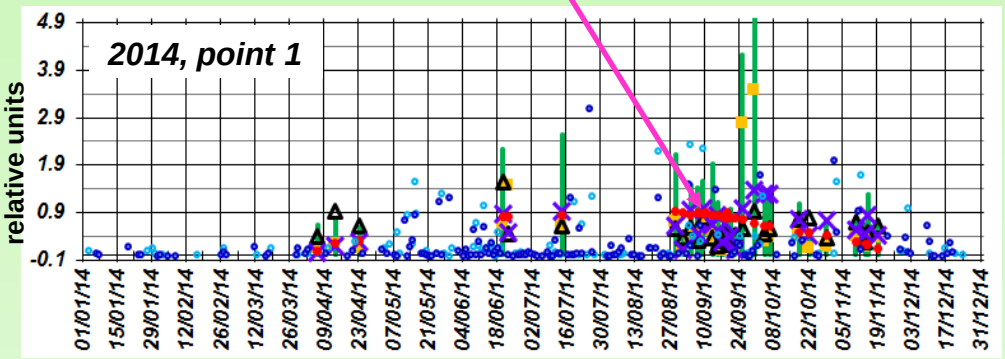
Fchl, mW /(cm^2 × μm × sr)

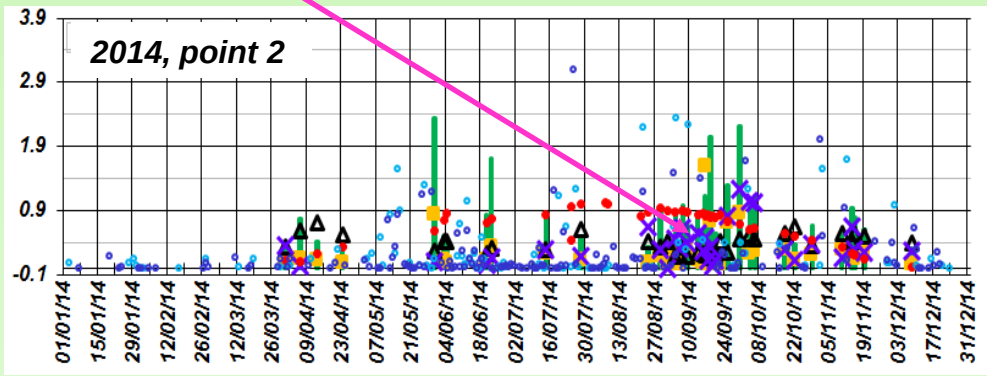
a_{dg}, m^{-1}

b_{bp}, m^{-1}

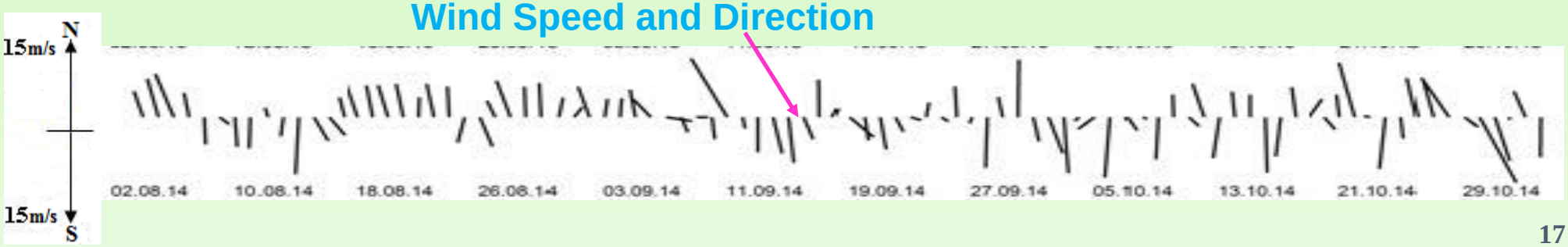
SST, ºC, 13/09/2014

Distributions of the Chl, Fchl, adg , bbp , SST parameters reflecting situations that contribute the near-bottom water hypoxia formation (according to MODIS-Aqua data). Time of the satellite information receipt is indicated by Greenwich Mean Time. Black color means that the data are absent.





Wind Speed and Direction



Conclusions

Features of time course on the water color characteristics

- **Features of spring and autumn phytoplankton bloom in Amur Bay and area near the Furungelma Island were determined according to chlorophyll-a fluorescence and concentration (Fchl, Chl).**

- **Increase of the organic matter content indicator (a_{dg}) is due to the accumulation of phytoplankton vital activity products during its bloom, at and after northern winds from about 3-7 m/s depending on the depth location of the water layer having an increased organic matter content, after long-term winds of southern directions from about 5-7 m/s depending on the runoff of the Razdolnaya River.**

- **Maximum of the suspended matter content indicator (b_{bp}) occurs at continental runoff (during spring flood on Razdolnaya River; runoff from eastern coast of the Amur Bay)**

- **Increase of Fchl parameter during the summer phytoplankton development minimum is due to the influence of runoff from the Razdolnaya River in Amur Bay and the Tumannaya River after a large quantity precipitation (about 50 mm/day), and at that strong south-eastern wind (about 10 m/s) in area near the Furungelma Island.**

Conclusions

Situations contributing the water hypoxia formation in the Amur Bay and area toward south-western from the Furungelma Island

- Spring phytoplankton bloom at the stable formation of water layer stratification, the decrease of exchange processes between the surface and the bottom; phytoplankton bloom because of the spring flood on Razdolnaya River.

- Continental runoff after a significant quantity of atmospheric precipitation (about 50 mm/day) and at that in area near the Furungelma Island at strong south-eastern wind (about 10 m/s).

- Continental runoff at the overflow of reservoirs located on the Sedanka and Bogataya Rivers after the accumulation of a large quantity of atmospheric precipitation.

- Single cases of the northern wind leading to the water mixing in the summer, which lead to move of nutrients into the surface layers together with water flows;
the beginning of the autumn phytoplankton development.

Thank you for attention