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Present and Future Changes in the Okhotsk Sea waters

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"Toward a Sustainable Low Carbon Society- Green New Deal and Global Change", November 2009

- Recent changes in the intermediate and surface waters of the Kuril Basin
- Main features of the CNP fluxes and biological productivity. Future changes of the CNP fluxes
- Impact of the East-China Sea waters
- Seawater acidification and excess carbonate dissolution



Okhotsk Sea. Intermediate waters.



Northern North Pacific. Circulation pattern.



Northern North Pacific

Sea level pressure, mbar, November-March Ν 60-NGAA/ESRL Physical Sciences Division BON 66N-**B**3N 60N 150 50-SubGyre 57N 54N 51N 48N 40-45N- σ_{Θ} =26.8, depth (m) 42N 39N 361 30-160W 15**0**W 140% 130% 16OE 170E 180 170% 120% 180 140 150 160 170 190 200 210 220 230 E Nov to Mar: 1973 to 1988 101D 1012 1018 102D 1008 1016 1002 1004 1008 1014 DO, µmol kg⁻¹ N 60-350 50 200 300 0 100 150 250 25.8 Alaska Gyre 26.0 50-26.2 σ_Θ 40140 26.6 σ_Θ=26.8, DO µmol kg⁻¹ Western Subarctic 26.8 Gyre 30-180 200 150 160 170 190 220 230 E 27.0 140 210

Okhotsk Sea

Temperature (blue and red dotted lines) and dissolved oxygen at $\sigma_{\Theta} = 26.8$



East-Kamchatka/Oyashio and East-Sakhalin Current volume transport



Okhotsk Sea and Alaska Gyre. Intermediate waters.



Northern North Pacific

NCEP/NCAR Reanalysis Sea Level Pressure (mb) Composite Mean



Bering Sea



Difference in temperature and chemical parameters between the eastern subarctic Pacific (Alaska Gyre) and the Okhotsk Sea (Kuril Basin region) on isopycnals of $26.8\sigma_{\Theta}$ and $27.0\sigma_{\Theta}$

Parameter	Alaska Gyre-	Accuracy of	
	Okhotsk Sea	measurements	
Temperature (C)	3.0	$\pm \ 0.001 \textbf{-} 0.005$	
Dissolved oxygen (µM)	-150	± 2-4	
Dissolved inorganic carbon	50	$\pm 2-3$	
(µM)			
Nitrate (µM)	6	± 0.2 -0.6	
Phosphate (µM)	0.4	± 0.02 -0.06	

Okhotsk Sea. Intermediate waters.







Okhotsk Sea. Intermediate and surface waters. Future changes

- Climate change will suppress vertical mixing by thermal stratification and decreases in surface salinity in the subpolar regions (i.e. Manabe, Stouffer, 1993; Manabe, Stouffer, 2000).
- Strengthening of the Aleutian Low in winter (Mohov et al., 2005) could force further an increase of the temperature and decrease of the dissolved oxygen in the intermediate waters of the subarctic Pacific and Okhotsk Sea.

CNP fluxes and biological productivity

Okhotsk Sea, February 2003; 5 m

Salt, dissolved inorganic phosphorus (DIP), nitrogen (DIN), and carbon (DIC) fluxes $(10^{12}, yr^{-1})$ and primary production $(10^{12}, yr^{-1})$ for the Okhotsk Sea. The water mass exchange (Q) is reported in Sverdrup (Sv)

	Salt	DIP	DIN	DIC
Pacific – Okhotsk	20±3	0.04 ± 0.01	1.0 ± 0.1	4.1 ± 0.7
Sea,	kg of salt	mole	mole	mole
Q = 5 Sv	-			
Japan Sea –Okhotsk	7± 4	-0.04 ± 0.01	-0.6 ± 0.1	-5.4 ± 2
Sea,	kg of salt	mole	mole	mole
Q=0.6 Sv	-			
Riverine and (P- E),	-27± 5	< 0.001	< 0.01	0.16±
$0.026 \pm 0.05 \; \text{Sv}$	kg of salt	mole	mole	0.03
	-			mole
Sea- air CO ₂ flux				4.5±1.5
				mole
Residual	0 ± 7	0.0±0.02	0.4 ± 0.2	3.4 ± 3
	kg of salt	mole	mole	mole
Total Primary	-			60
Production				mole



CNP fluxes and biological productivity



 Biological productivity of the seawater is determined by a solar radiation, seawater temperature, macro (P, N, Si)- and micro (Fe, Zn)-nutrients availability, water column stratification etc.

• In summer, the high primary production values in the Okhotsk Sea are commonly confined to dynamically active zone (Shelikof Bay, Penzhinskaya, Udskaya Guba, Sakhalin Bay, northern and central Kuril Islands areas, and on Kashevarov Bank), where nutrients are supplied to the upper mixed layer, as well in the zone of the influence of the Amur River.

•In the adjacent regions Kashevarov Bank and off the Yamskoy Islands, the primary production is increased up to $3-4 \text{ gC m}^{-2} \text{ day}^{-1}$. The utilization of nutrients supplied at the Kashevarov Bank may provide production of $\sim 1.8 \cdot 10^{14} \text{ gC yr}^{-1}$, which is more than one-third of the annual production of the Okhotsk Sea (Arzhanova and Zubarevich, 1997).

CNP fluxes and biological productivity Okhotsk Sea. Kashevarova Bank area.



CNP fluxes and biological productivity Okhotsk Sea. Kashevarova Bank area.



CNP fluxes and biological productivity Okhotsk Sea

 Δ (Phyt _Biomass)/(Phyt _Biomass) $\approx \Delta$ Chl/Chl~ $\psi^{T} \cdot I/I^{opt}exp(1-I/I^{opt}) \cdot f([NO_3],K_N, [SiO_2], K_{Si}) - \lambda^P$, I -sun irradiance (PAR - photosynthetically available radiation), ψ^{T} - the maximum photosynthetic rate, K_N and K_{Si} - the half saturation constants of phytoplankton for nitrate and λ^P is the decrease rate of biomass of phytoplankton due to grazing, mortality etc.

 $\Delta Chl/Chl \{\Delta ln(Chl)\} \sim k \cdot \Delta PAR$ $PAR \leq PAR^{opt}$, 2007, 55.7°N, 145.5°E 45 -0.4 August-September 2007 50.6°N, 146.7°E ln(Chl, ug l⁻¹) PAR, E m⁻² day 35 -0.7PAR^{op} -1.0 25 -1.3 15 8 -1.6 24 27 33 36 39 42 45 5 30 PAR, $E m^{-2} day^{-1}$ 249 263 270 212 219 227 234 241 256 Julian Day September 2007 -0.3 59.0°N, 155.5°E Δ ln(Chl, ug l⁻¹) -0.5 -0.7 -0.9 18 21 24 27 30 PAR, $E m^{-2} day^{-1}$

Impact of the East-China Sea waters



Impact of the East-China Sea waters



Yangtze River discharge~ 900 km³ yr⁻¹; Okhotsk Sea is getting~ 0.8 Sv (Soya volume transport)/3 Sv (volume transport through Tsushima Strait)· 900 km³ yr⁻¹ ~ 240 km³ yr⁻¹
Amur River discharge ~ 320 km³ yr⁻¹

•Yangtze River (per year) \rightarrow dissolved organic carbon (1.2 ·107 tones), nitrogen (5.4 ·105 tones), toxic elements (arsenic-1600 tones, thallium), organic pollution.

 Dam construction led to decreased
 Yangtze sediment discharge and seawater SiO₂ (East-China and Japan Seas)

CNP fluxes and biological productivity North Pacific and Okhotsk Sea. Atmosphere-ocean CO₂ flux



CNP fluxes and biological productivity Okhotsk Sea. Atmosphere-ocean CO₂ flux



CNP fluxes and biological productivity Okhotsk Sea. Future changes.

- Climate change will suppress vertical mixing by thermal stratification and decreases in surface salinity in the subpolar regions (i.e. Manabe, Stouffer, 1993; Manabe, Stouffer, 2000). These changes would lead to the decreased of the autotrophic phytoplankton biomass (expressed by chlorophyll concentrations) in the subarctic Pacific, Bering and Okhotsk Sea (i.e. Sarmiento et al., 2004). However the model applied to study climate changes of the biological productivity do not take into account the effect of tidal mixing on seawater productivity. The high primary production values in the Okhotsk Sea are commonly confined to dynamically active zone. Increased stratification should not significantly reduce the nutrient input and biological productivity in the areas (straits, shelf breaks, banks) with the strong vertical mixing induced by tides.
- For the northern Okhotsk Sea area the future changes in biological productivity will be determined by impact of climate change on cloudiness (and solar radiation) over the Okhotsk Sea.
- Increased seawater temperature may lead to shifts in Okhotsk Sea ecosystem structure and dynamics. Decrease of diatom biomass due to warming could significantly reduce the biological productivity in the off shore areas of the Okhotsk Sea. The role of Okhotsk Sea as a sink for the atmospheric CO₂ will be significantly decreased.

Seawater acidification and excess carbonate dissolution Subarctic North Pacific



Seawater acidification and excess carbonate dissolution Okhotsk Sea



Seawater acidification and excess carbonate dissolution Okhotsk Sea

• Due to low carbonate content of the shelf sediment (less than 1%) (Saidova, 1997), Okhotsk Sea probably could not be considered as important agent able to neutralize the anthropogenic CO₂ supply into the seawater.

Thank you!