2nd International Symposium Effect of Climate Change on the World's Oceans,
May 17, 2012, Yeosu, Korea

Seasonal hypoxia of the Amurskiy Bay (Japan/East Sea)

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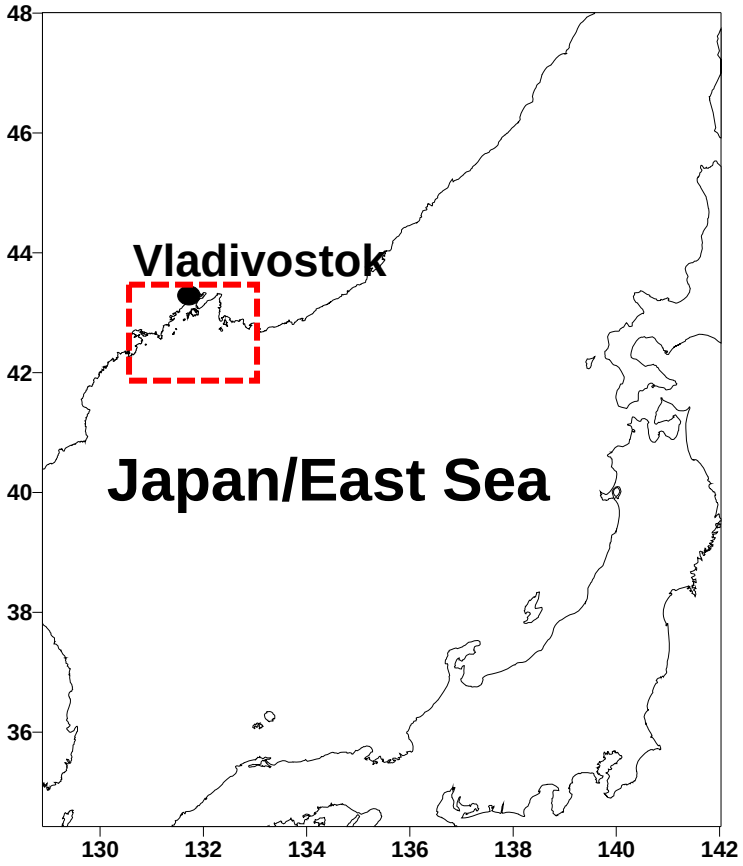
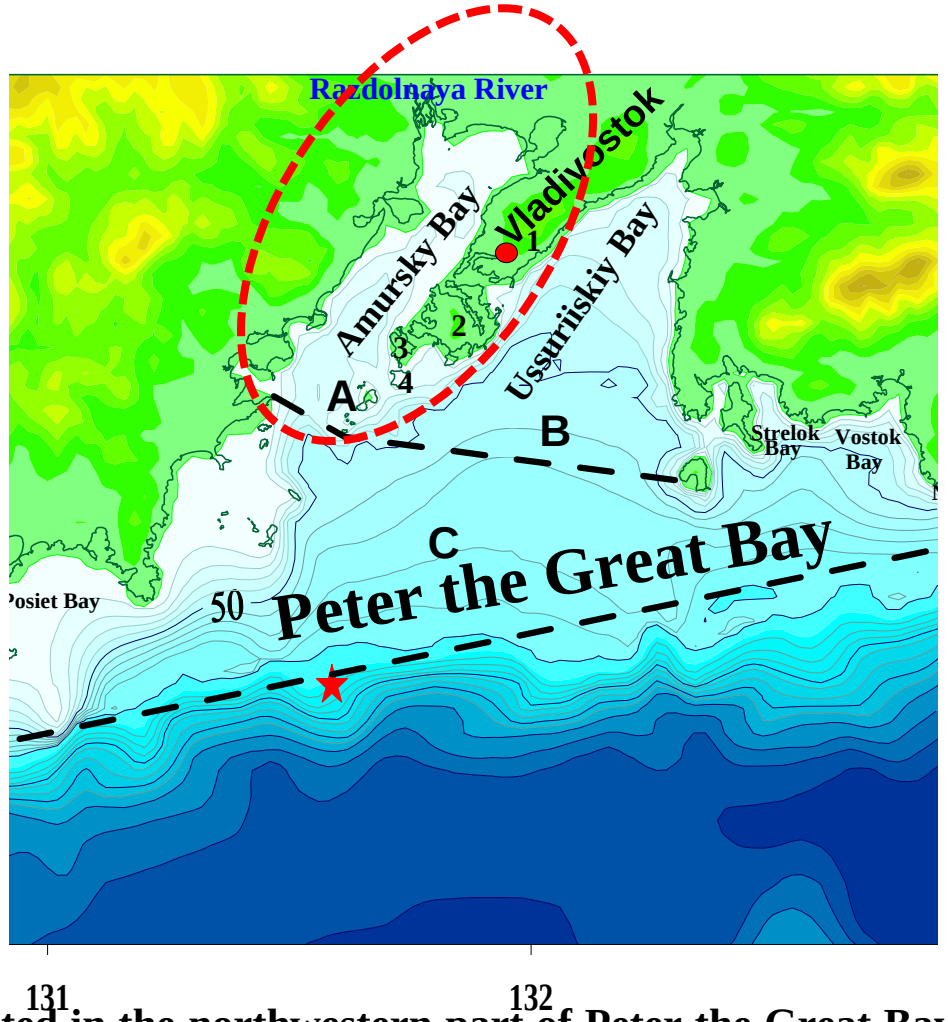
Study area: Amurskiy Bay - part of Peter the Great Bay, the Japan/East Sea





<u>Amurskiy Bay</u> is semiclosed basin. It is located in the northwestern part of Peter the Great Bay. Its length is about 70 km and depth varies from 0 up to 53 m (average depth is about 15 m). Square of the bay is about 1000 km^2. Annual river-runoff is 2.5 km^3. Population around Amurskiy Bay is 300,000. Northern part of the Bay is covered by ice in winter time.

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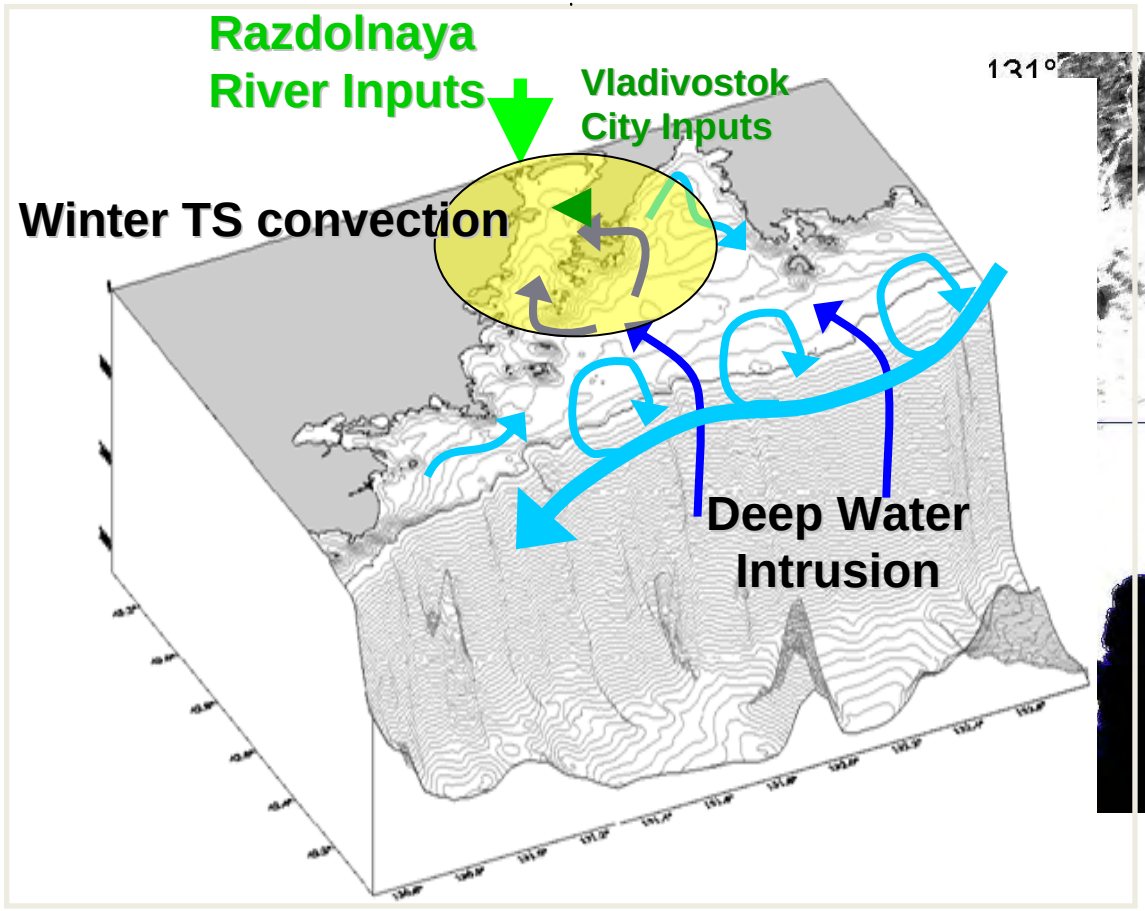

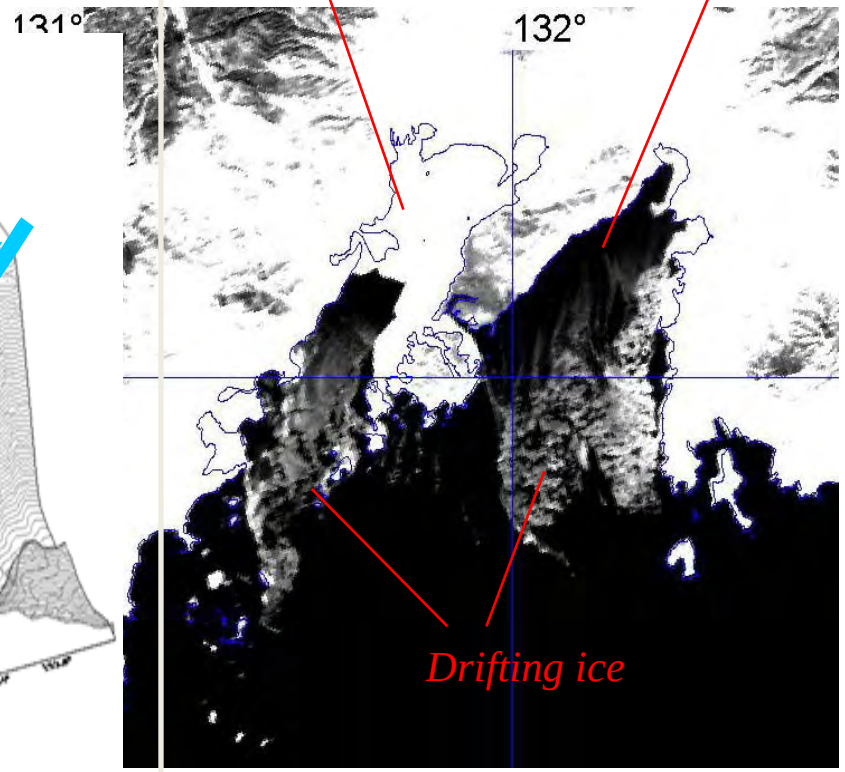

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Motivation

Hypoxia is a below critical content of DO, when hetero-trophic life is not possible

(30% in RF, 75 uM commonly)

Hypoxia is a form of ecosystem instability which leads to significant changes and may cause negative consequences

Hypoxia became a world wide phenomena for coastal waters recently *(e.g. Diaz, 2001; Diaz and Rosenberg, 2010)*

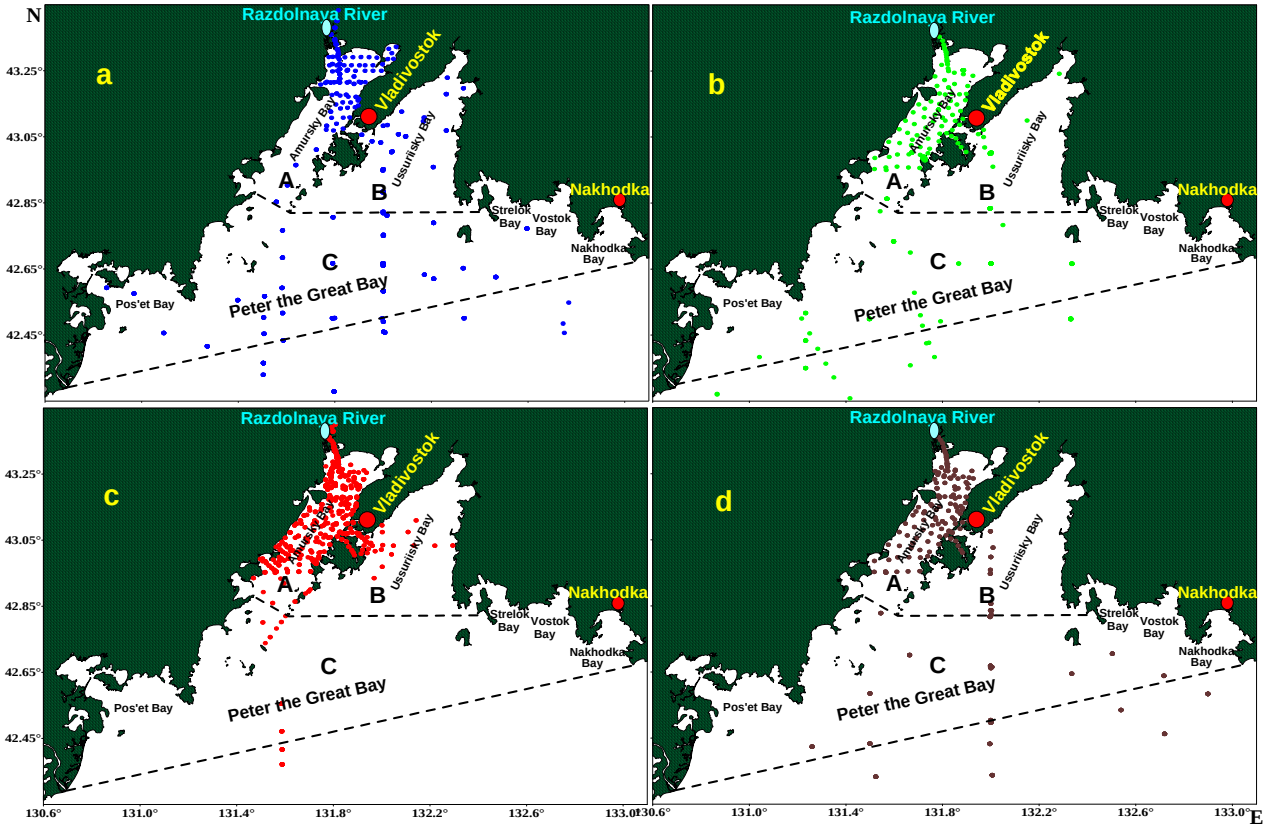
Goals of this study

Mechanisms of hypoxia formation and destruction in the Amurskiy Bay, Japan/East Sea

Contribution of natural and anthropogenic factors

Inter-annual tendencies

Data Observations in four seasons during 1999-2010



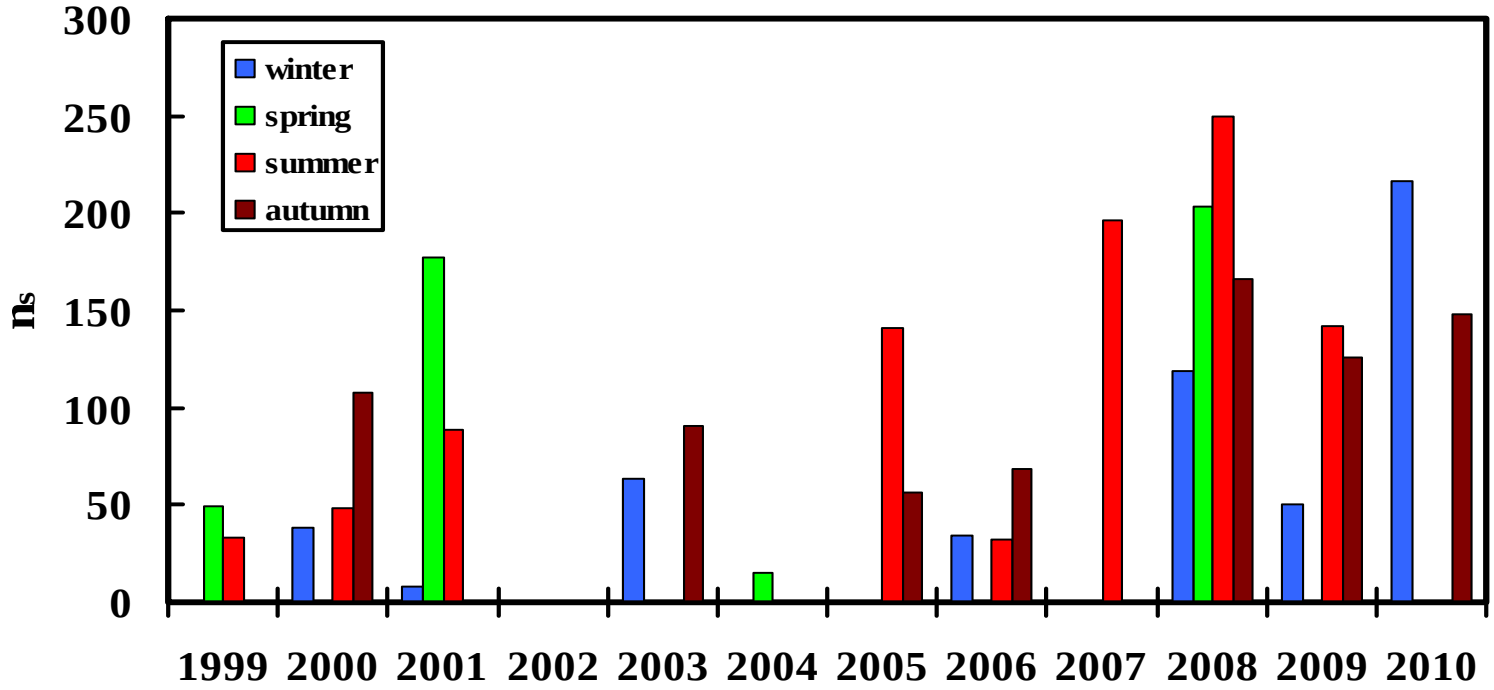
Measured parameters:

Profiles: CTD, Oxygen, Fluorescence, turbidity – RBR XR-620, SBE-19+

Samples from surface and from near-bottom : Dissolved Oxygen, Nutrients (Silicate, Nitrite, Nitrate, Ammonium, Phosphate), pH, Total Alkalinity, Chlorophyll, Humic Substances, Transparency by disc Secci.

Data

Number of stations in four seasons



In total:

Stations - >1000

Taken samples - >2600

Measurements - > 20 000

Winter – 197

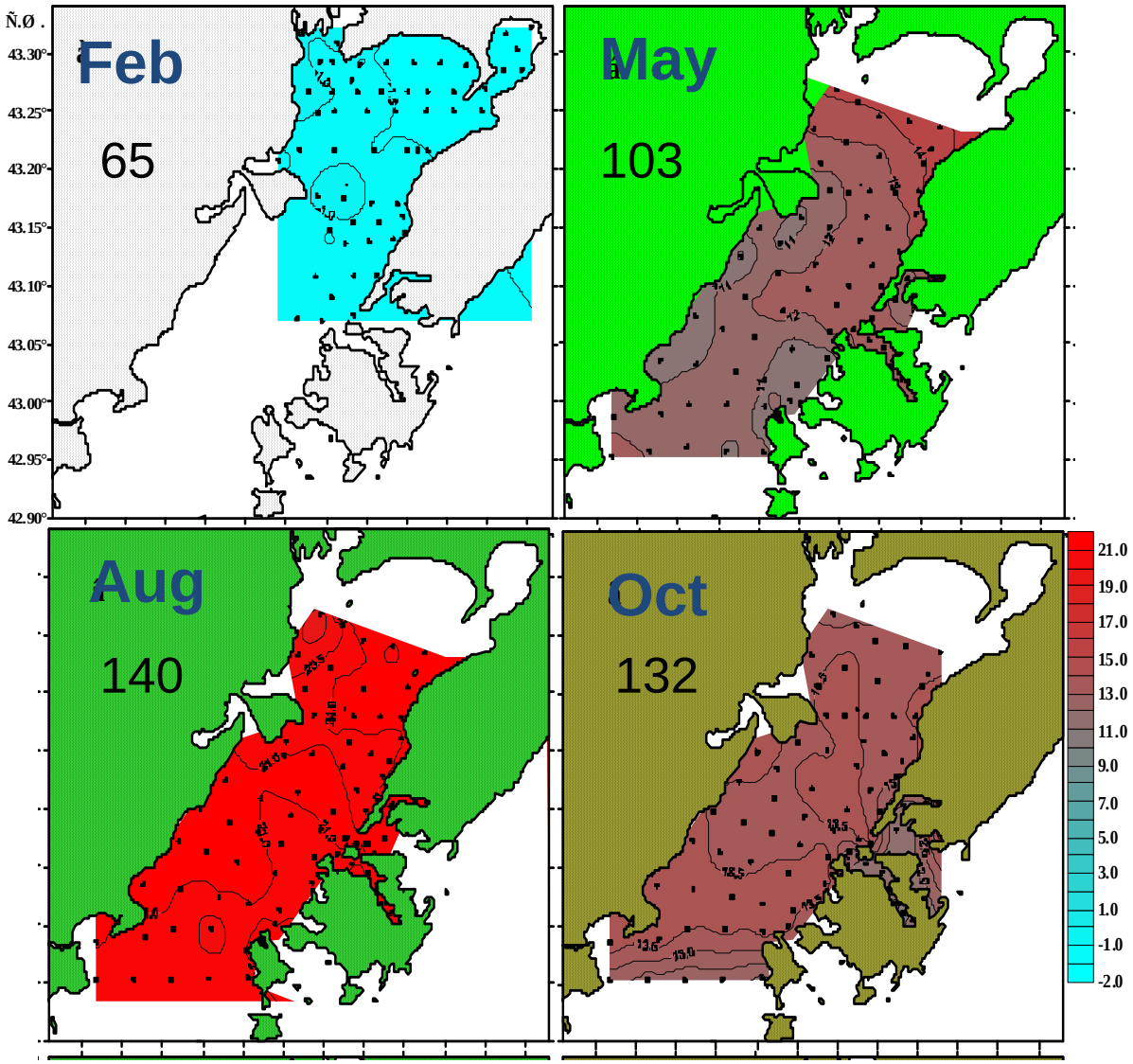
Spring – 144

Summer – 456

Autumn - 152

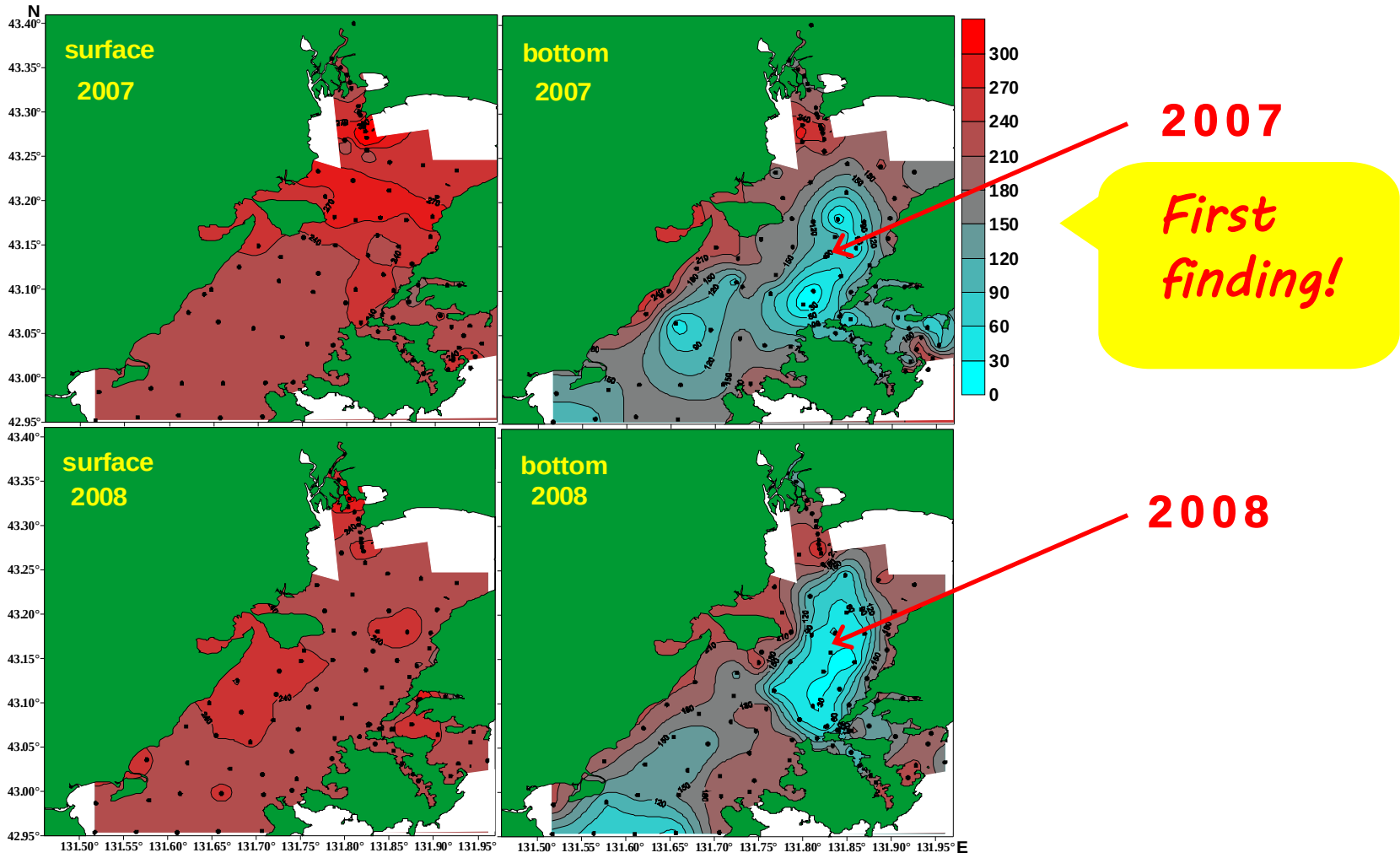
Data

Special seasonal surveys in 2008



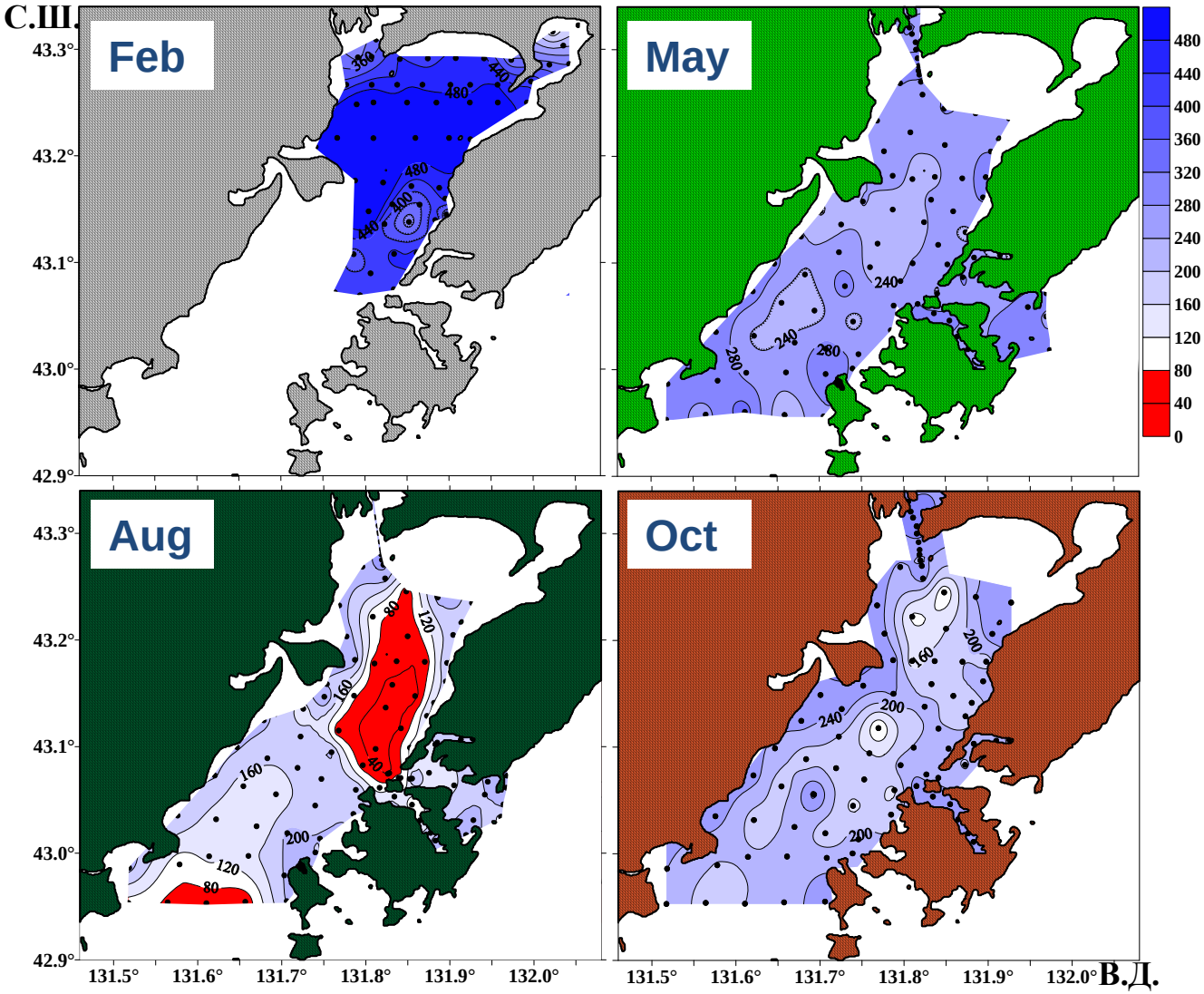
Severe hypoxia of near-bottom layer in the Amurskiy Bay

Lowest oxygen concentration was **4 μmol / kg. (1.5%)**

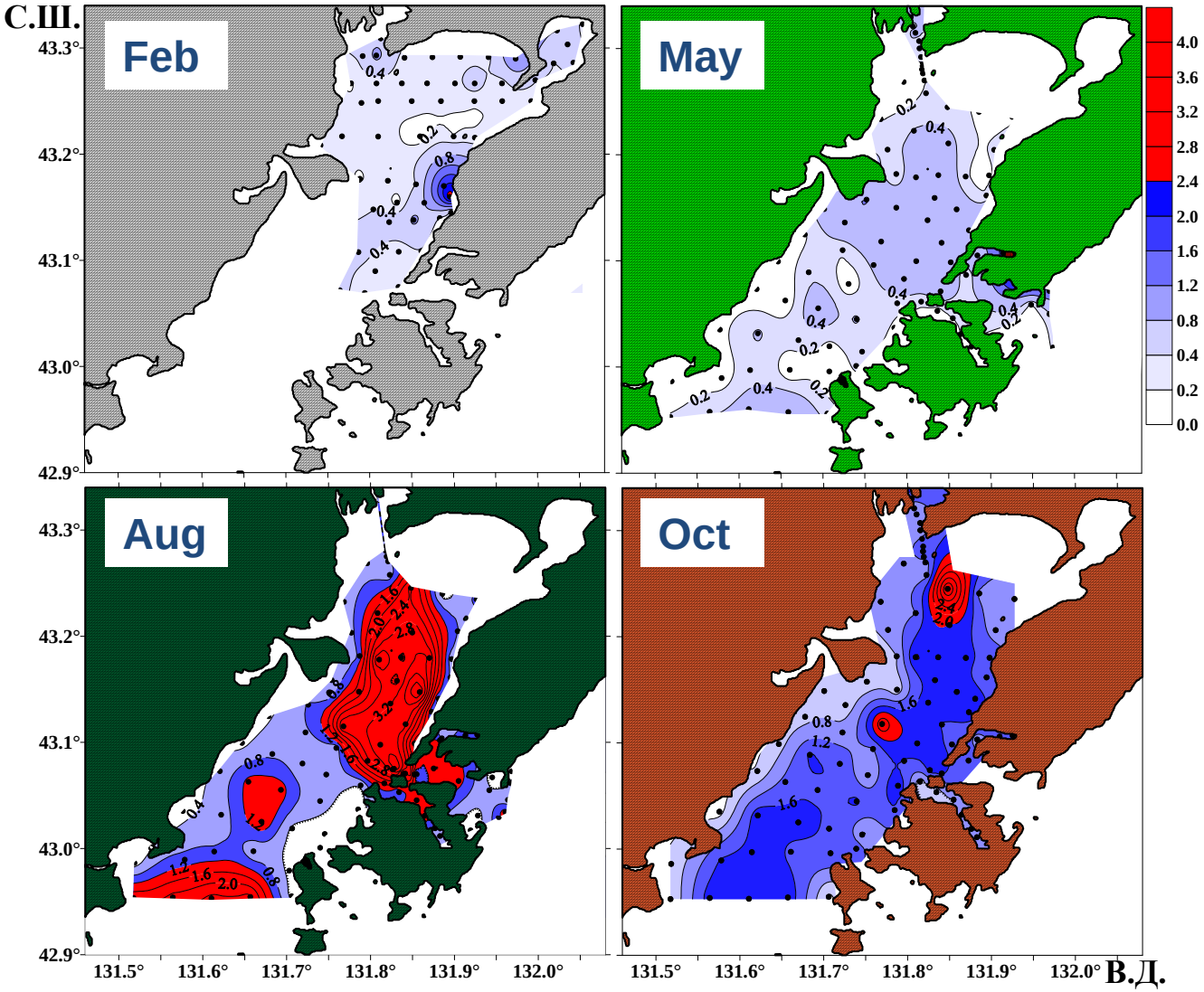


Distribution of oxygen concentration (umol/kg) in Amurskiy Bay, in surface and bottom layers. August, 2007 (upper panel). August, 2008 (bottom panel).

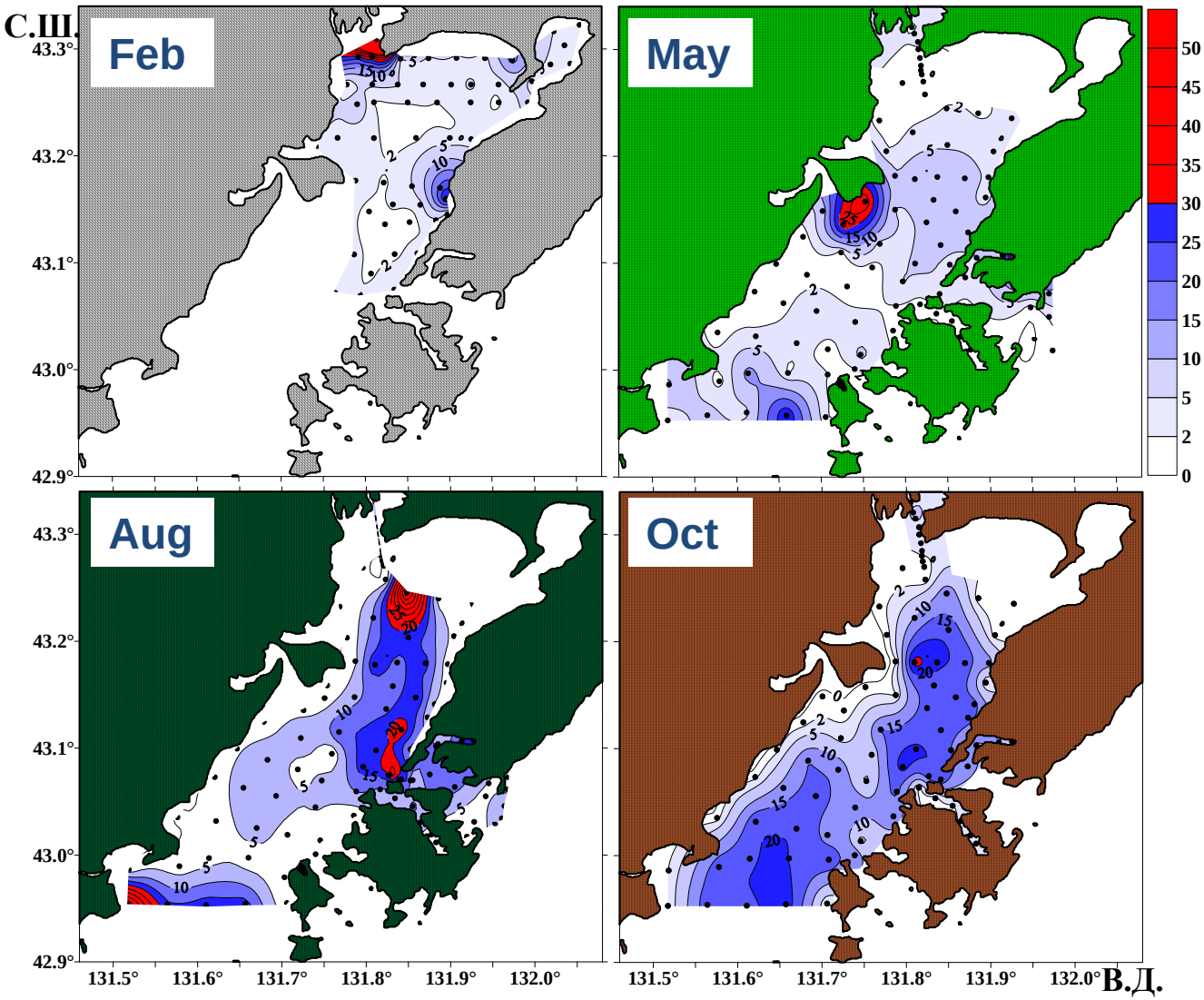
Seasonal variations of DO at bottom layer, 2008



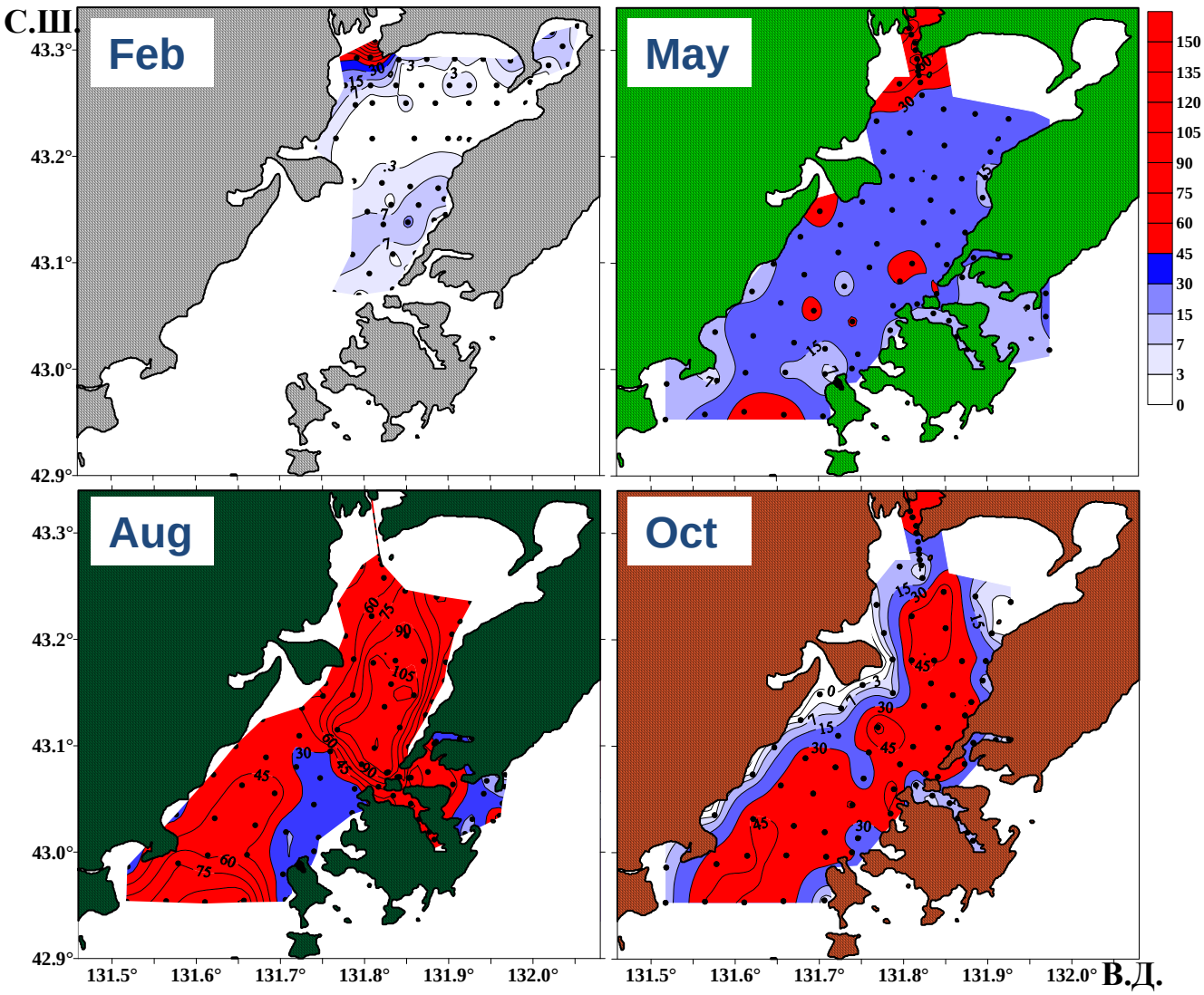
Seasonal variations of DIP at bottom layer, 2008



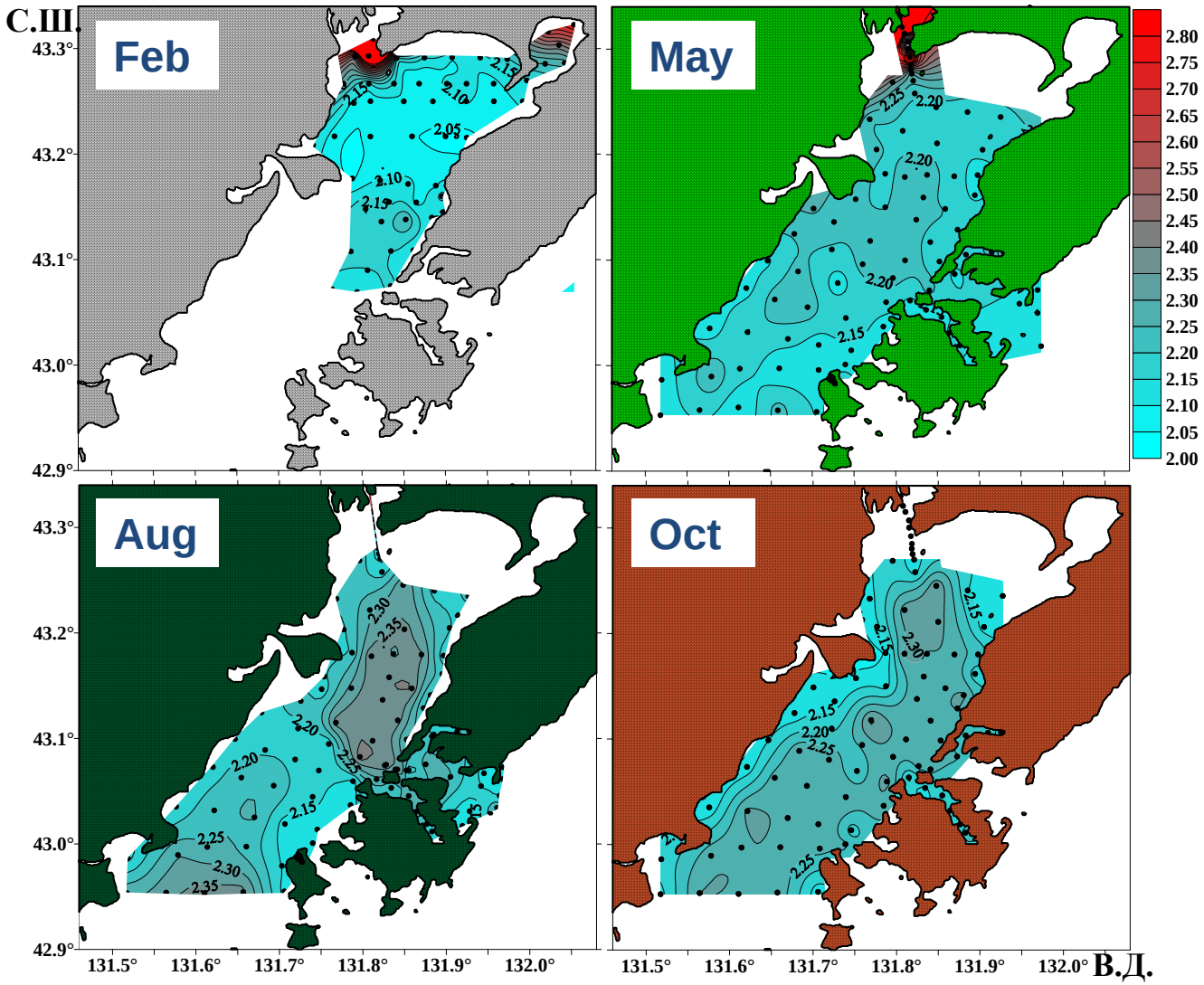
Seasonal variations of DIN at bottom layer, 2008



Seasonal variations of DISi at bottom layer, 2008



Seasonal variations of NDIC at bottom layer, 2008



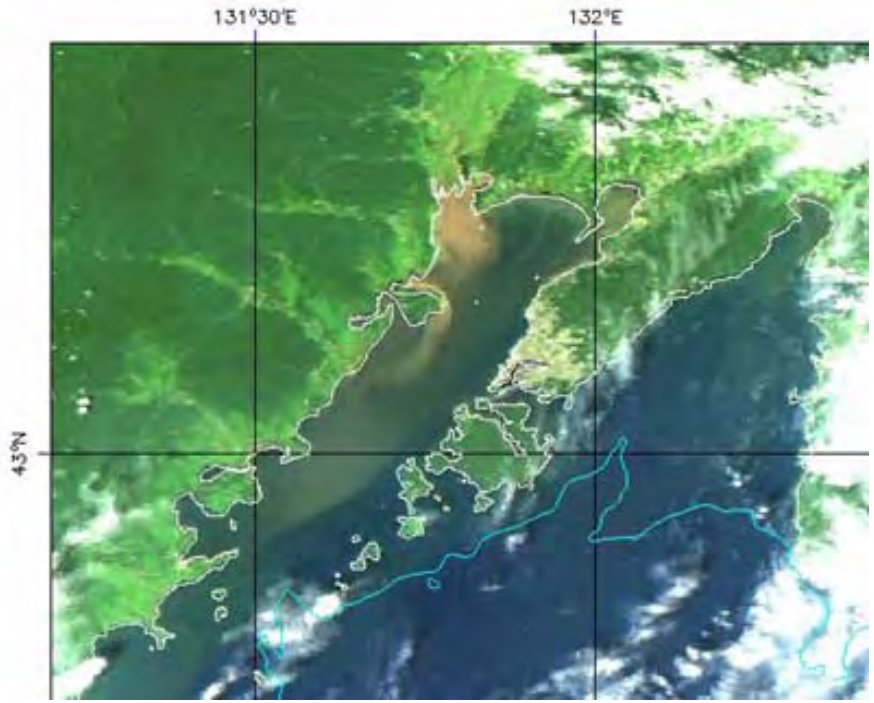
Summer is a period of hypoxia formation

- coincidence of hypoxia areas and areas of maximum of nutrients and DIC suggests microbial destruction of large amount of organic matter in the areas of hypoxia;

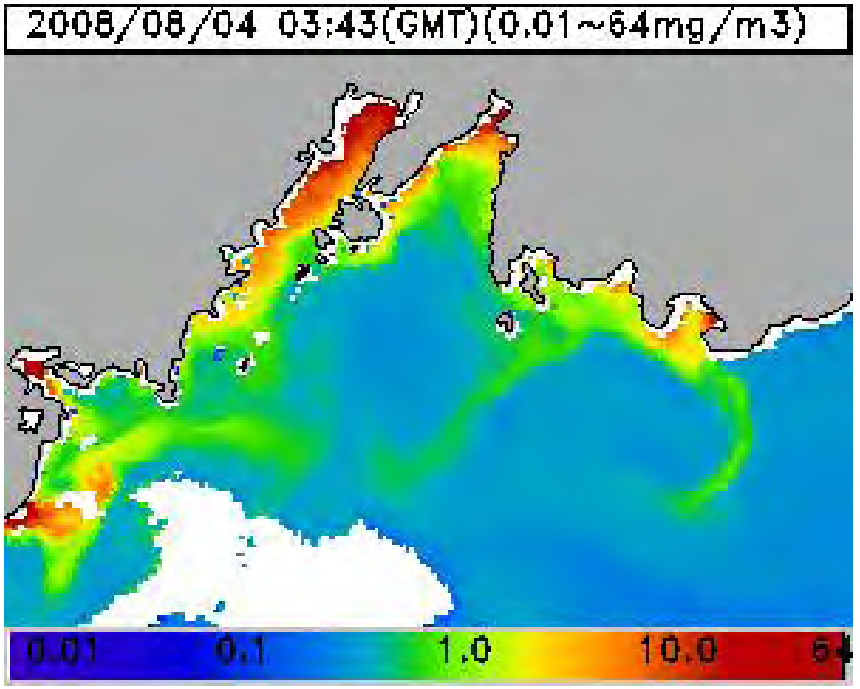
- formation of hypoxia is related to excess of phytoplankton biomass caused by eutrophication of the bay;

- there are 2 main sources of nutrients: Vladivostok city waste waters and Razdolnaya River discharge

Load of nutrients by Razdolnaya River and Vladivostok City waste waters



(a)



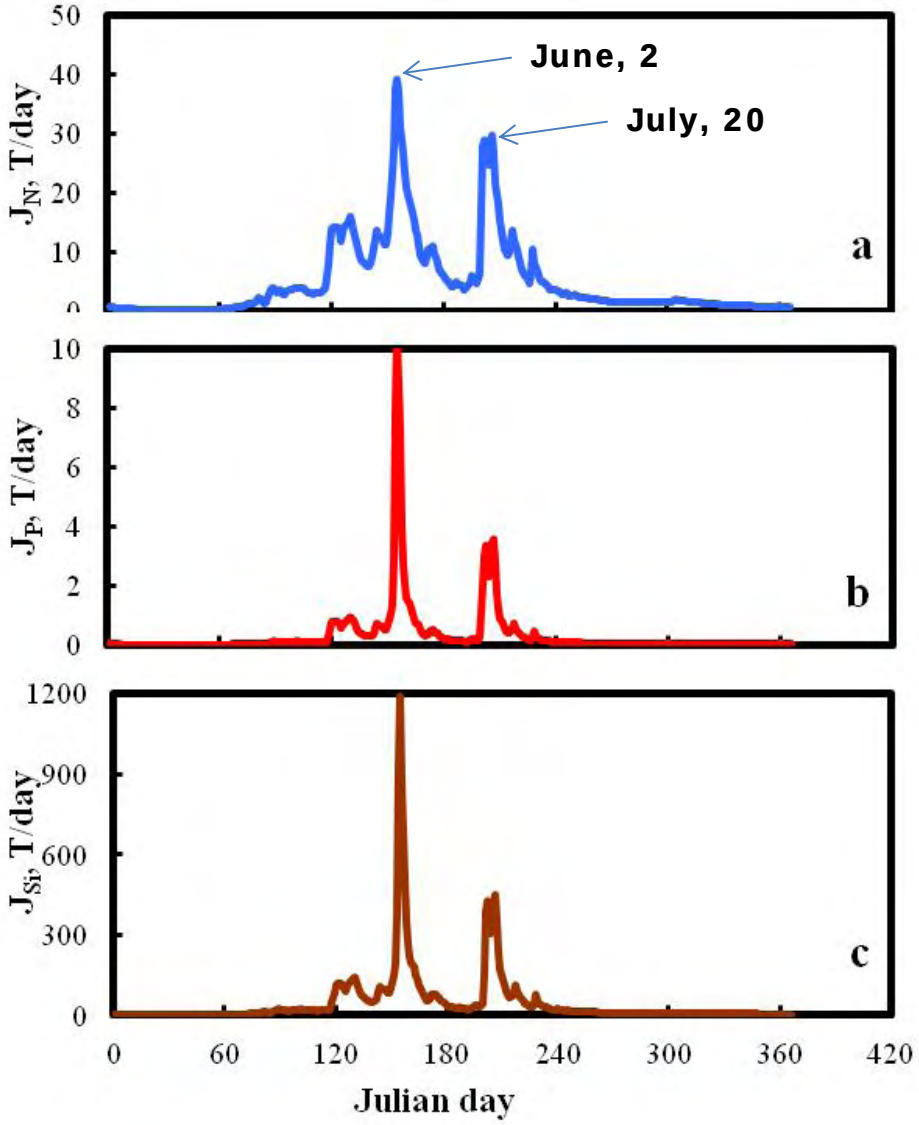
(b)

Monthly load of nitrogen (TN) and phosphorus (TP) into Amurskiy Bay in 2008

Period of the year	Jan-Dec		May-Aug		Sep-Apr	
Sources	City	River	City	River	City	River
TN: т/(км2month)	0.1	0.35	0.1	0,84	0.1	0.1
Portion from total	**22%**	**78%**	**11%**	**89%**	**50%**	**50%**
TP: т/(км2month)	0,01	0,04	0,01	0,1	0,01	0,02
Portion from total	**24%**	**76%**	**11%**	**89%**	**40%**	**60%**

River – ¾ , Vladivostok City – ¼ of total load

- **Main source of eutrophication is Razdolnaya River**
- **City discharge is stable while river discharge is variable**



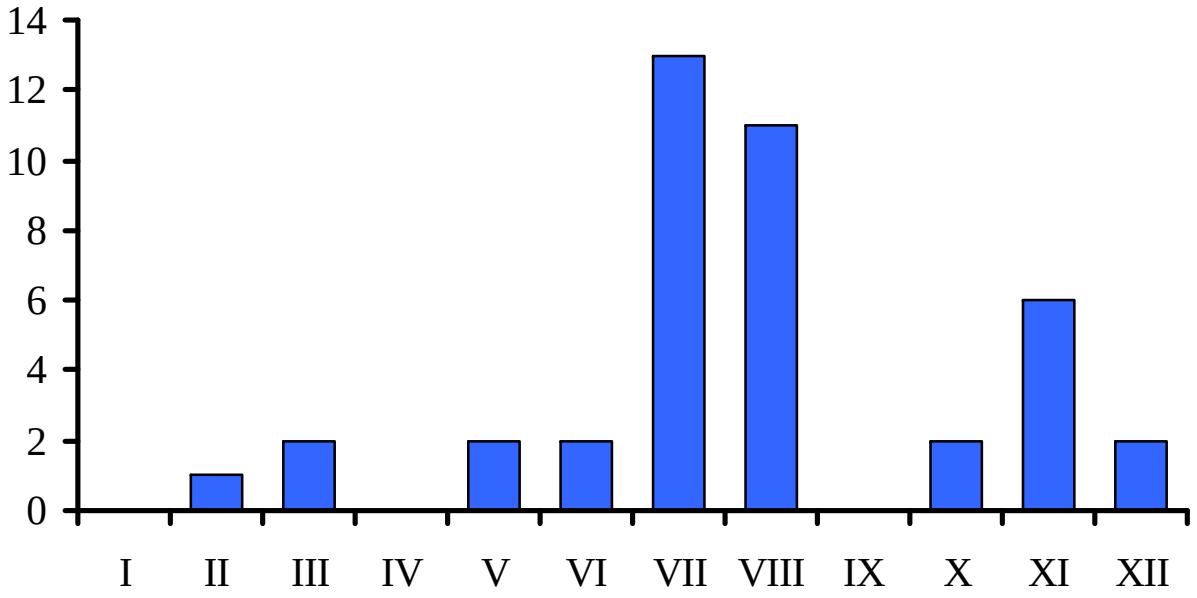
Nutrients fluxes into Amurskiy Bay by Razdolnaya River in 2008:

a – DIN
b – DIP
c – DISi

Nutrients	DIN	N-tot	DIP	P-tot	DISi
River runoff	1800	4200	120	450	17040

Annual fluxes (T/year) of nutrients into Amurskiy Bay by river runoff

Seasonal variation of plankton bloom events 1991-2007



Number of bloom events by month in Amurskyi Bay (1991–2007).
Source: Center of Monitoring of HABs & Biotoxins of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm (*Tatiana ORLOVA)*

Scenario of near-bottom hypoxia formation :

1. **Eutrophication hit -** due to heavy precipitations at June and July in watershed of Razdolnaya River, high water of the River supplies nutrients and suspension matter into surface of Amursky Bay

2. **Diatoms bloom -** after settling of suspension matter, diatoms bloom is occurred at 14 June, and 25 July, 2008

3. Due to short time changes, **zooplankton and fishes are excluded from food chain,** therefore **diatoms died and settled on the bottom**

4. High water turbidity - decay of diatoms is going under deficit light conditions for most of the Amursky Bay area because turbidity of waters. Then hypoxia of near-bottom waters is occurred through microbiological processes such as:

Ammonification or denitrification **-**

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 84.8NO_3^- + 99.8H^+ \rightarrow 106CO_2 + 148.4H_2O + 16NH_4^+ + 42.4N_2 + H_2PO_4^-, \quad (1)$$

and sulfatreduction -

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 53SO_4^{2-} \rightarrow 38H_2S + 16NH_4^+ + H_2PO_4^- + 106HCO_3^- + 15HS^- \quad (2)$$

Small fishes mortality event in Amurskiy Bay on September 14, 2008

Died fishes on 14th September 2008 at the coast of Amurskiy Bay. Most part of the fishes were junior smelt and had a specific smell.

Photo: Vladimir Kolesnikov

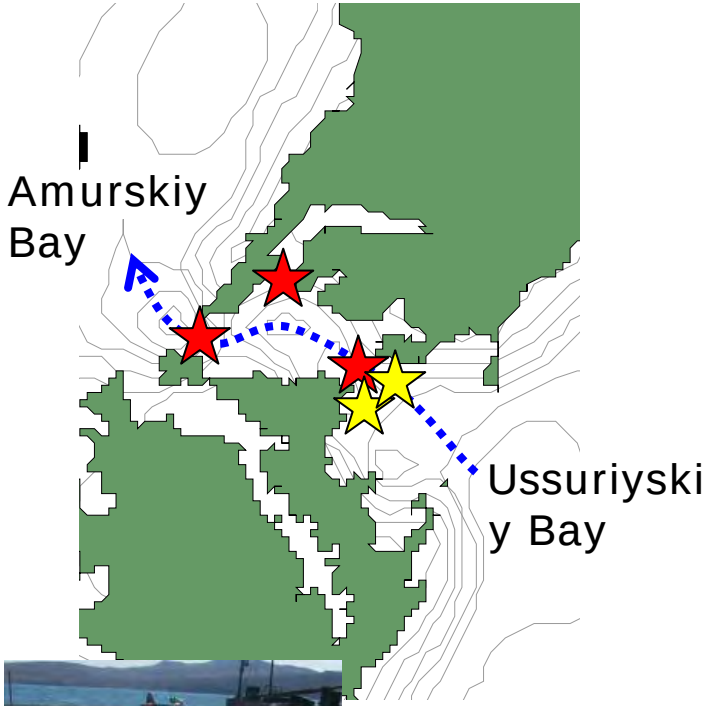
5. Strong stratification and calm weather in Summer over last years prevent vertical mixing of hypoxic bottom layer.

Autumn is a period of hypoxia destruction

- coastal upwelling during season of monsoon shift and horizontal advection of open sea water up into the bay;

- vertical mixing caused by stronger winds and convection

Bosfor Vostochniy Strait: Water Exchange Between Ussuriyskiy and Amurskiy Bays (23.07-14.09. 2009)



RDCP-600

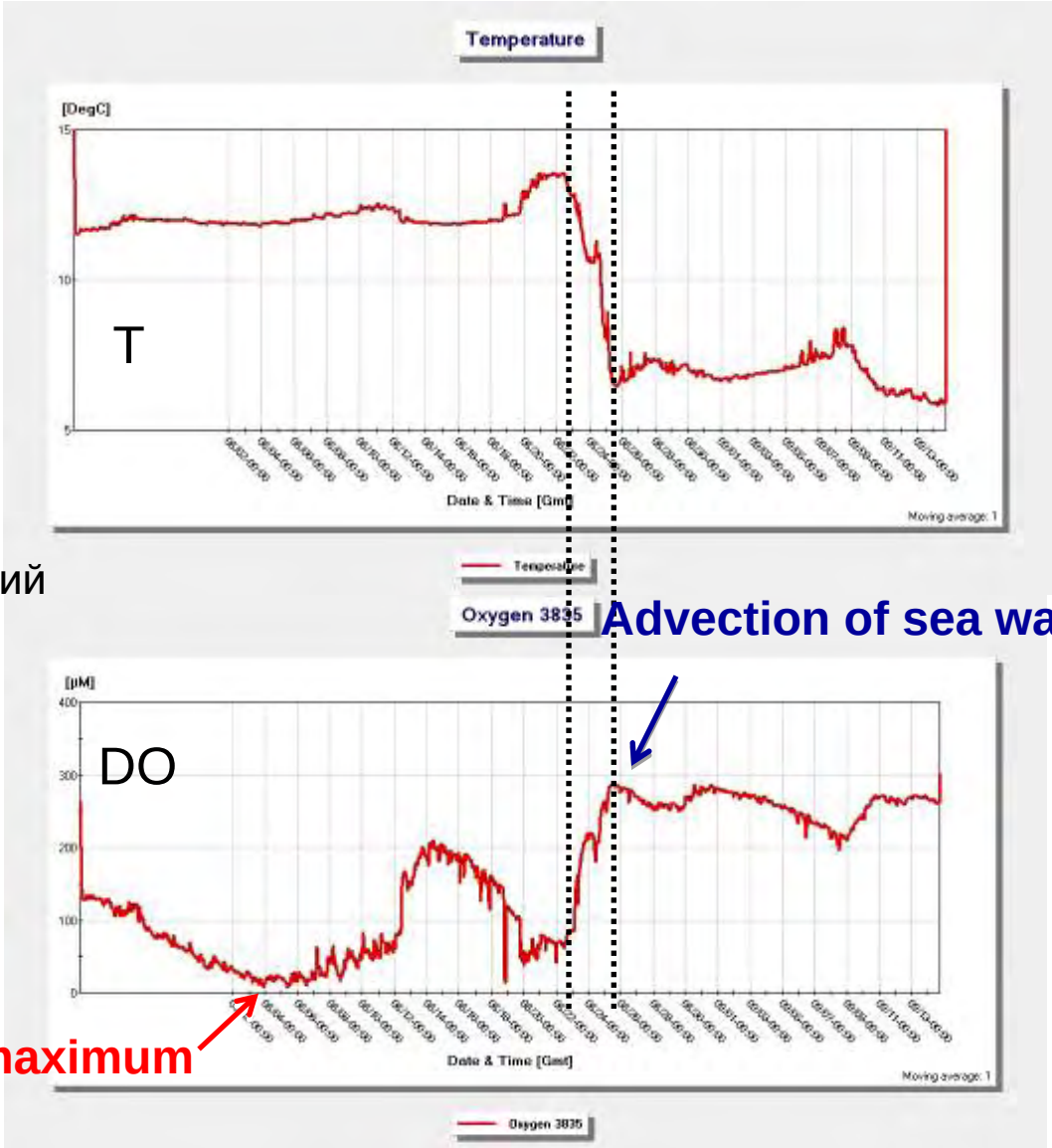
H =20-40m

№	Период	Место	Продолжительность
1	16.06-26.10.09	Токаревский прол.	132
2	14-22. 09.09	м. Назимова	8
3	28.10-22.11.09	б. Золотой Рог	26
4	4-20.06. 10	м. Назимова	15
5	4-20.06. 10	м. Назимова	15

Bosfor Vostochniy Strait: Water Exchange Between Ussuriyskiy and Amurskiy Bays (23.07-14.09. 2009)

H=48 m
RDCP-600

22-25.08

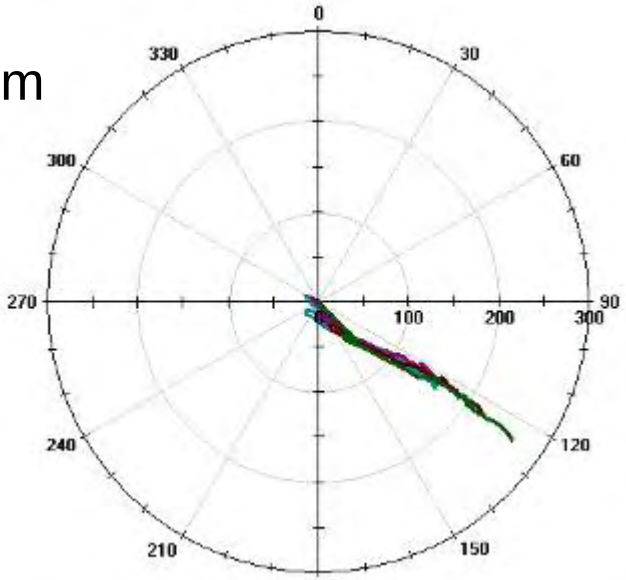


Advection of sea water

Hypoxia maximum

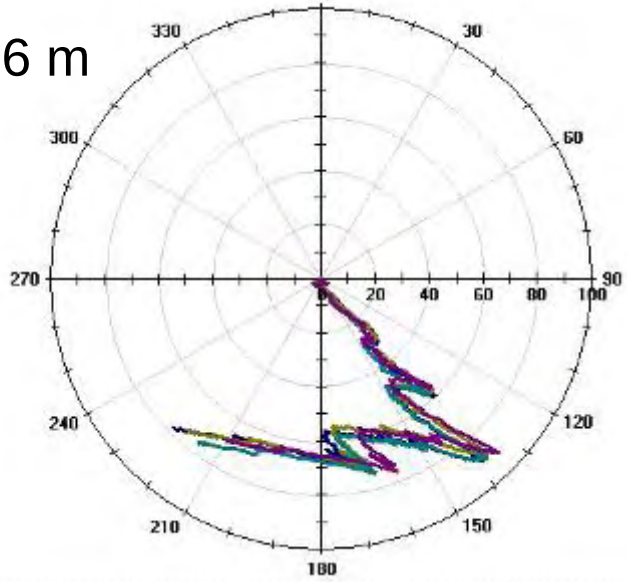
Bosfor Vostochniy Strait: Water Exchange Between Ussuriyskiy and Amurskiy Bays (23.07-14.09. 2009)

0-30 m

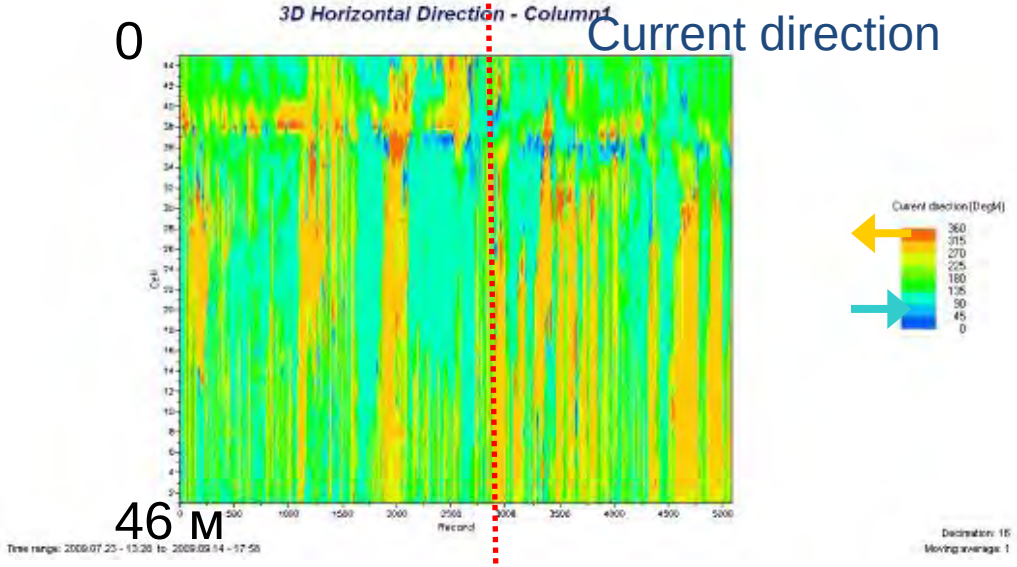


Shift of mean transport

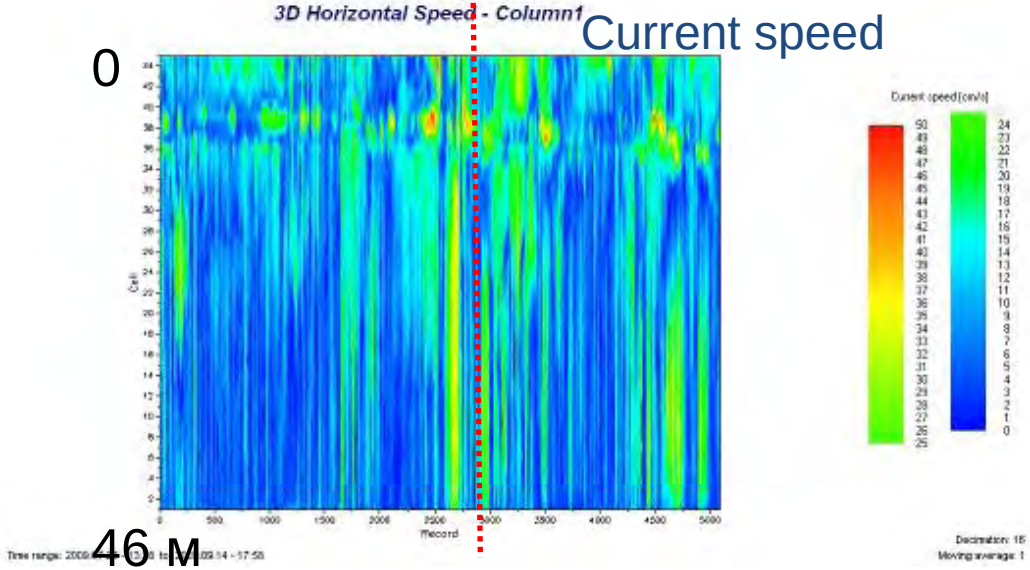
31-46 m



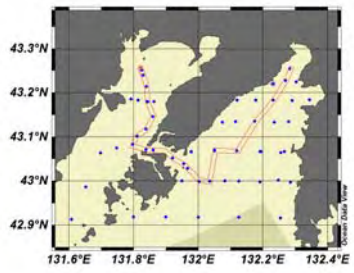
Current direction



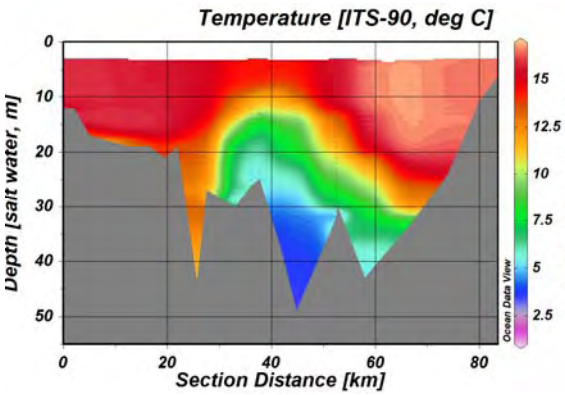
Current speed

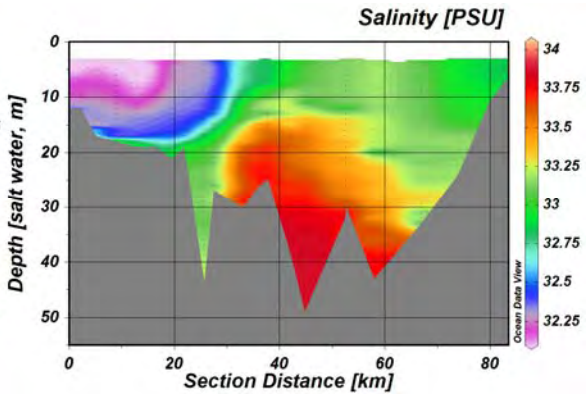


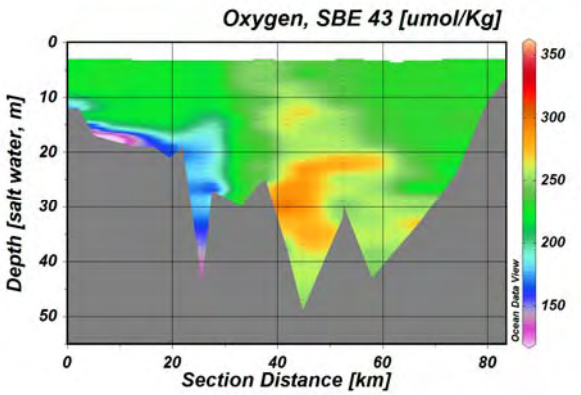
Removal of hypoxia in the Amurskiy Bay



изменение T, S и DO на разрезе через Амурский и Уссурийский заливы 1-7 октября 2011







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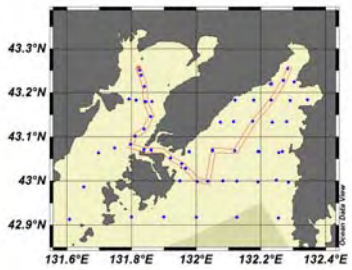
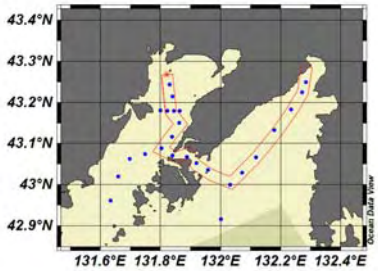
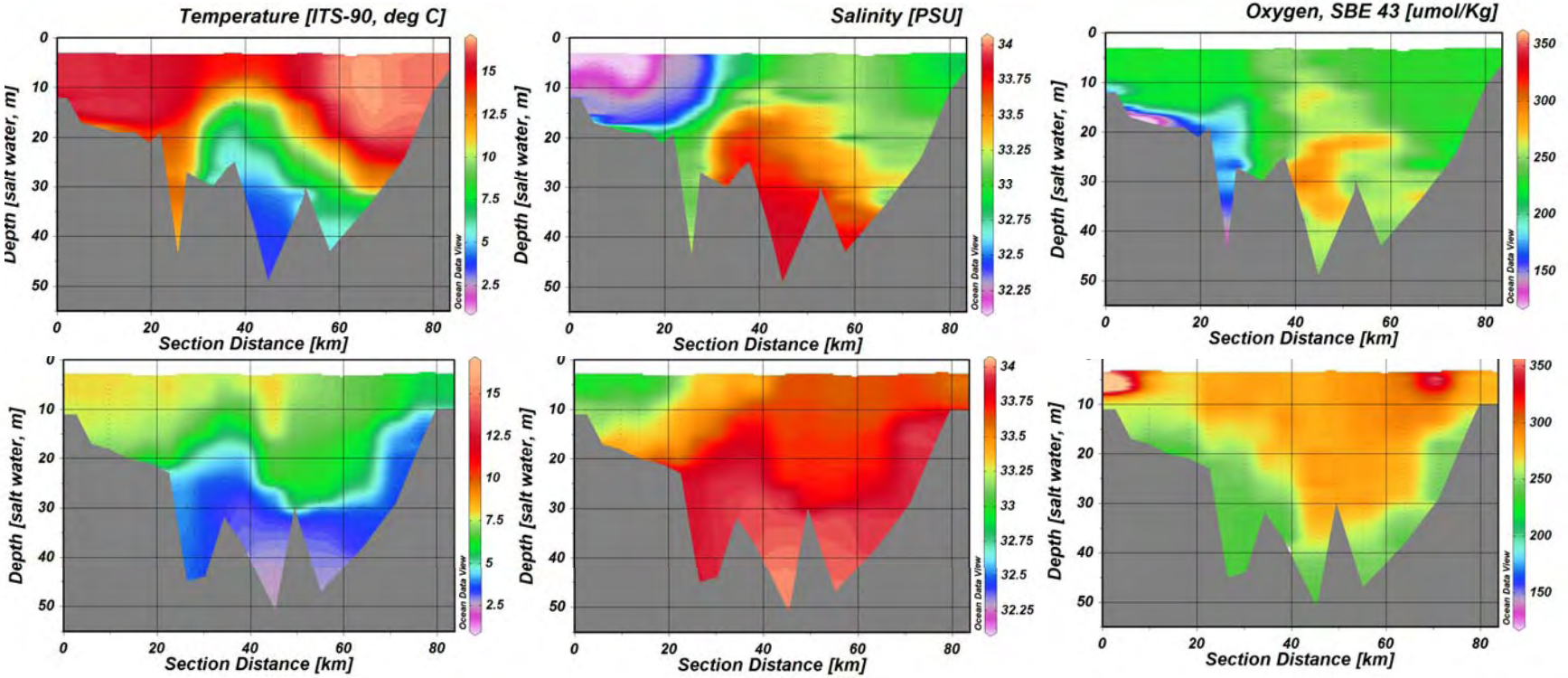


изменение T, S и DO на разрезе через Амурский и Уссурийский заливы 1-7 и 27-30 октября 2011



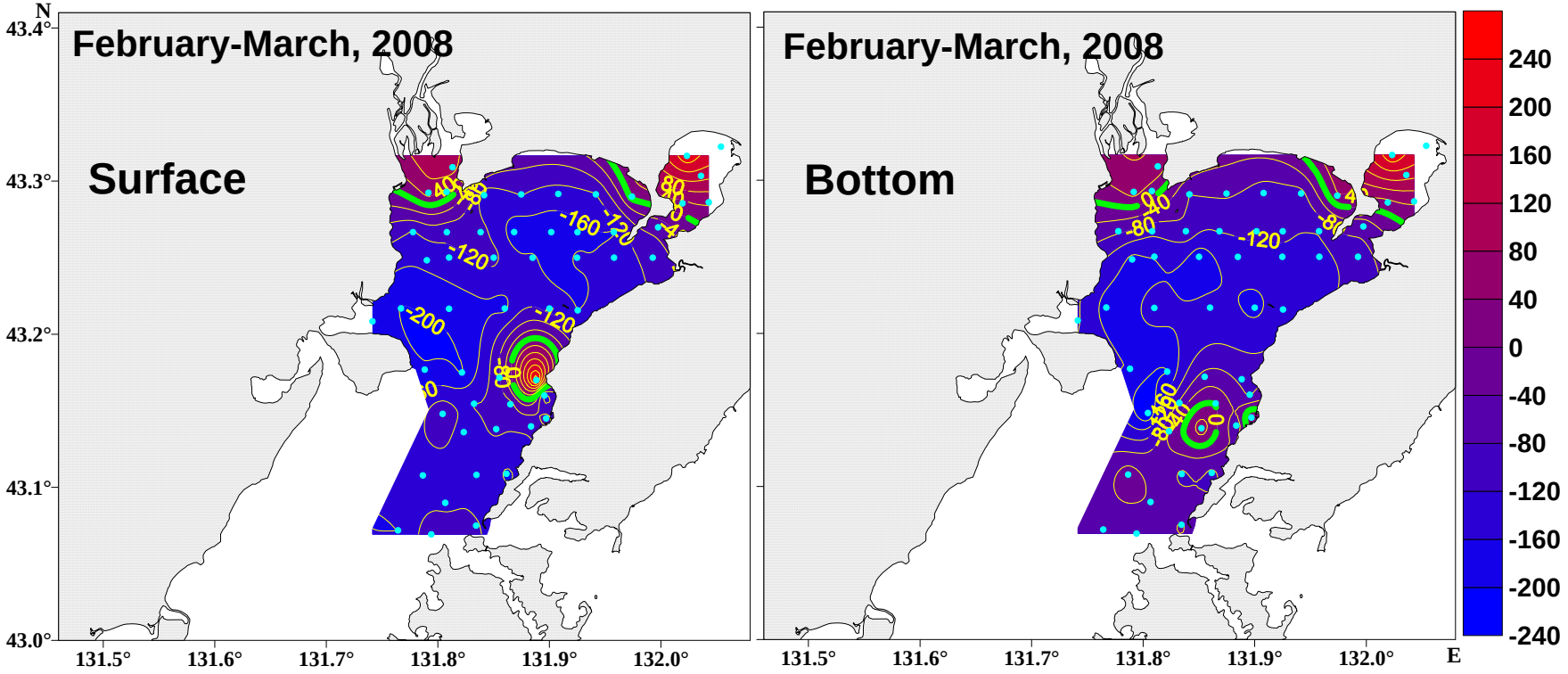


Winter is a period of DO regeneration

- **high primary production;**
- **vertical mixing by thermo-haline convection**

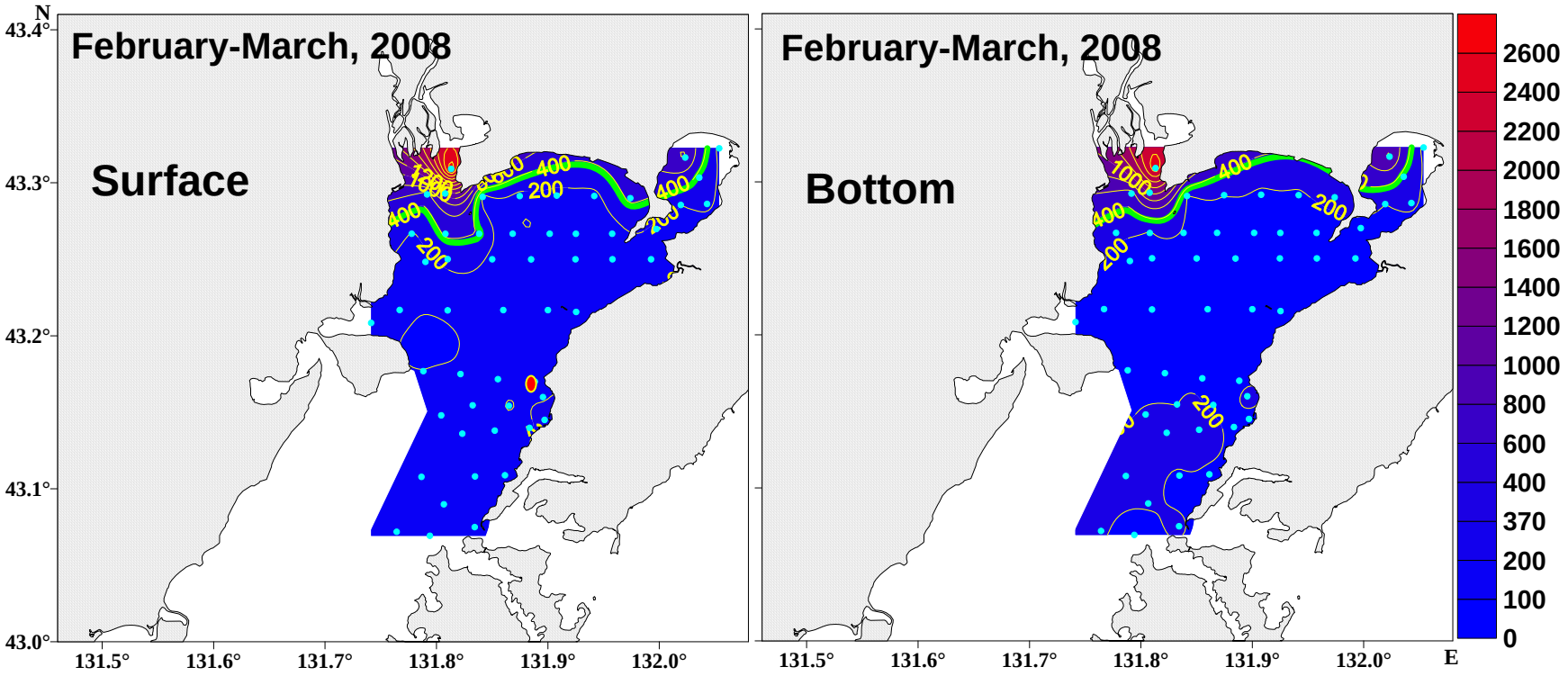
Winter AOU – oxygen oversaturation

High biological productivity of Amursky Bay in winter season which utilizes nutrients due to primary production and including of zooplankton and fishes into food chain



Distribution of AOU in surface (a) and bottom (b) waters. It is demonstrated that most part of Amursky Bay area is supersaturated by oxygen. Green line notes equilibrium state

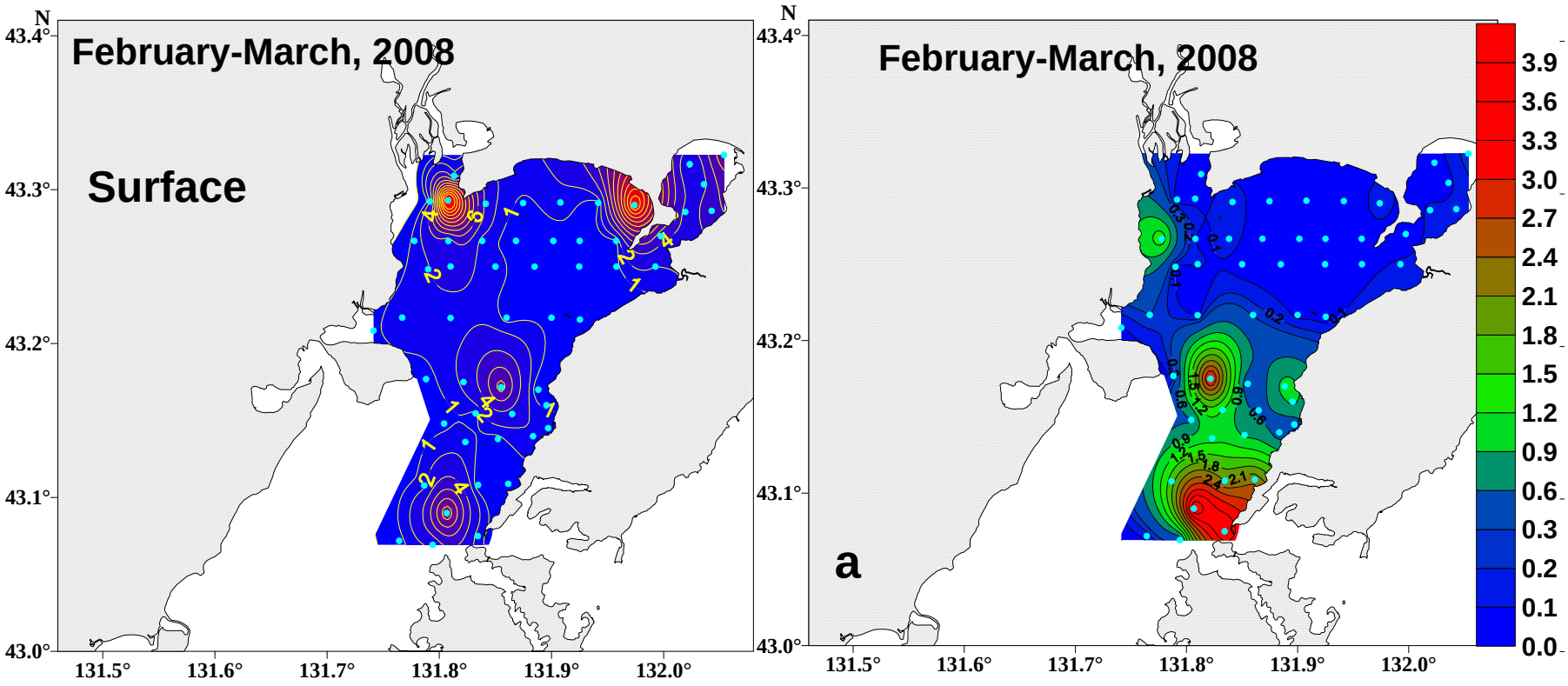
Winter pCO_2 – undersaturated



Distribution of CO_2 partial pressure surface (a) and bottom (b) waters. It is demonstrated that most part of Amursky Bay area is undersaturated by carbon dioxide. Green line notes equilibrium state

Winter Chl-a and PP – highly productive area

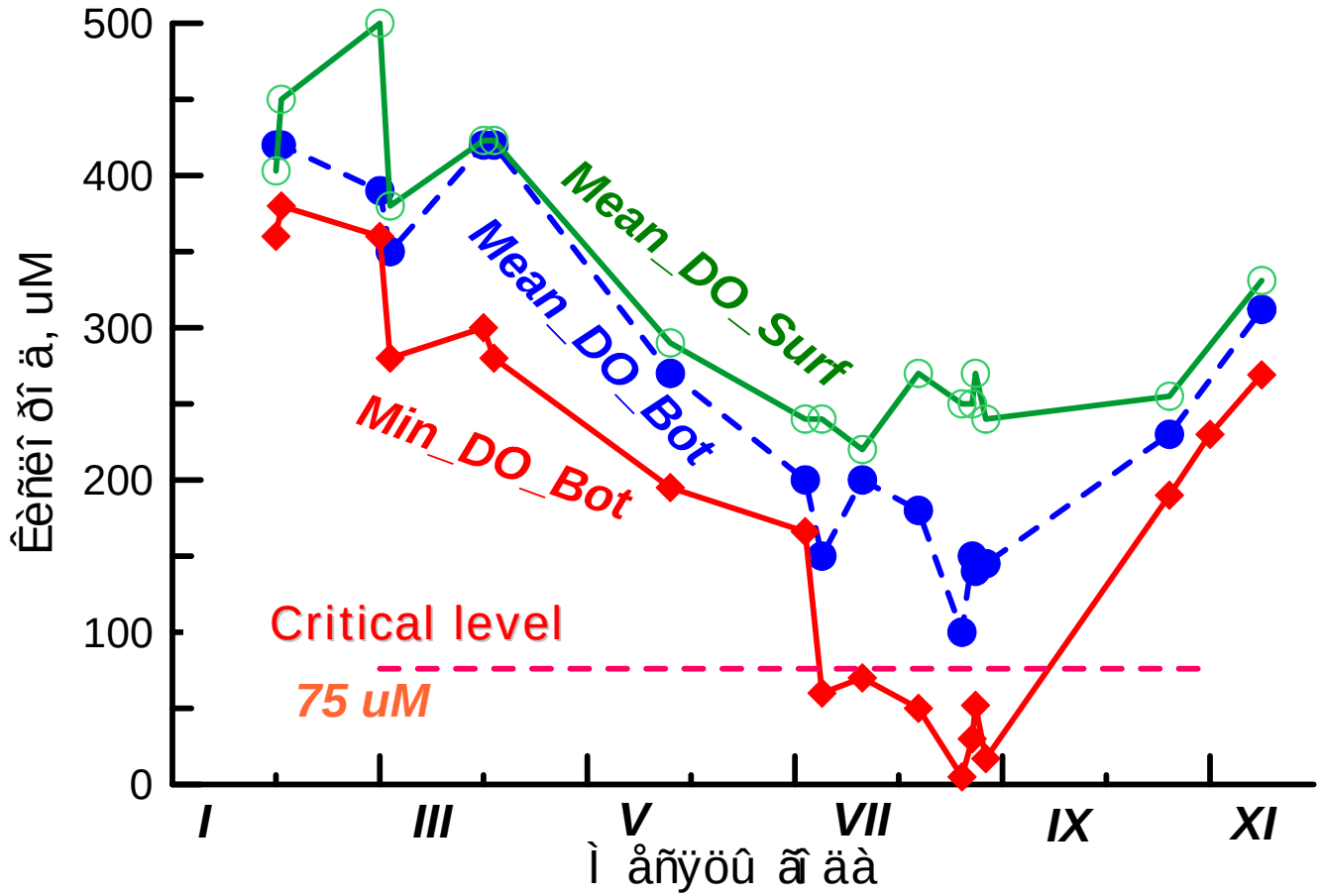
Highest production area is associated with non-consolidate ice area “ice-edge effect”



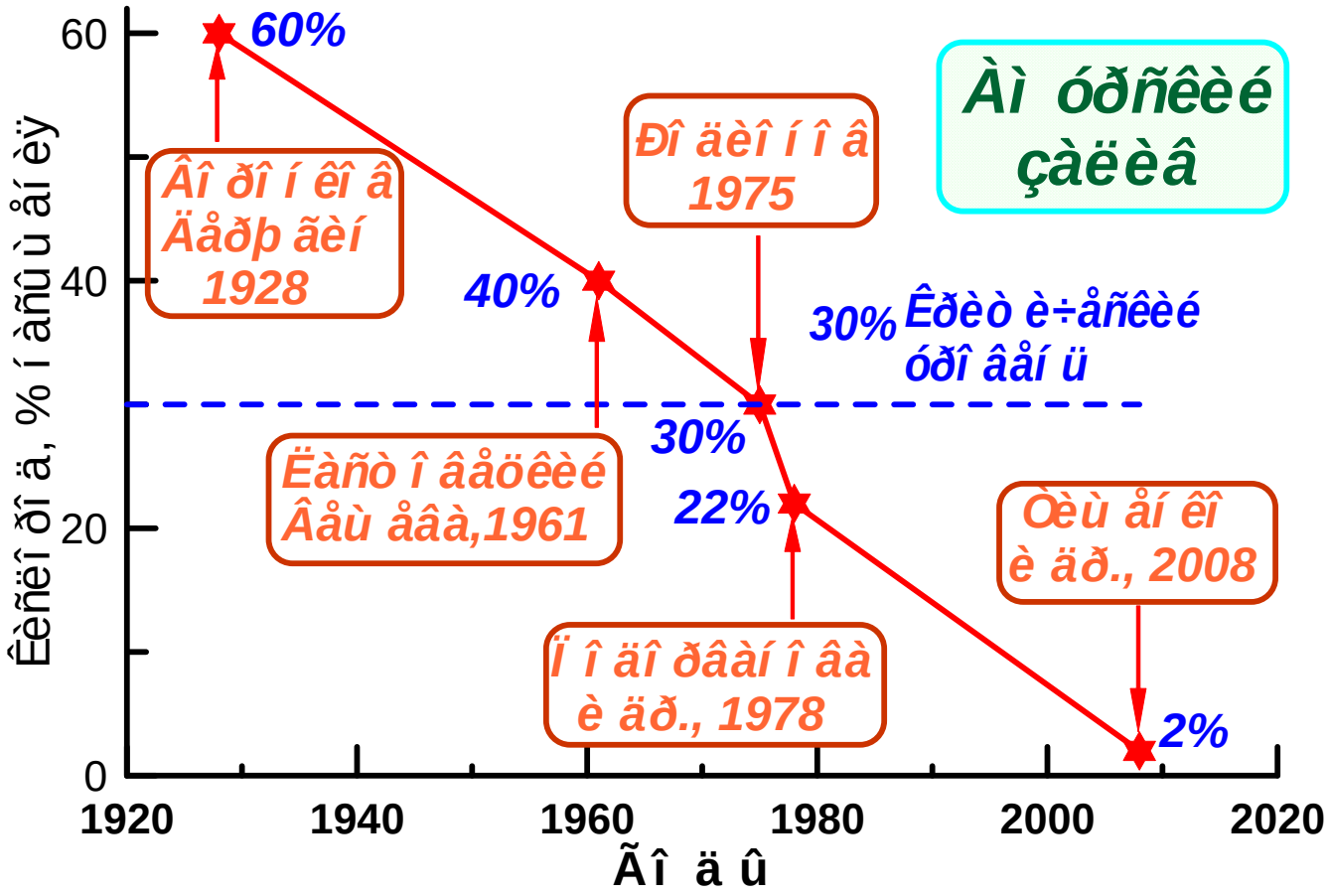
Distribution of chlorophyll-*a* concentration and primary production (gC/(m^2 day)) in surface waters. It is demonstrated that Amursky Bay area is highly productivity area.

Seasonal variation of DO

(based on 18 cruise data 1999-2010)



Variation of DO min value in the Amurskiy Bay over 85 years



Decreased by 30 times

Conclusion:

1. Hypoxia in the Amurskiy Bay has a seasonal occurrence. Strong decrease of DO is observed in Summer and is associated with euthrophication hits caused by fluctuation of Razdolnaya River. Autumn upwelling and advection of deep sea water onto shelf removes hypoxia. High PP in winter regenerates DO and makes whole water column oversaturated.

2. Strong hypoxia (below in Summer became a permanent feature of the Amurskiy Bay bottom layer over last 5 years at least.

3. Retrospective analyses of available data over 85 years shows gradual decrease of DO minimum in bottom layer.


Thank you for attention !