The spatial dimension of the environmental problems existing in coastal zone due to land-sea interactions

Vladimir Shulkin

Pacific Geographical Institute, FEBRAS,
Vladivostok 690041, Radio 7, Russia. E-mail:
shulkin@tig.dvo.ru

Aim of presentation

- To propose simple biogeochemical indicators for the assessment of the size characteristics of coastal areas which depend on the matter fluxes from the land

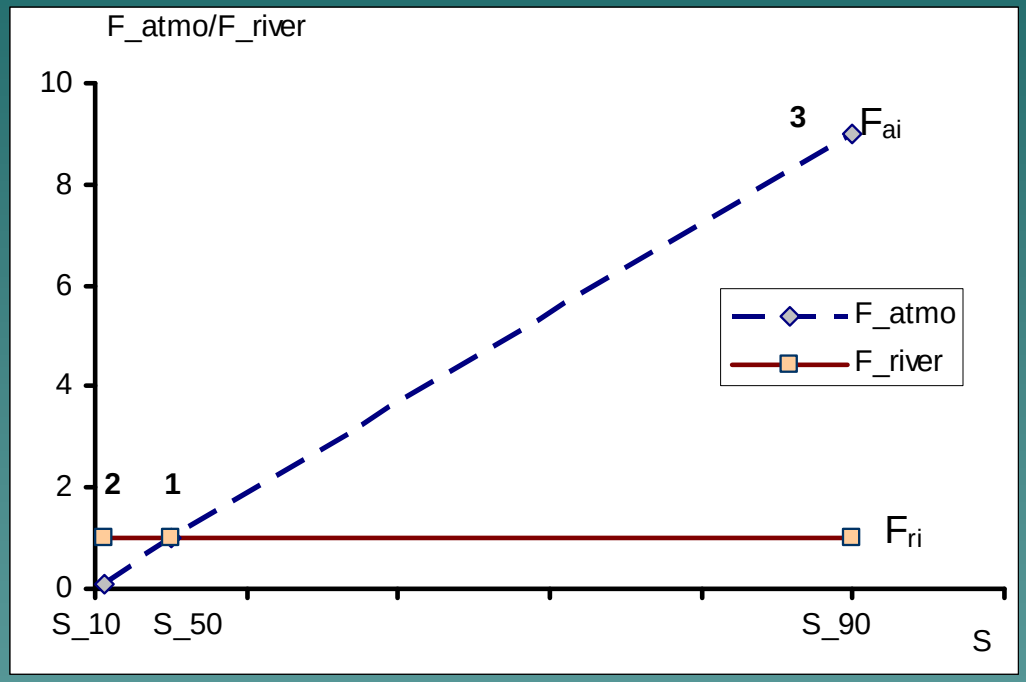
Outline

- Introduction – the significance of spatial aspects at the land-sea interaction.
- The spatial aspect at the assessment of the relative contribution of river runoff and atmospheric deposition as inputs to the coastal areas.
- The evaluation of the coastal areas size where observed phytoplankton production could be provided by the river runoff.
- The evaluation of the coastal area size where observed river runoff could led to the eutrophication.
- The assessment of some features of Fe behavior in the Amur River estuary (Amurskyi Liman) and Sakhalin Bay. **(in collaboration with I.A.Zhabin, POI FEBRAS)**

Introduction

- The proper determination of spatial scales of land-sea interaction is crucial for the understanding of the links between watersheds, rivers, estuaries and coastal ecosystems.
- The criteria are needed for the selection of coastal waters with varying degrees of land-sea interaction, and for the evaluation of the spatial extent (size) of these areas.
- The spatial features are very site specific, and it restricts the use of existing advanced models elaborated for some coastal areas as universal.
- There is possibility to use some simple algorithms as alternative indicators evaluating the size and characteristics of coastal areas under the dominating influence of natural and anthropogenic processes at the catchments and estuaries.

The assessment of the contribution of river and atmospheric inputs of nutrients and trace metals to the coastal areas of different size.



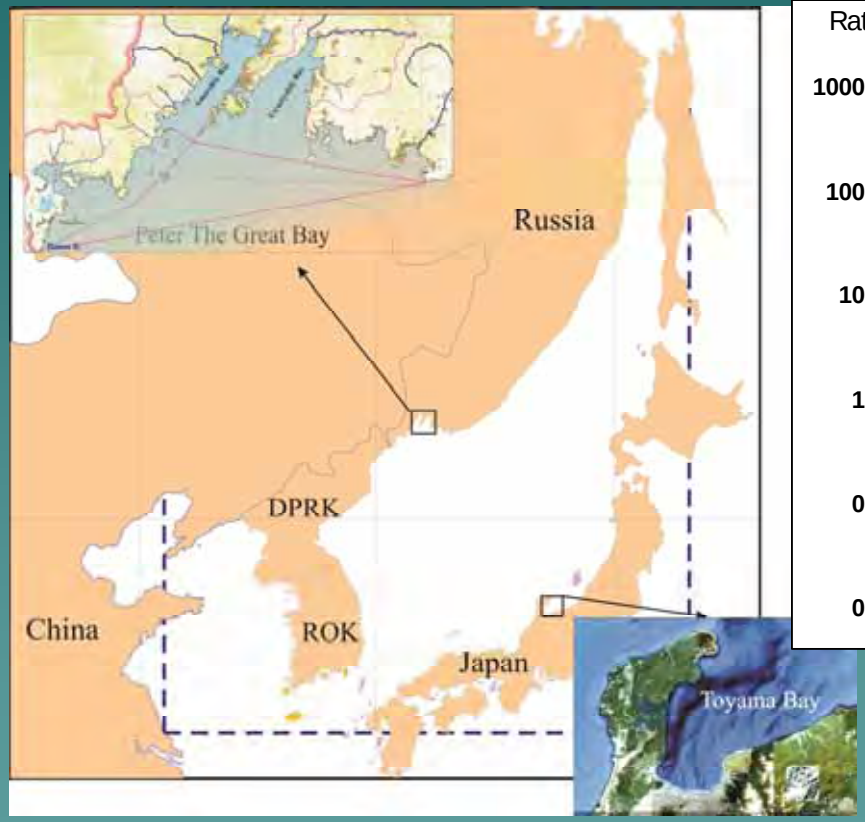
- Point (1) corresponds to a situation where river runoff is equal to the atmospheric input, the point (2) when air supply is 10% of the total, i.e. river input is dominated, and the point (3) when the supply of air is 90% of the total input.

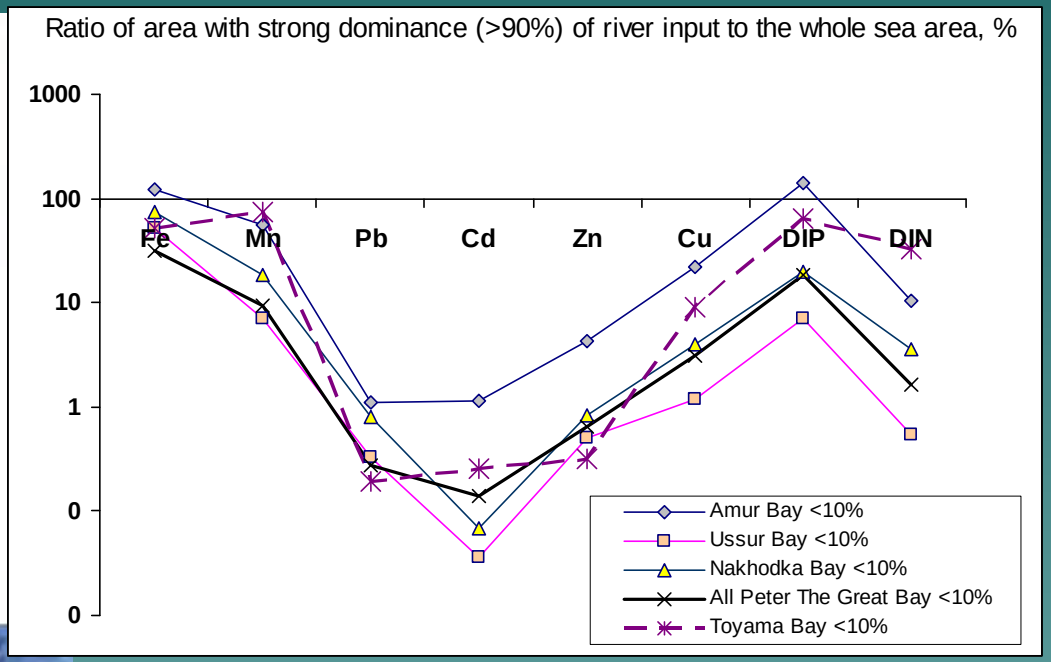
Accordingly, we can calculate the area of coastal waters, where such a relationship should be observed by the simple formulas

$$S\_{50} = F_{Ri}/f_{Ai};$$
$$S\_{10} = F_{Ri}/9f_{A};$$
$$S\_{90} = F_{Ri}/0.1f_{Ai}$$

- Comparison of calculation with the actual size of water bodies can help to suggest more reliable hypotheses about the sources of different substances, including pollutants, to zoning of coastal waters, and to evaluate the effectiveness of measures to improve ecosystem quality.

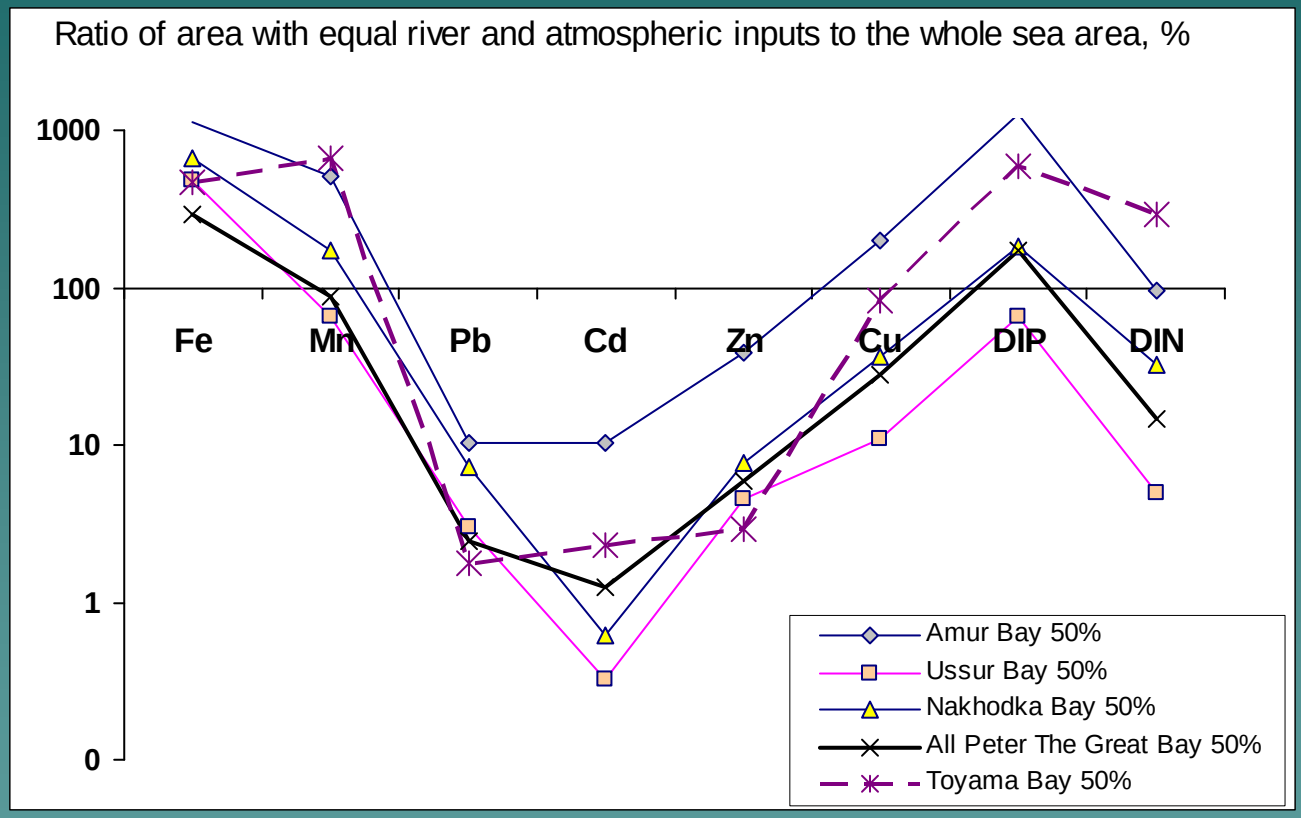
Such calculation was performed for parts of Peter the Great Bay – Amurskyi Bay (area 997 km2), the Ussuriskyi Bay (area 1889 km2) of bays, the Gulf of Nakhodka (921 km2) and Peter the Great Bay as a whole (area 9088 km2), as well as for the Toyama Bay (area 3460 km^2) on the west coast o.Honsyu (Japan).





- River runoff from NOWPAP POMRAC Technical Reports #4, 2006, # 7, 2009, Shulkin et al., 2007;
- Atmospheric deposition intensity from Mishukov et al., 2004, Yoshioka et al., 2009, Sakata & Asakura, 2009

Thus, in all coastal areas the dominance of river input is most pronounced for Fe, Mn, P, followed by dissolved forms of Cu and N, and minimum river input is in the land based supply of Zn, Pb, Cd.



- To estimate the size of the sea areas with equal river and atmospheric inputs is also useful. It is necessary to consider both sources: riverine and atmospheric in these areas

Conclusions on riverine/atmospheric inputs

- For all studied coastal areas contribution of river runoff is maximum for dissolved Fe, Mn, and P, followed by dissolved forms of Cu and N, and minimum river input is in balance of the Zn, Pb, Cd supply from the land-based sources.

- The ratio of river input and atmospheric deposition varies greatly between different parts of the coastal waters as a function of river runoff, precipitation intensity and size of the area considered that allows to use index $S=F_{ri}/f_{Ai}$ and its derivatives as classification indicators.

- As an indicator of the size of the area with strong dominance of river input the index $S= F_{ri}/9f_{Ai}$ is proposed

The evaluation of the coastal areas size (S) where observed phytoplankton production (PP) could be provided by the river runoff (C_i*Q) as indicator of provision of coastal ecosystem by riverine nutrients.

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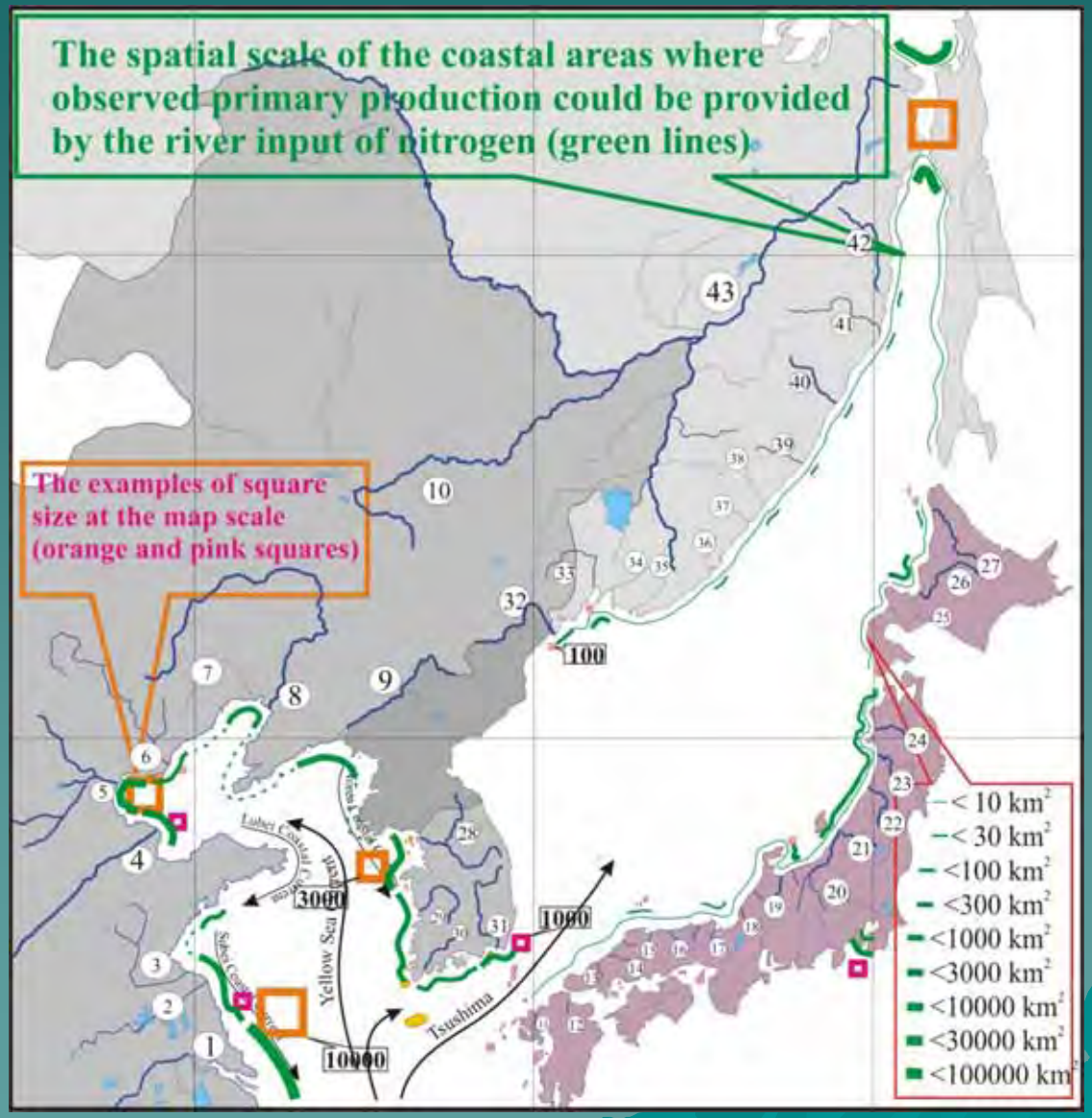
- **$S = C_i * Q / PP * KR$**

- P_i [g/m^2.day] = PP * KR – the rate of uptake of nutrients (N, P, Si) at the plankton biomass production (PP) in according with Redfield ratio (KR);
- S – sea area [m^2];
- C_i [g/m^3] – concentration of the nutrient
- in the river discharge Q [m^3/day]

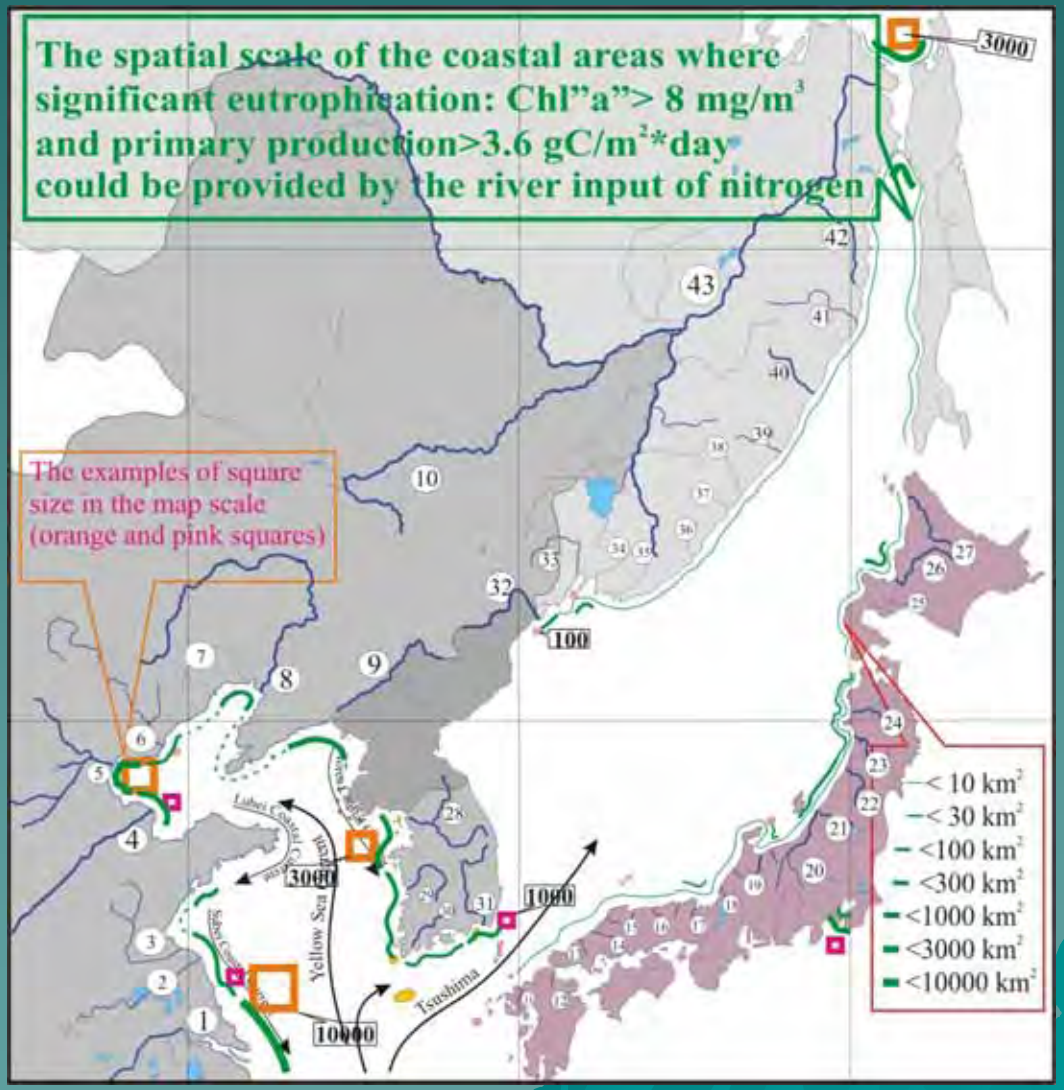
Plankton production (gC/m^2.day) of the coastal areas within NW Pacific

Area	Plankton production	Reference
Jiaozhou Bay	0.44±0.04	Liu et al., 2007
Yellow Sea	0.8-1.5-2.8	UNDP/GEF, 2007, Hama et al., 1997
Toyama Bay	1.0	
Korean coastal waters	0.53-0.89	Son et al., 2005, UNDP/GEF, 2007
Russia, Peter The Great Bay	0.6-3.0-6.0	Zvalinsky et al., 2008
Russia, Sea of Japan, northwest coast	0.5-1.0	Zvalinsky et al., 2008

The size of coastal areas where phytoplankton production could be provided by “riverine” nitrogen



The evaluation of the coastal area size where observed river runoff could led to the eutrophic level (> 3.6 gC/m^2.day or > 8 mg Chl "a"/m^3).



The evaluation of the size of the coastal sea areas where existing level of plankton production or eutrophication could be provided by riverine flux of nitrogen is rather rough estimation of the river runoff influence on the adjacent coastal waters.

The main reason is ignoring of oceanographic and/or biological features of specified localities.

- But we assume this measure (indicator) allows looking at and to compare the situation at the regional and sub regional level.

The assessment of some spatial features of Fe behavior in the Amur River estuary (Amurskyi Liman) and Sakhalin Bay (1).

- The elevated level of Fe concentration in the Amur River comparing with other big rivers (3-5 μM vs 1 μM)
- The significant annual runoff (>300 km3)
- The evidences of Amur runoff influence on the coastal waters of eastern side of Sakhalin Is.

The assessment of some spatial features of Fe behavior in the Amur River estuary (Amurskyi Liman) and Sakhalin Bay (2).

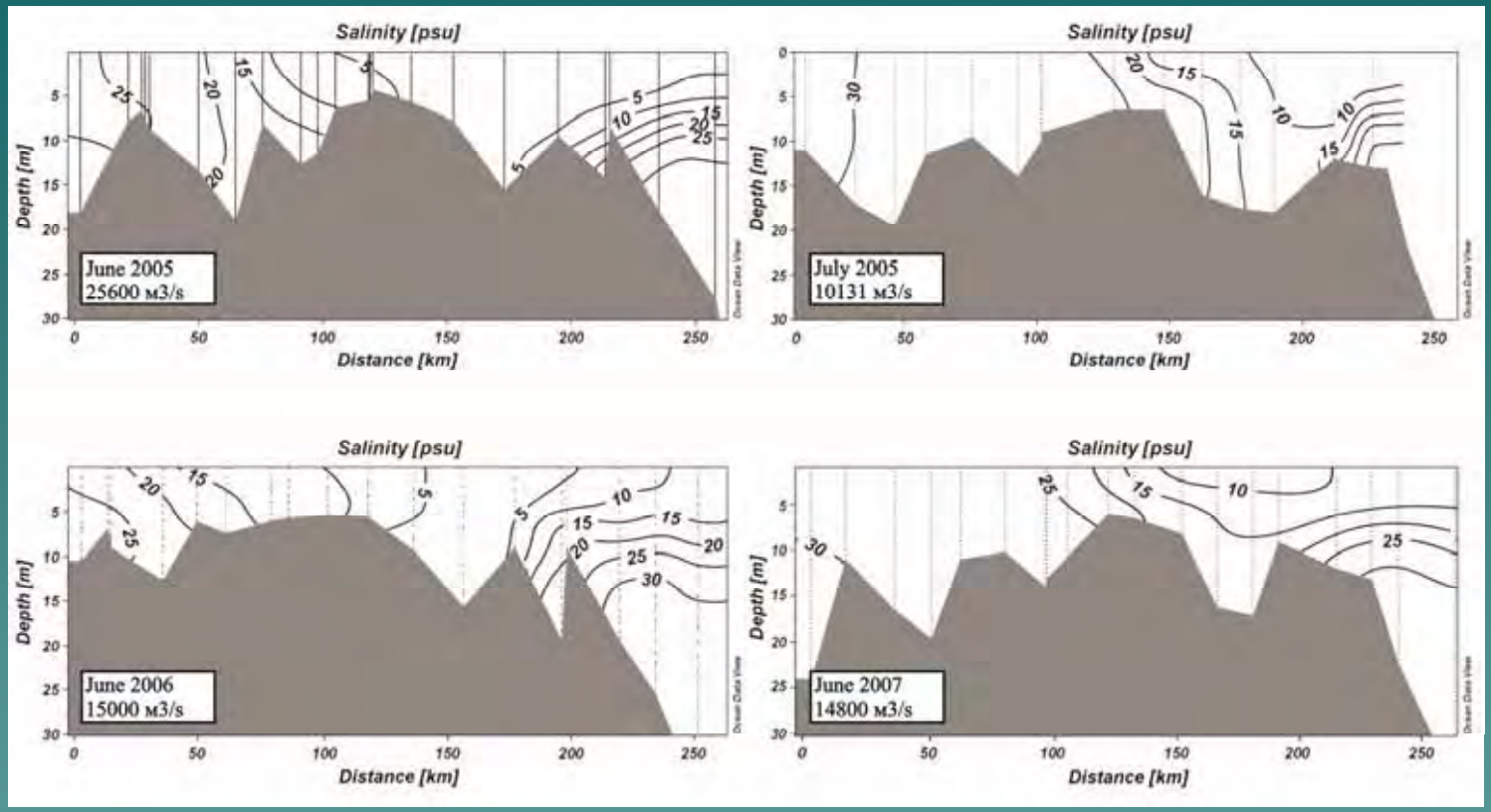
These circumstances have led to the hypothesis of the main contribution of Amur river to the Fe supply within south part of Okhotsk Sea and Oyashio region (e.g. Nishioka et al, 2007)

- During the “Amur-Okhotsk” Project the unique data on the biogeochemistry of Fe in the south part of Okhotsk sea was obsertved and published (Nakatsuka et al., 2010, Nishioka et al., 2011 etc.)
- The contribution of the processes in Amur Liman (Amur River Estuary) was less studied though very important.

The assessment of some spatial features … (3).

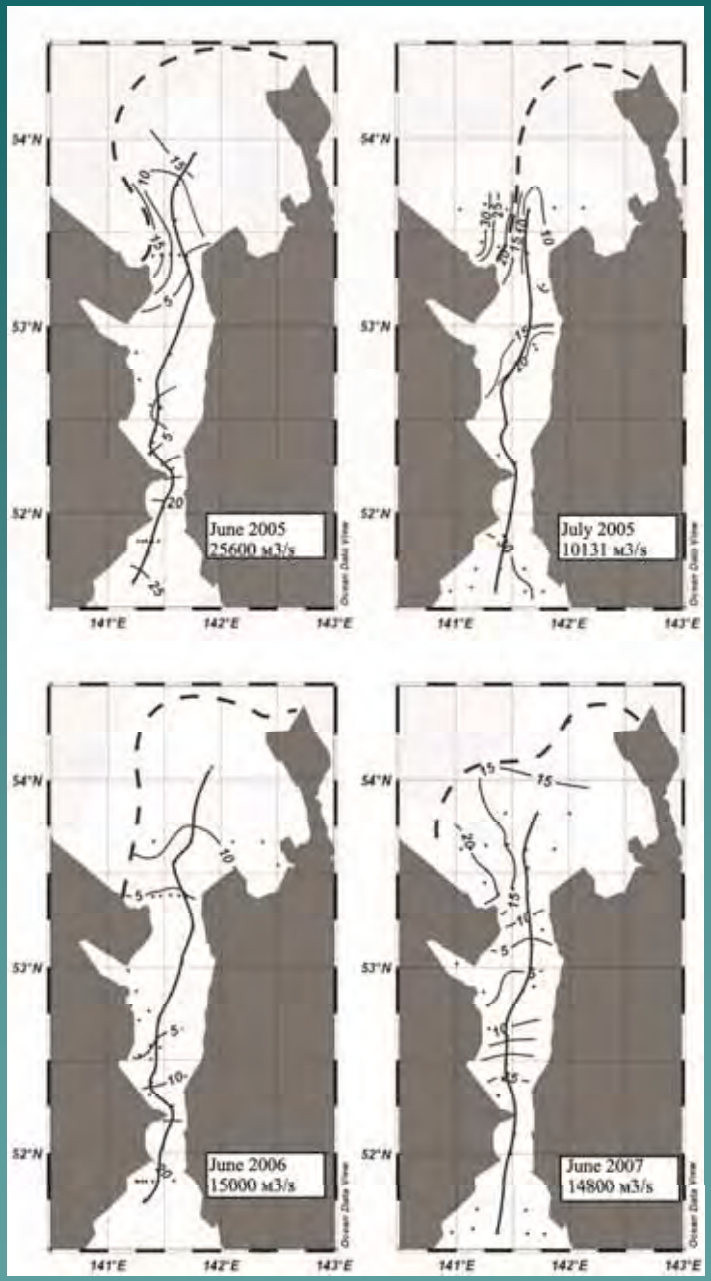
- The covariation of properties is a main indicator of the interdependence of the biogeochemical processes in such related systems as Amur River, estuary Amur Liman and adjacent coastal area Sakhalin Bay
- The salinity distribution and temporal variations are the convenient indicators of the spatial scale of the river runoff influence on the coastal area

The assessment of some spatial features … (4)



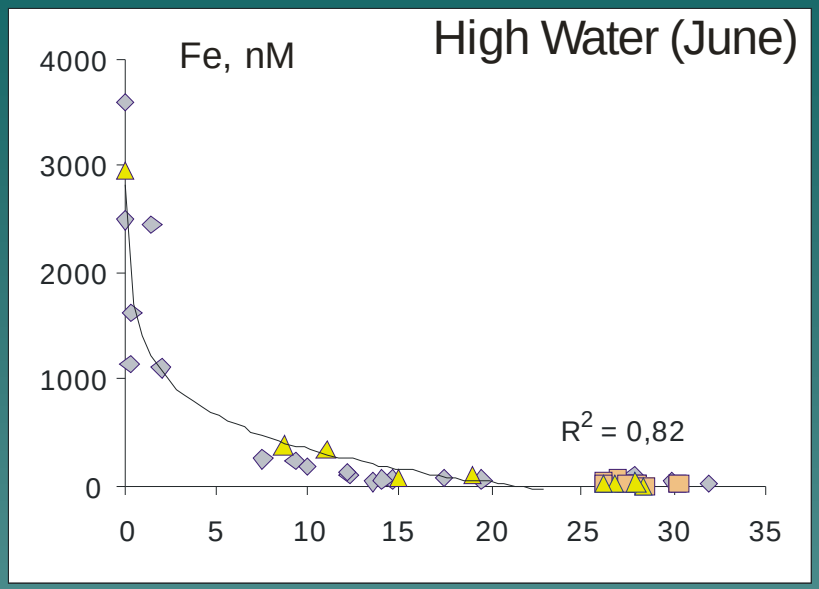
- 4 surveys with the 2.5 times different river discharge
- Stable stratification in the north part of estuary

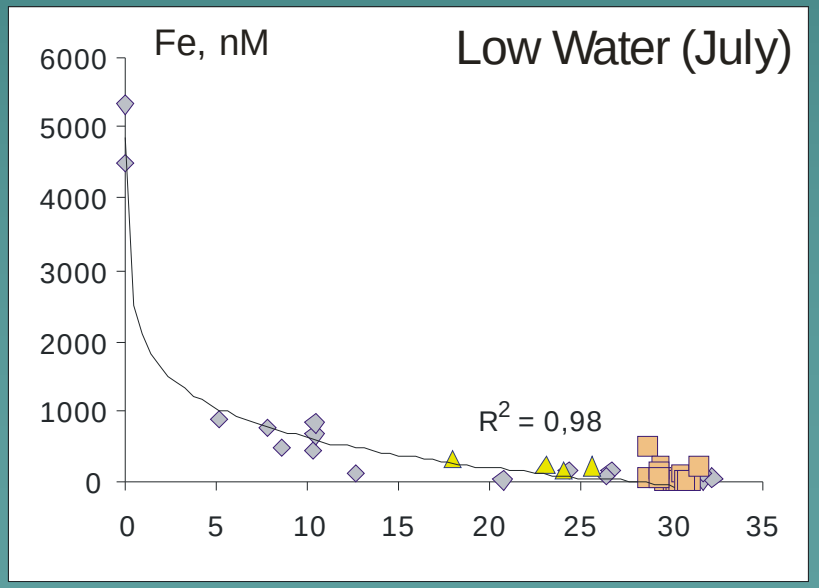
The assessment of some spatial features … (5)



- The lens of coastal waters freshened by the Amur River runoff, is located in the eastern part of Sakhalin Bay and has a salinity of 10-25 ‰ . Its north boundary does not go beyond Sakhalin Bay, despite the significant (up to 2.5 times) variation of river discharge

The assessment of some spatial features … (6)





- **Dissolved Fe distribution in the Amur river estuary– accelerated decrease at the any initial concentration during the first stage of mixing (<5 ‰) due to coagulation of colloids**
- **2 times increase of initial concentration of “dissolved” Fe at low water leads to small increase (60 nM vs 80nM) in the water of intermediate salinity**
- **The rapid removal of Fe from the solution at the initial stages of mixing reduces the effect of variability in river discharge**

The assessment of some spatial features … (8)

- Phytoplankton production (PP) is most obvious key factor
- PP is 0.41-0.82 gC/m^2.day off bloom period (Sorokin & Sorokin, 1999) and 0.8-2.0 gC/m^2.day during bloom (Sorokin & Sorokin, 2002)

	June 2005	July 2005	June 2007
River Discharge, m3/s	26500	10130	15000
Initial Flux of dissolved Fe, g/day	H.O.	$262{,}6*10^6$	$194{,}4*10^6$
Flux of dissolved Fe to Sakhalin Bay, g/day	H.O.	$3{,}5*10^6$	$2{,}6*10^6$
Initial Flux of suspended Fe, g/day	$1832*10^6$	$1400*10^6$	$1037*10^6$
Flux of suspended Fe to Sakhalin Bay, g/day	$550*10^6$	$306*10^6$	$73*10^6$
Fe uptake by phytoplankton (g/day) in the east part of Sakhalin Bay at PP=0.41 gC/m2.day*	$0{,}6*10^6$	$0{,}6*10^6$	$0{,}6*10^6$
Fe uptake at PP= 0,82 gC/m2.day*	$1{,}1*10^6$	$1{,}1*10^6$	$1{,}1*10^6$
Fe biosorption by total plankton (g/day) in the east part of Sakhalin Bay at PP=0.41 gC/m2.day**	$21{,}7*10^6$	$21{,}7*10^6$	$21{,}7*10^6$
Fe biosorption at PP= 0,82 gC/m2.day**	$43{,}6*10^6$	$43{,}6*10^6$	$43{,}6*10^6$

Amur's Conclusions

- Analysis of the distribution of salinity, dissolved and suspended forms of Fe in the Amur estuary and Sakhalin Bay, in combination with an evaluation of Fe uptake by phytoplankton, suggests that the key factors controlling the variability of dissolved Fe in the Sakhalin Bay is a phytoplankton uptake, including sorption to particulate matter, and meteorological conditions;

- Physical processes of precipitation / resuspension of particulate matter and physico-chemical coagulation of river colloids are dominated within Amur Liman itself. Amur runoff is a necessary initial pulse, which supplies Fe in Sakhalin Bay ecosystem;

- Seasonal variations of river discharge are equalized within the vast bay area due to phytoplankton activity.

Concluding Remarks:

- The size of the marine waters, which is influenced by processes at the land, is one of the key factors in the investigation of "land-sea interaction".

- To estimate the size of such water bodies the simple indicators are proposed. These indicators are based on the characteristics of river runoff, atmospheric precipitation intensity, plankton production of coastal waters, and the coincidence of the variations of the runoff from the land with the variations of parameters in coastal waters.

- Such indicators are particularly suitable for regional and subregional assessments in addition to sophisticated mathematical models that describe the balance of matter and biogeochemical processes in specific sea areas.