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Present and Future Changes in the Okhotsk Sea waters

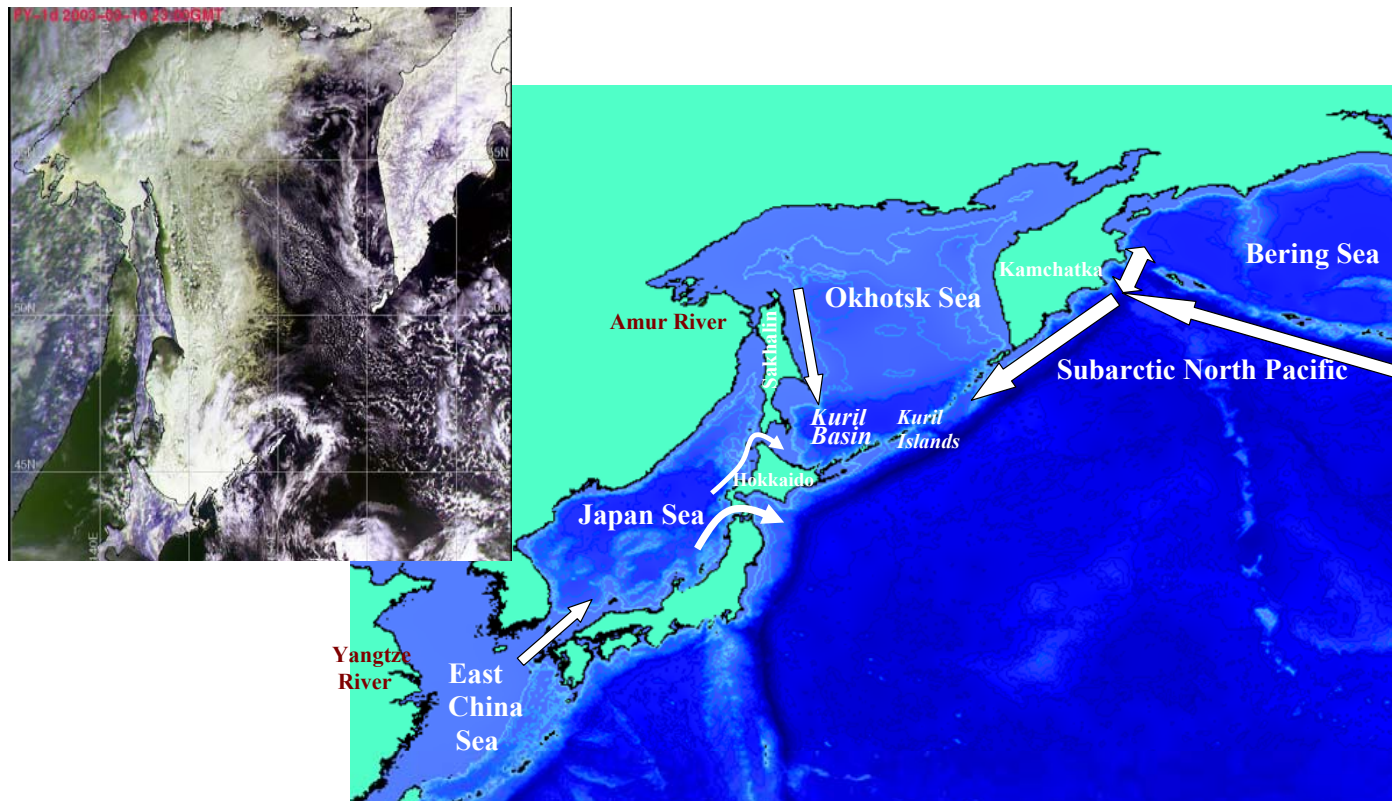
Andrey G. Andreev

Pacific Oceanological Institute, Vladivostok

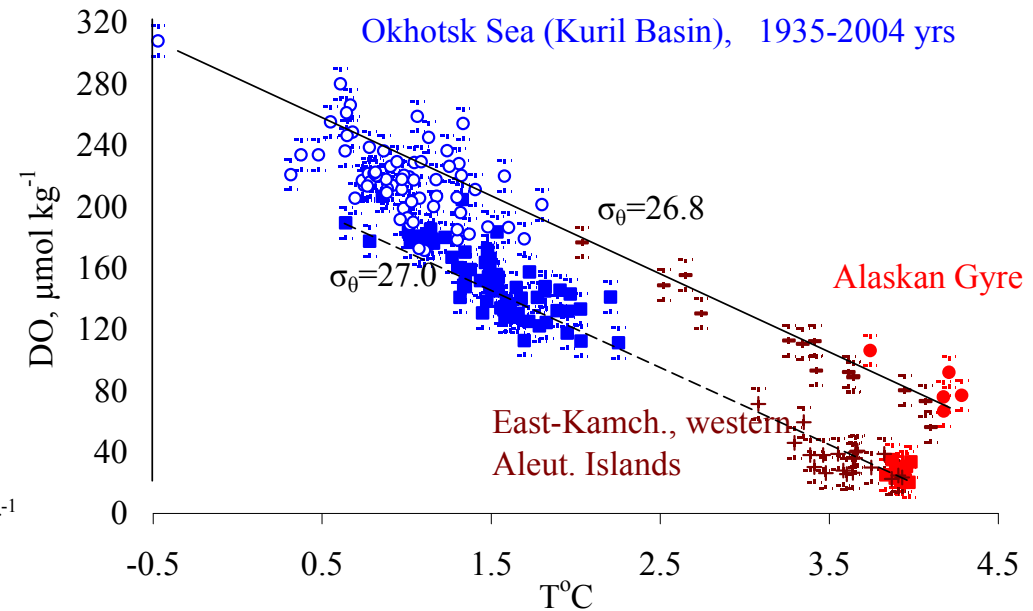
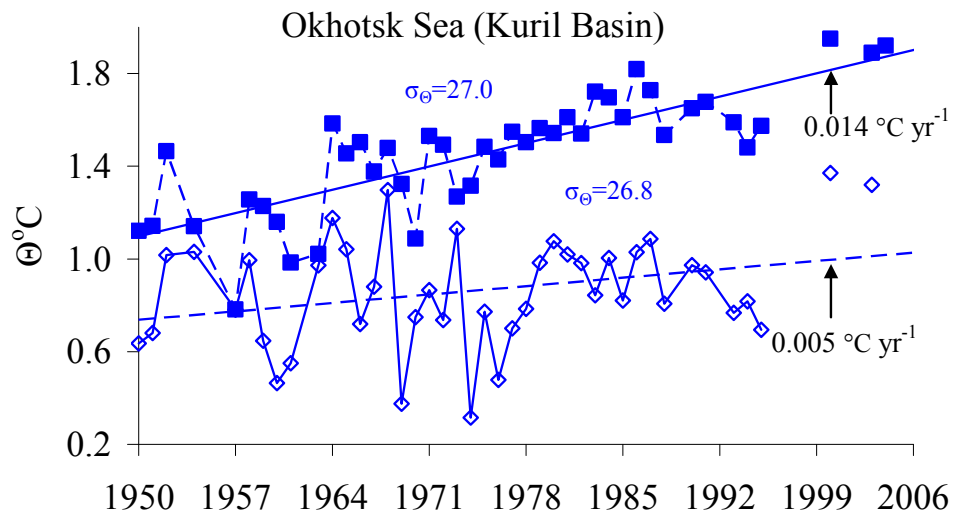
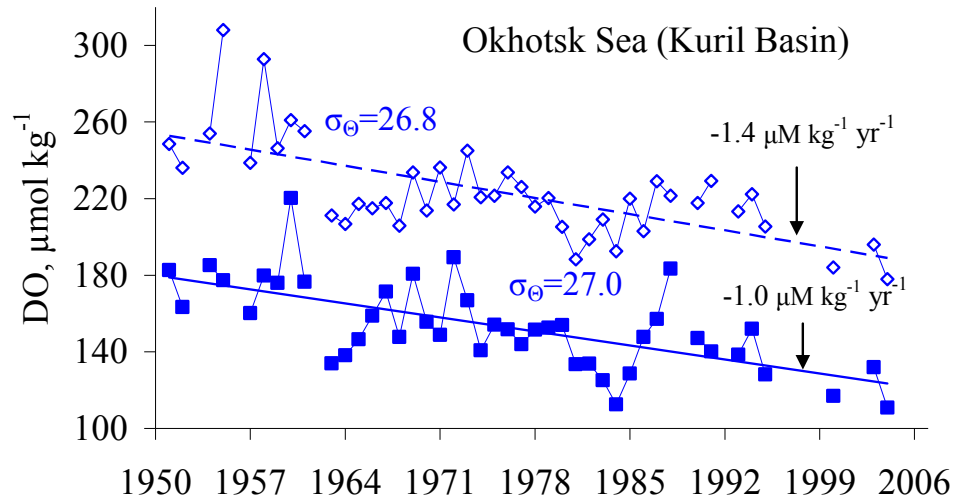


“Toward a Sustainable Low Carbon Society- Green New Deal and Global Change”, November 2009

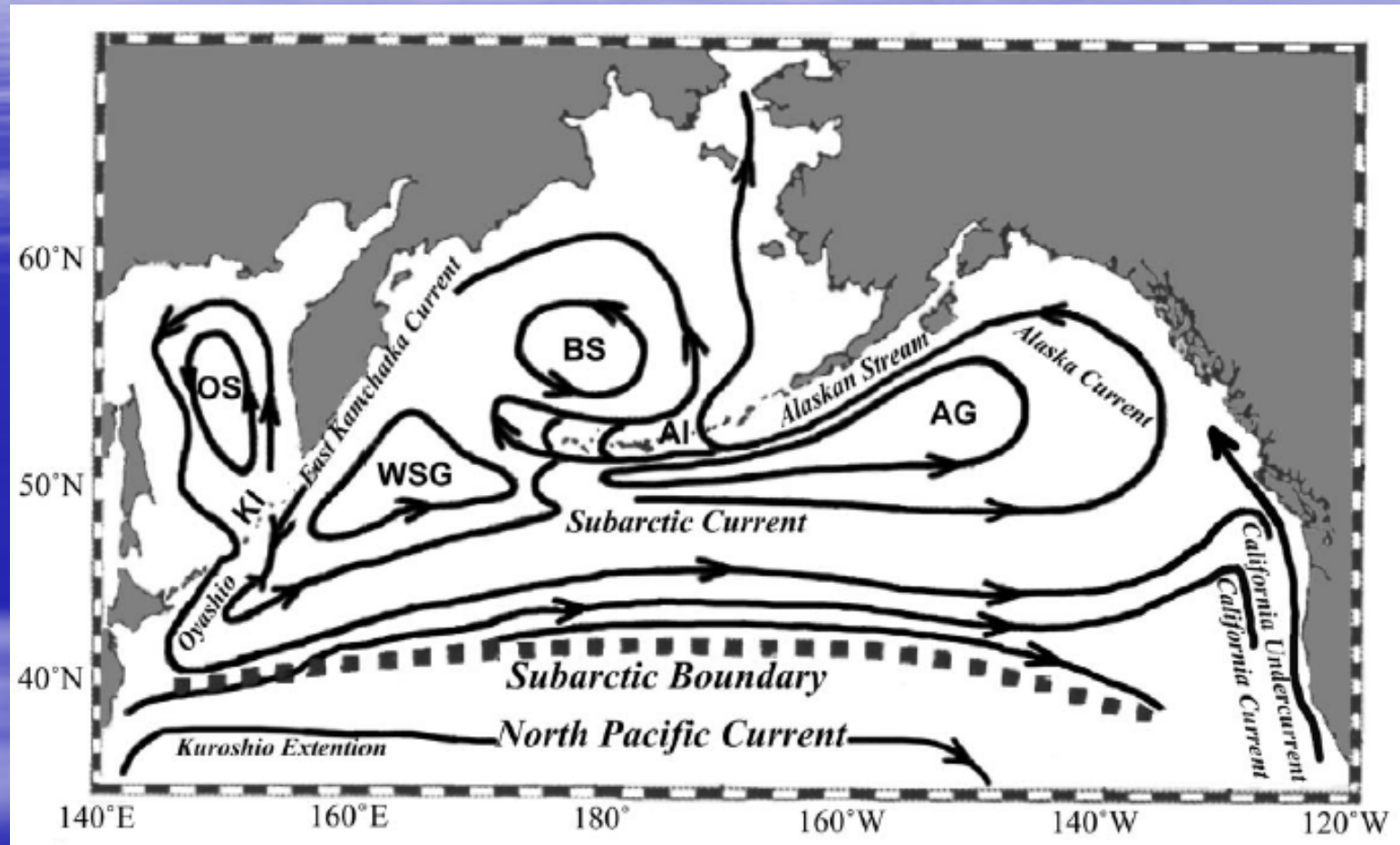
- Recent changes in the intermediate and surface waters of the Kuril Basin
- Main features of the CNP fluxes and biological productivity. Future changes of the CNP fluxes
- Impact of the East-China Sea waters
- Seawater acidification and excess carbonate dissolution



Okhotsk Sea. Intermediate waters.

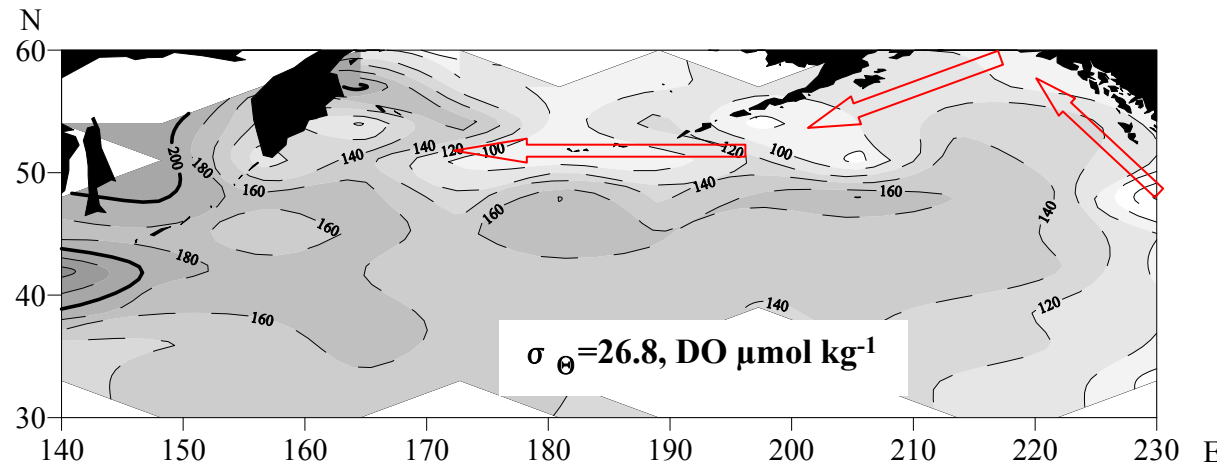
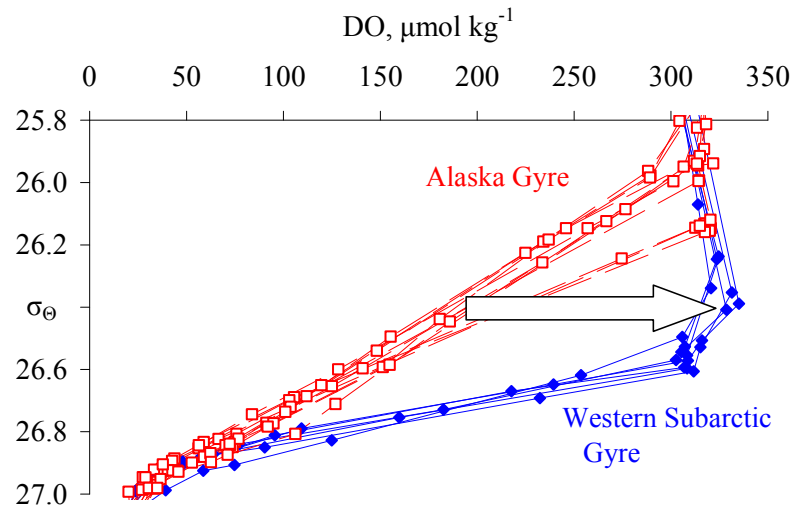
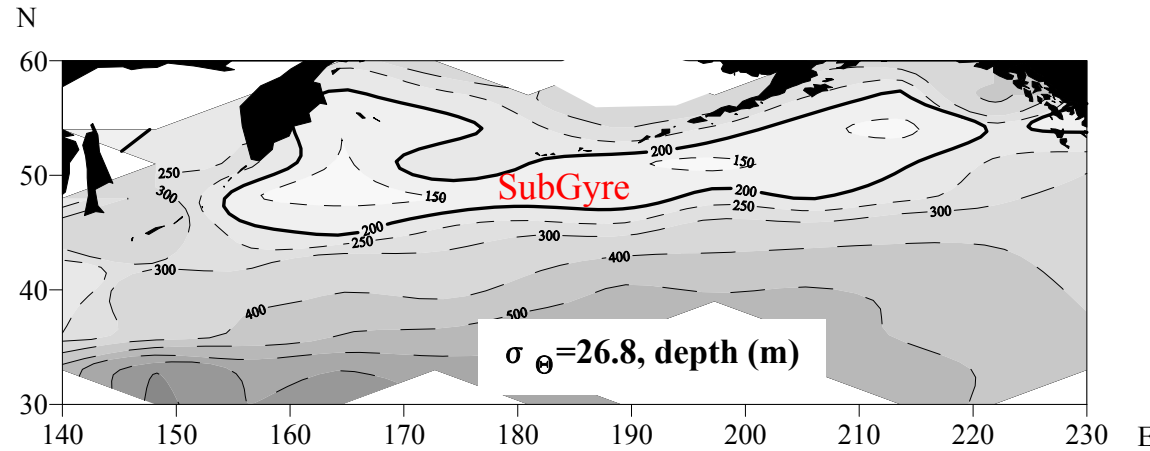
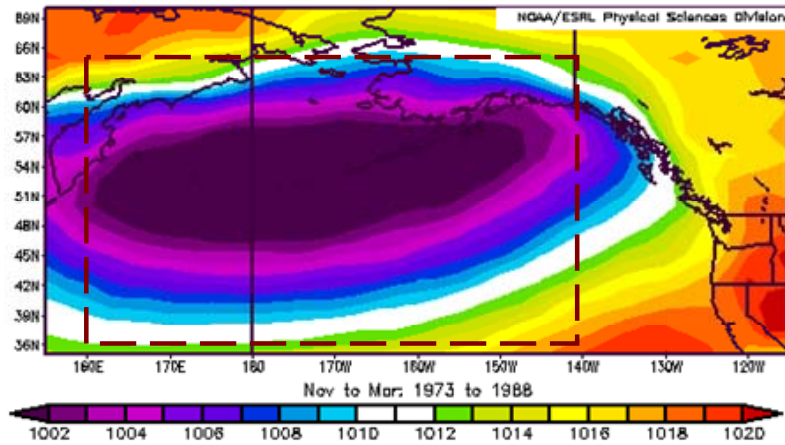


Northern North Pacific. Circulation pattern.



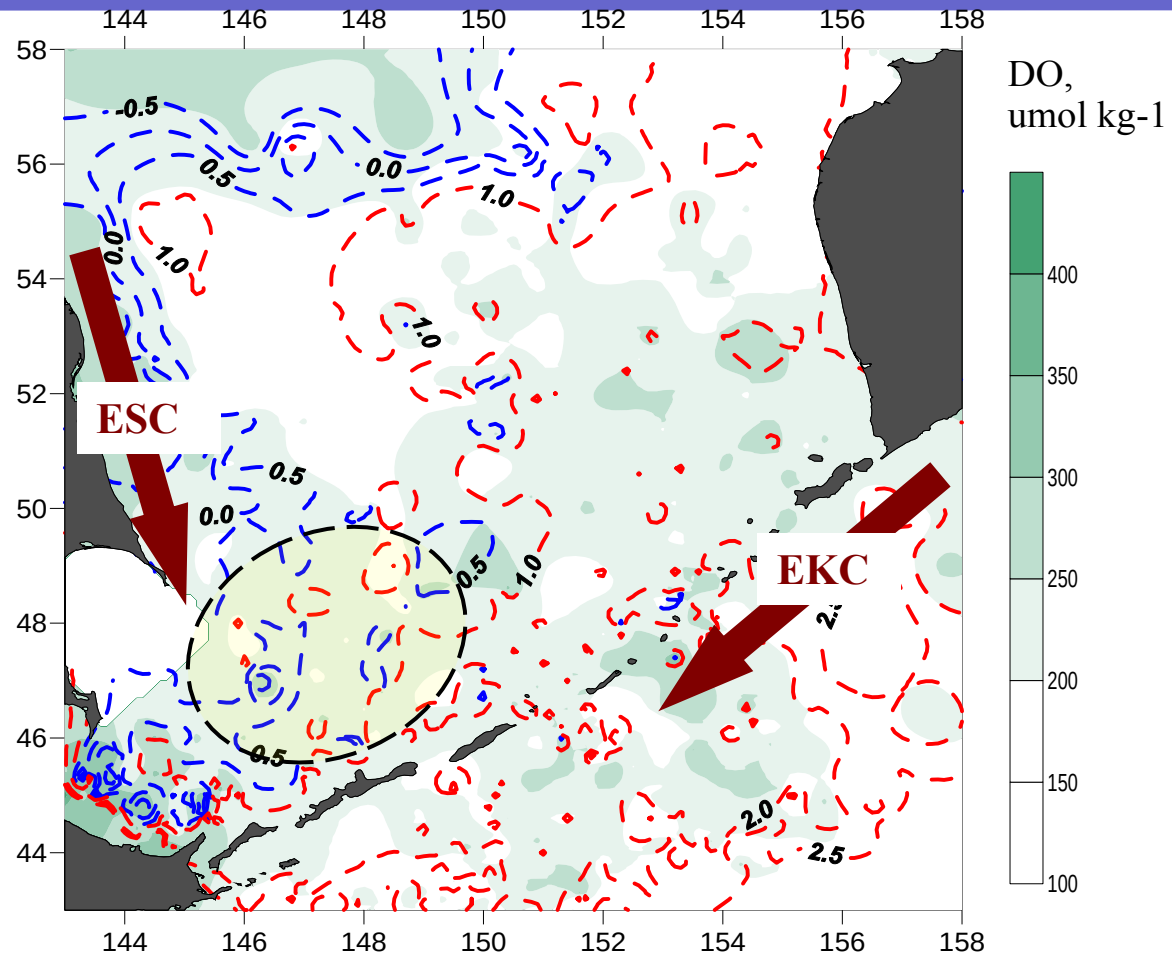
Northern North Pacific

Sea level pressure, mbar, November-March

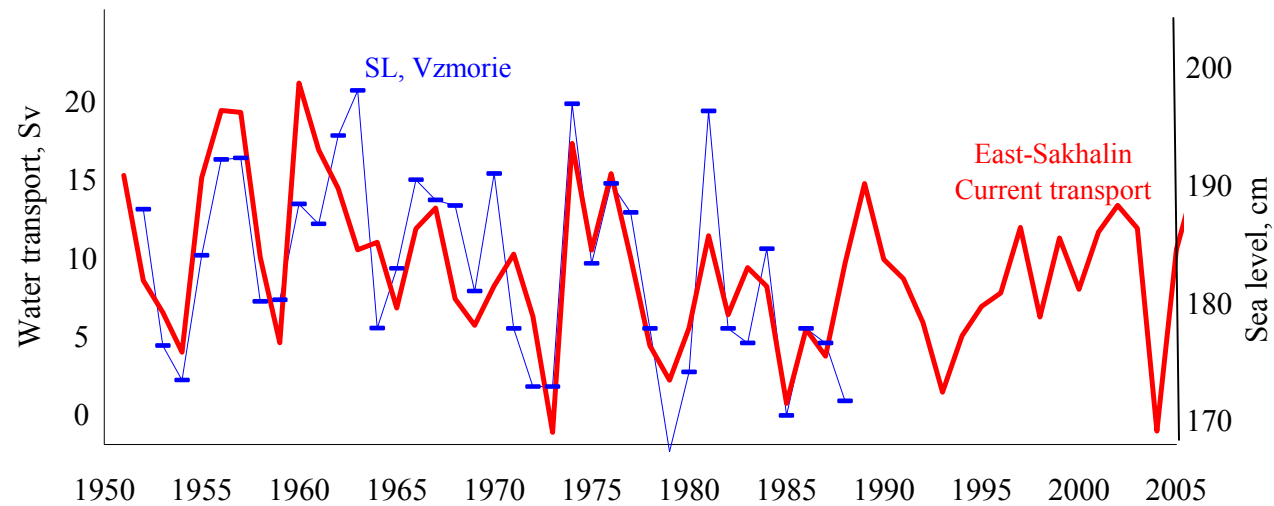
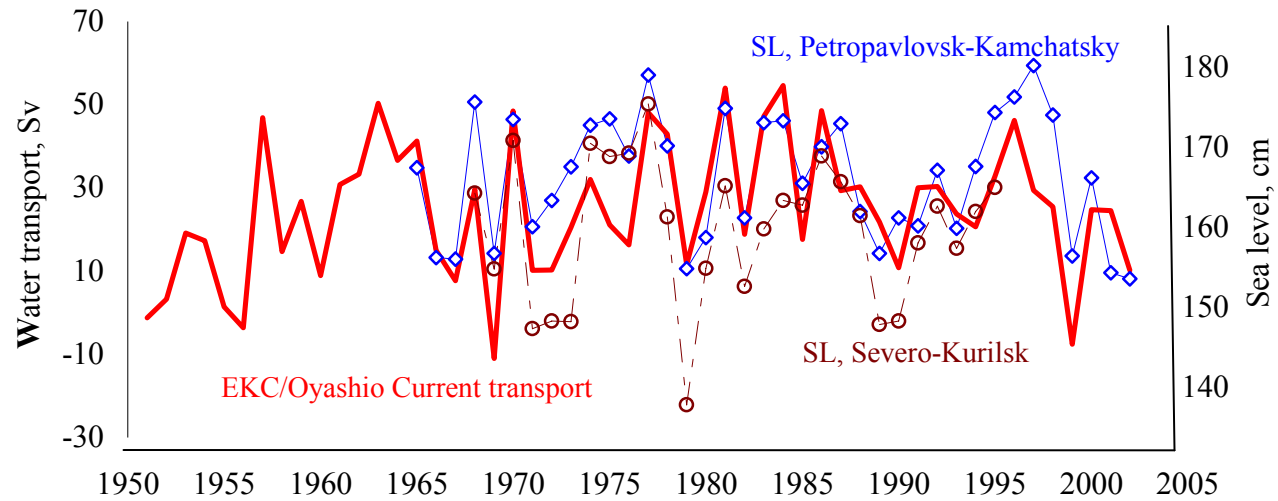


Okhotsk Sea

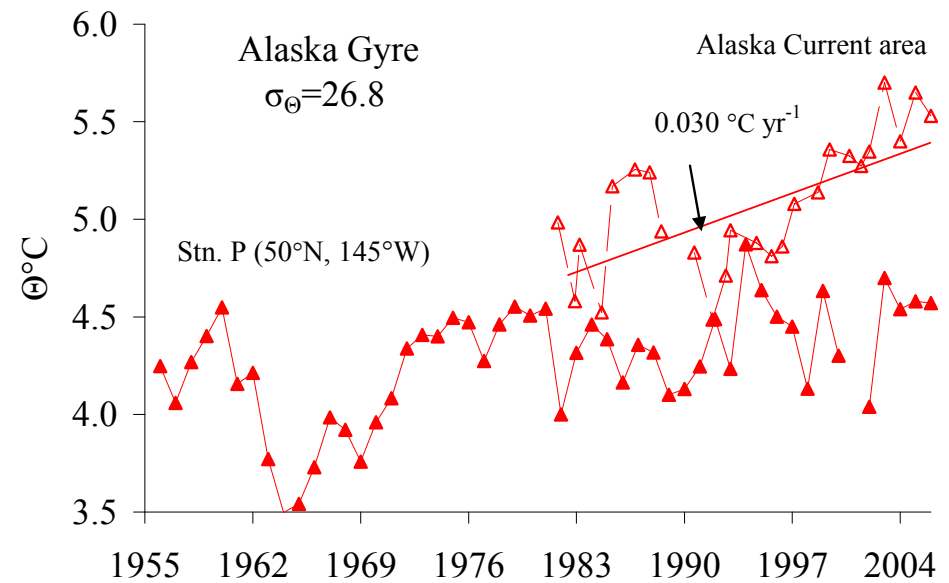
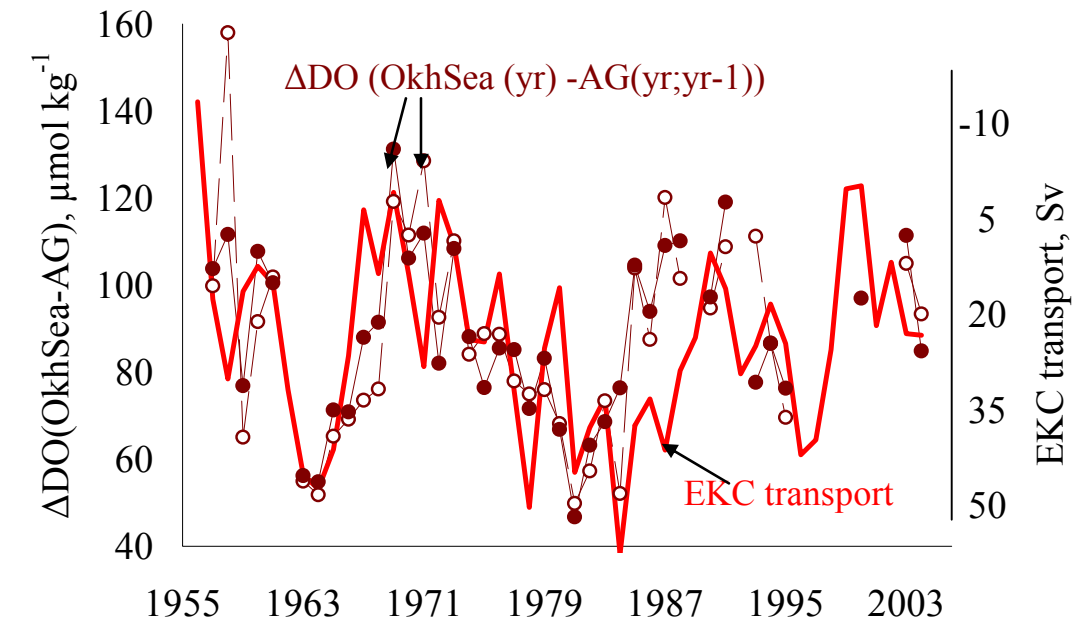
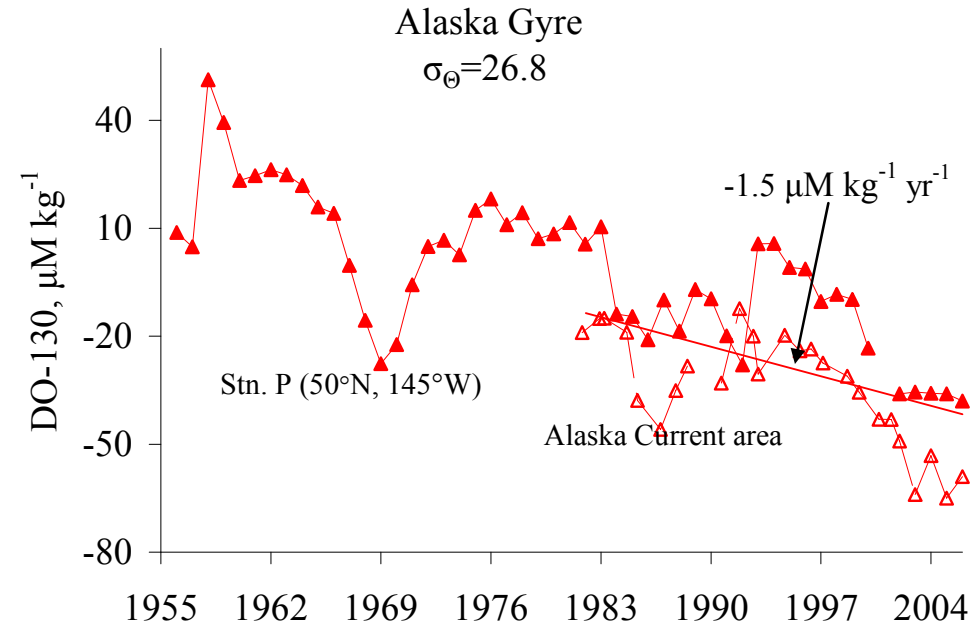
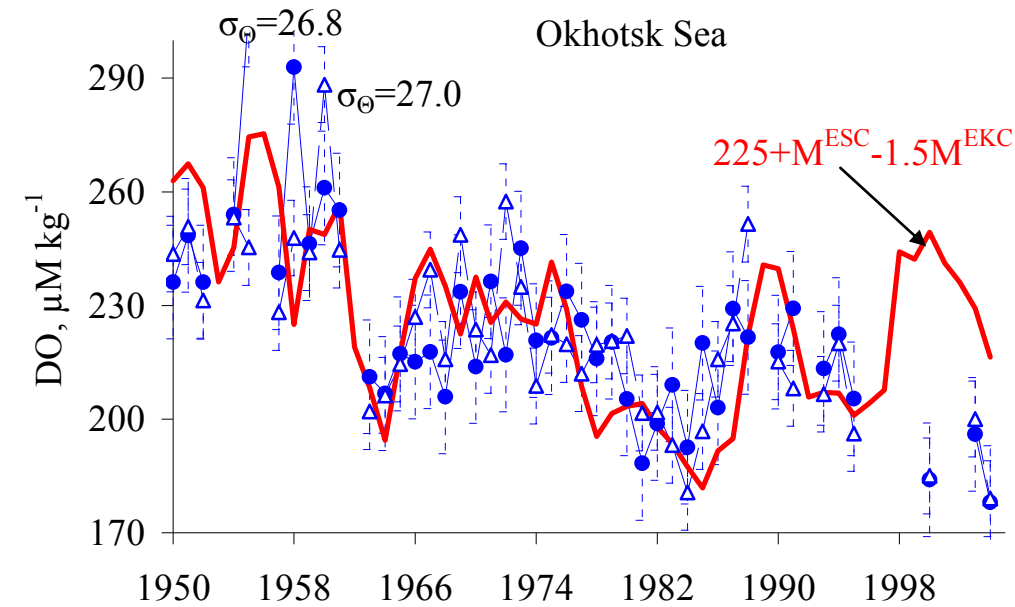
Temperature (blue and red dotted lines) and dissolved oxygen at $\sigma_\theta = 26.8$



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

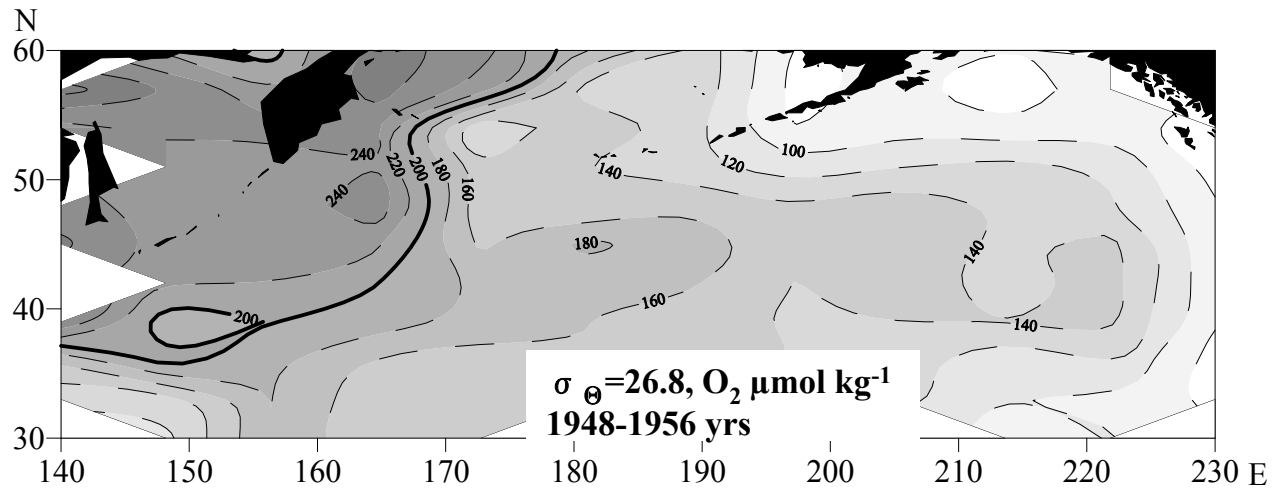
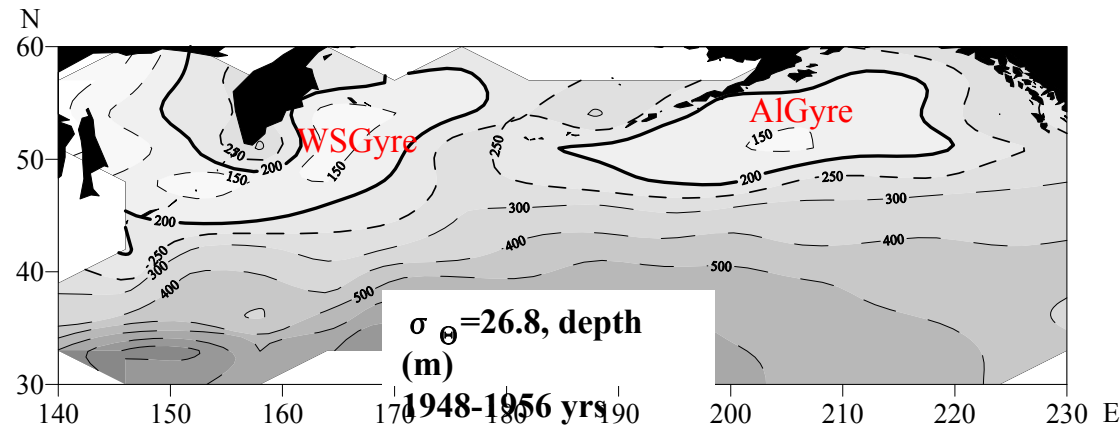
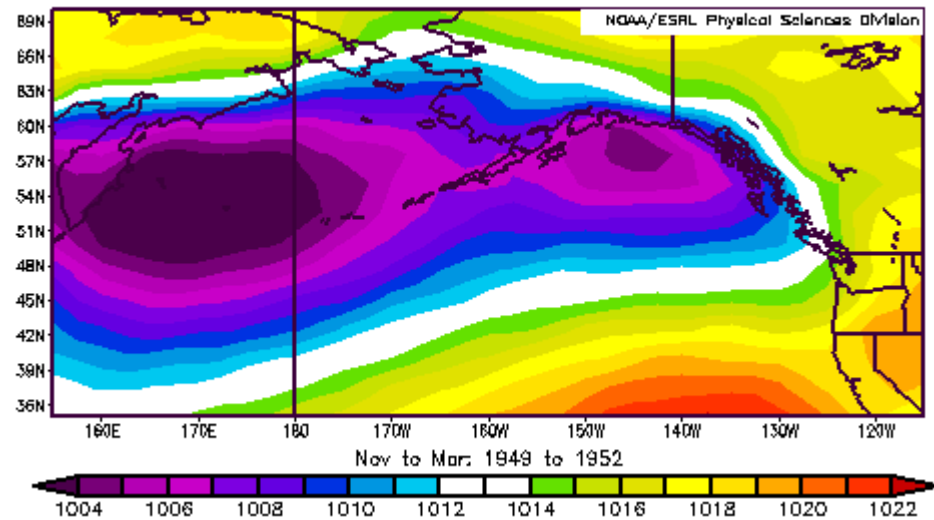


Okhotsk Sea and Alaska Gyre. Intermediate waters.

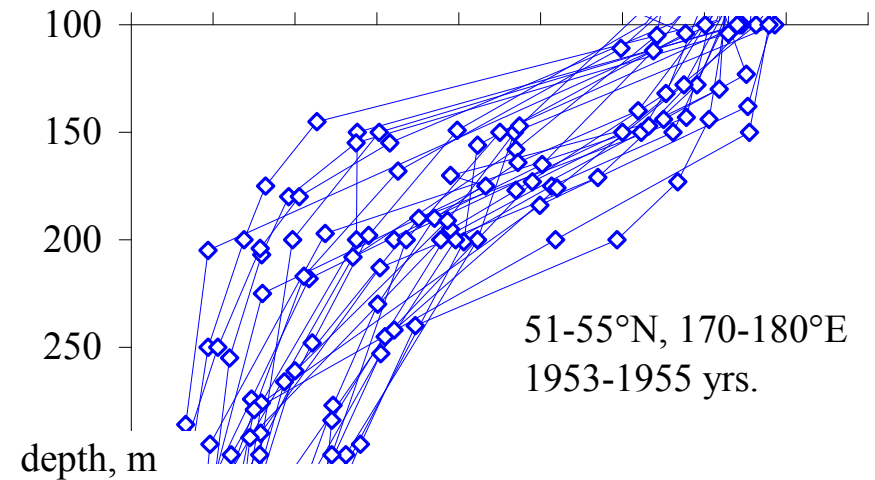
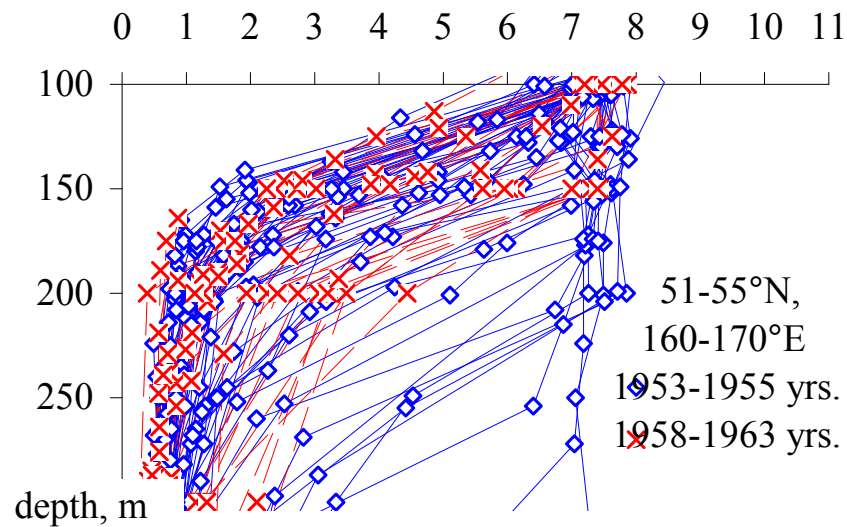
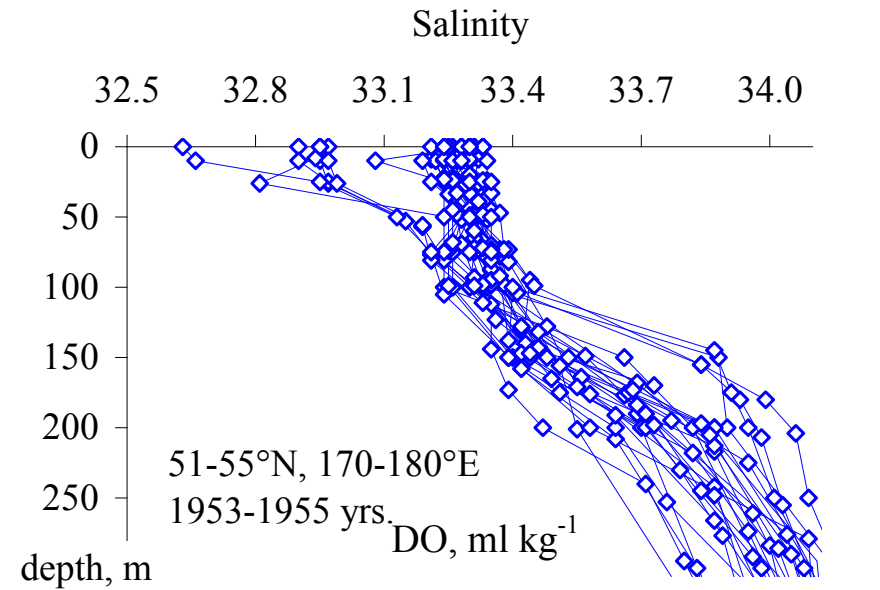
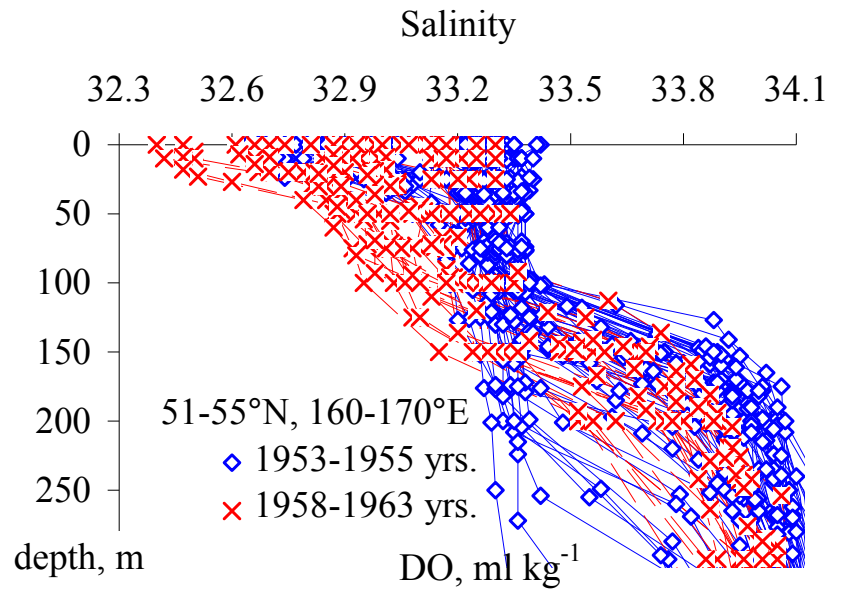


Northern North Pacific

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



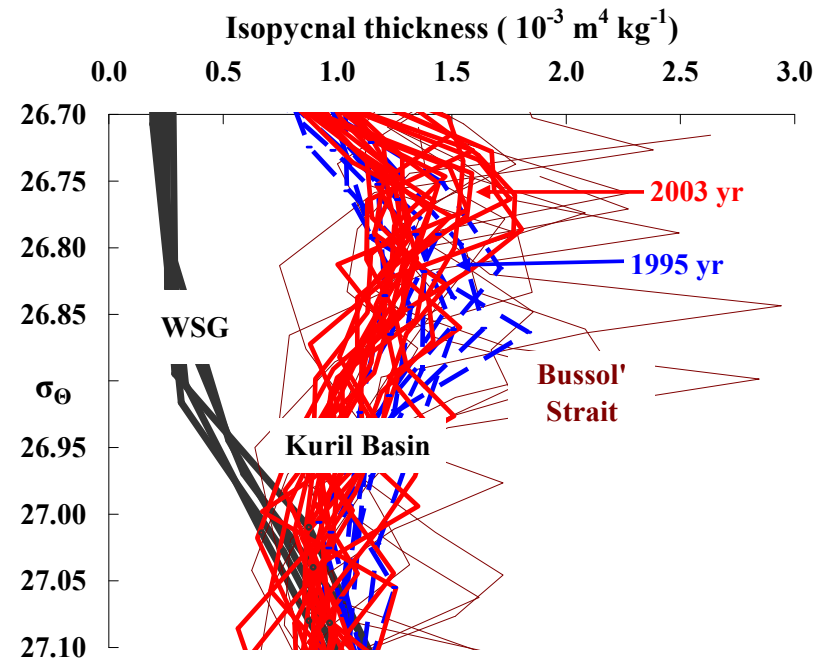
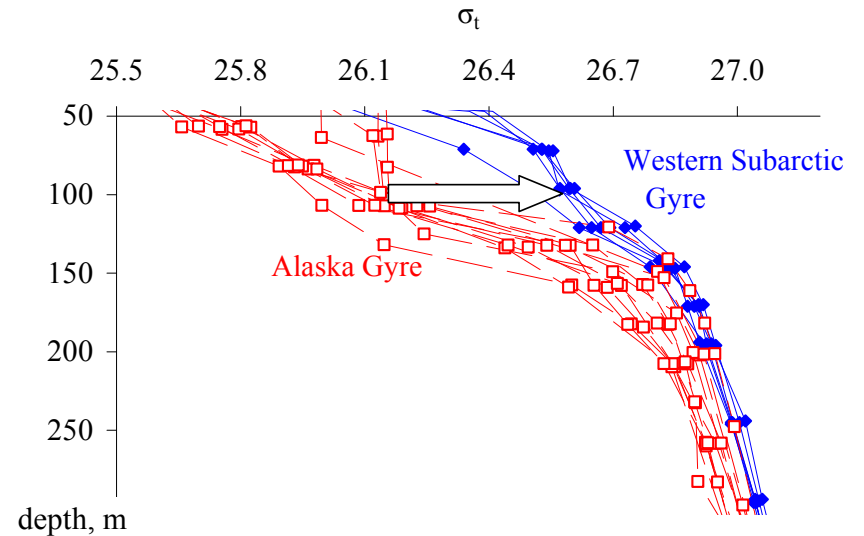
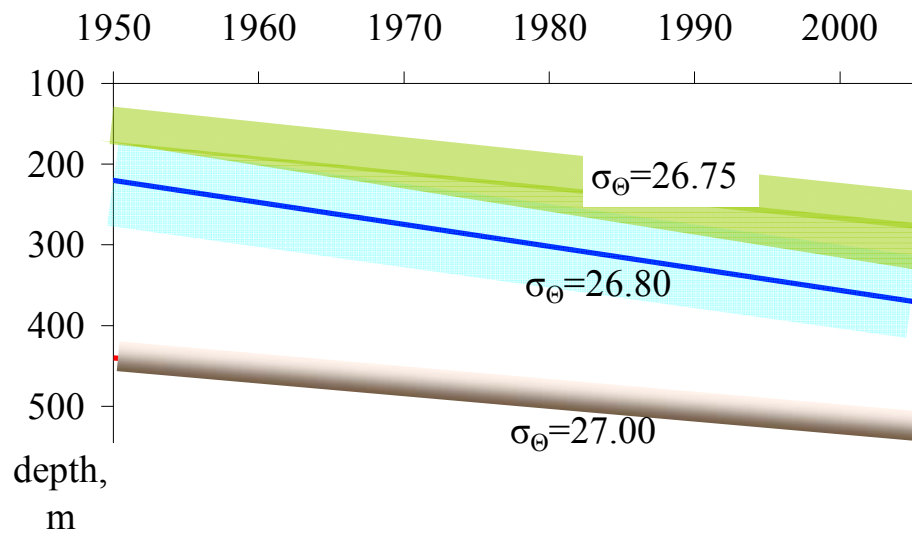
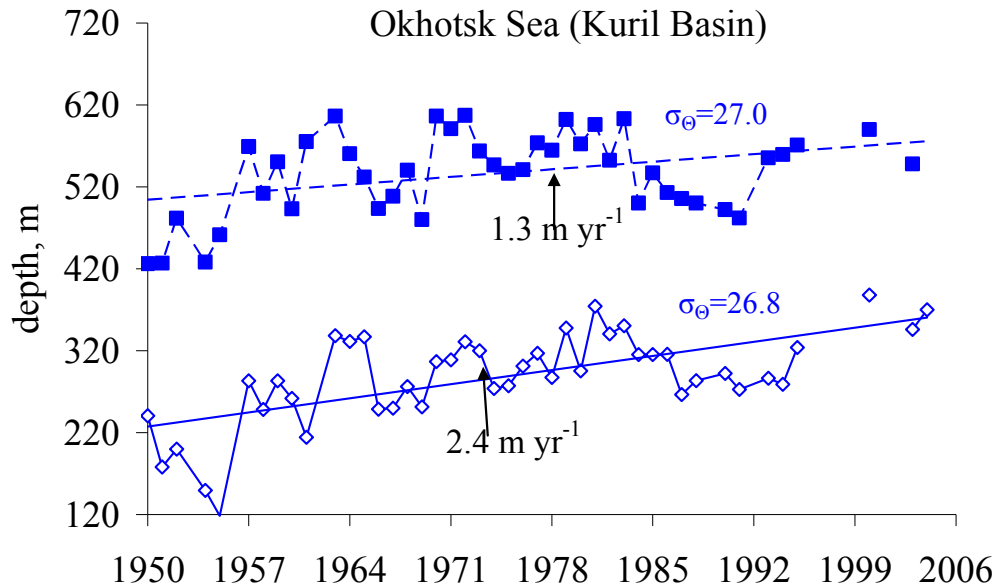
Bering Sea



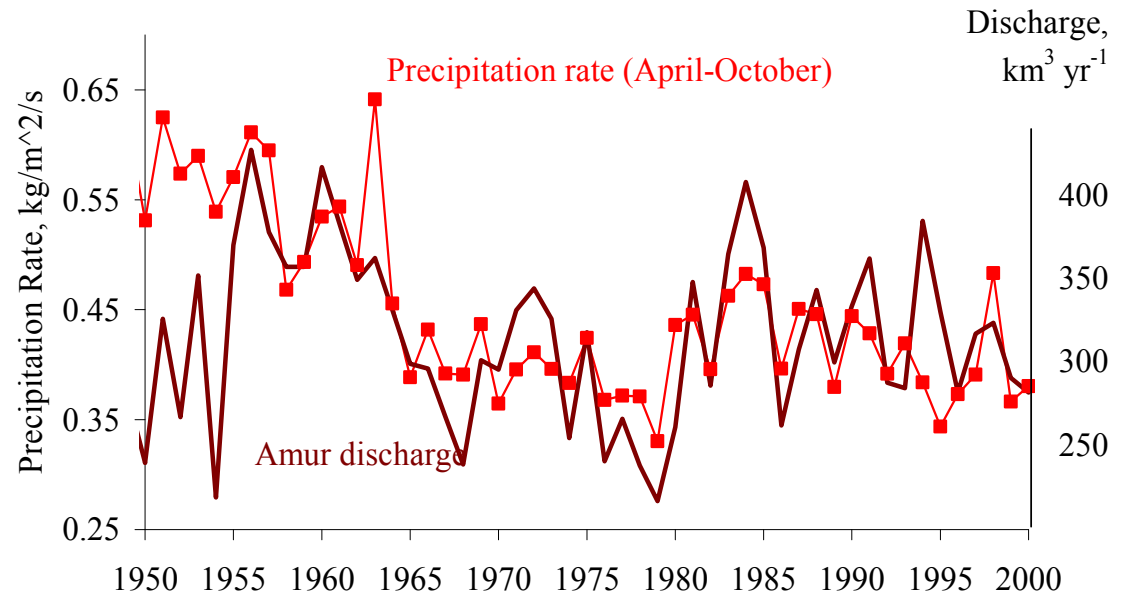
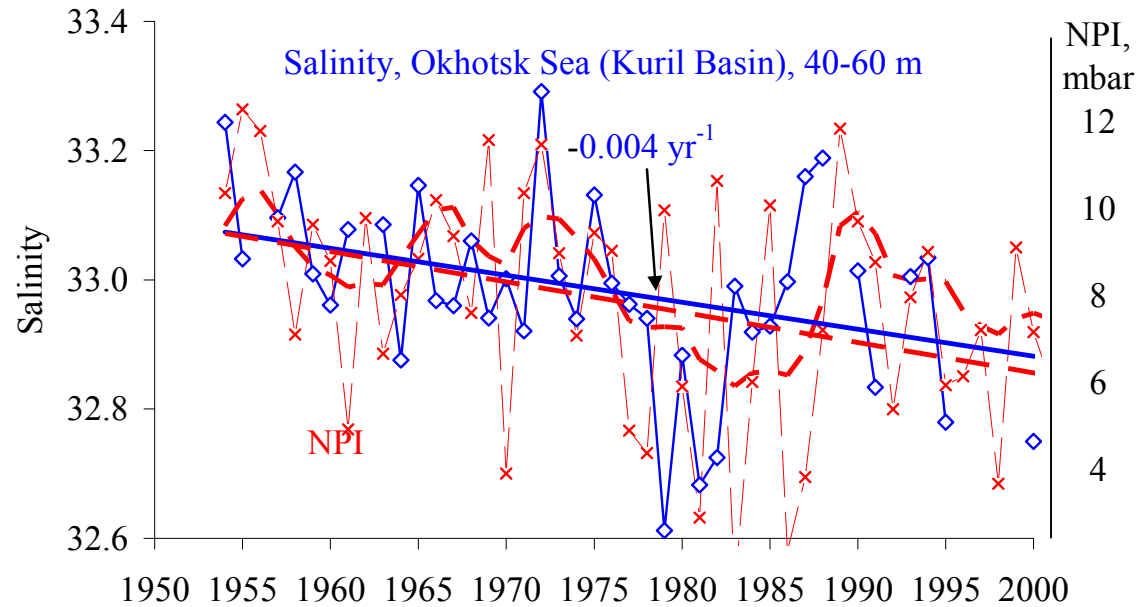
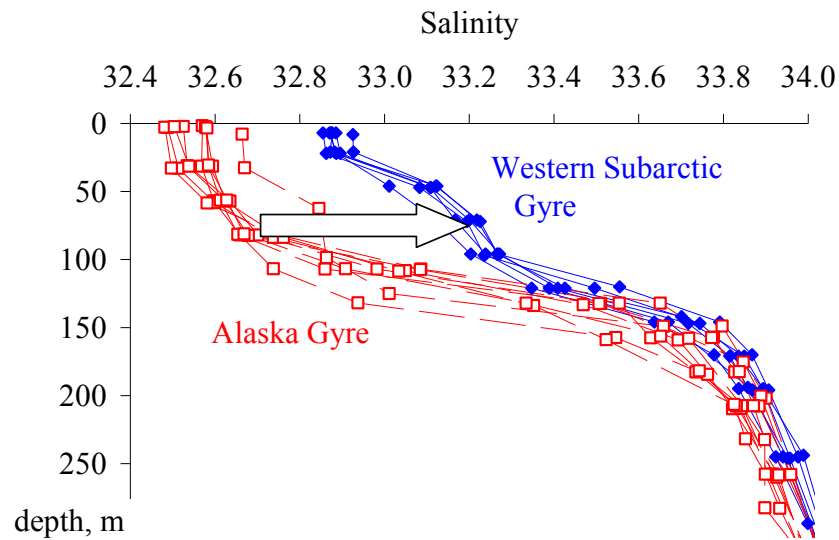
Difference in temperature and chemical parameters between the eastern subarctic Pacific (Alaska Gyre) and the Okhotsk Sea (Kuril Basin region) on isopycnals of $26.8\sigma_{\theta}$ and $27.0\sigma_{\theta}$

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

Okhotsk Sea. Intermediate waters.



Okhotsk Sea. Surface waters



Okhotsk Sea. Intermediate and surface waters. Future changes

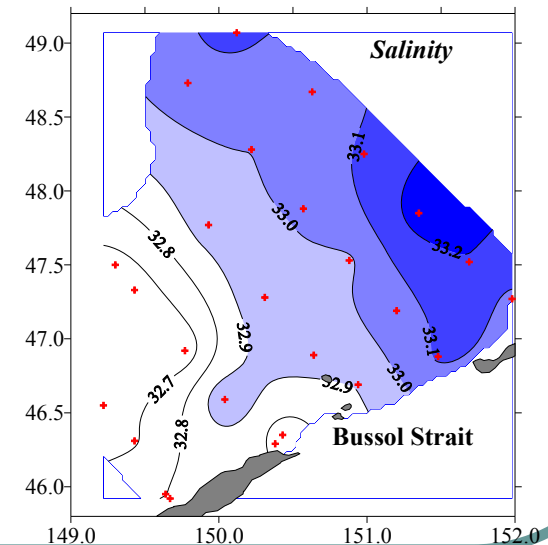
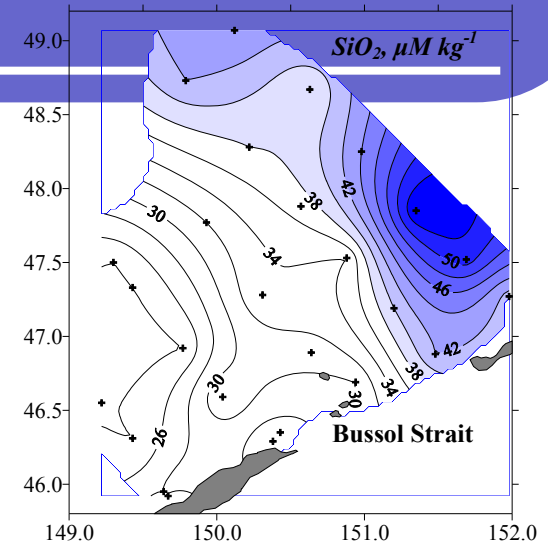
- Climate change will suppress vertical mixing by thermal stratification and decreases in surface salinity in the subpolar regions (i.e. Manabe, Stouffer, 1993; Manabe, Stouffer, 2000).
- Strengthening of the Aleutian Low in winter (Mohov et al., 2005) could force further an increase of the temperature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

CNP fluxes and biological productivity

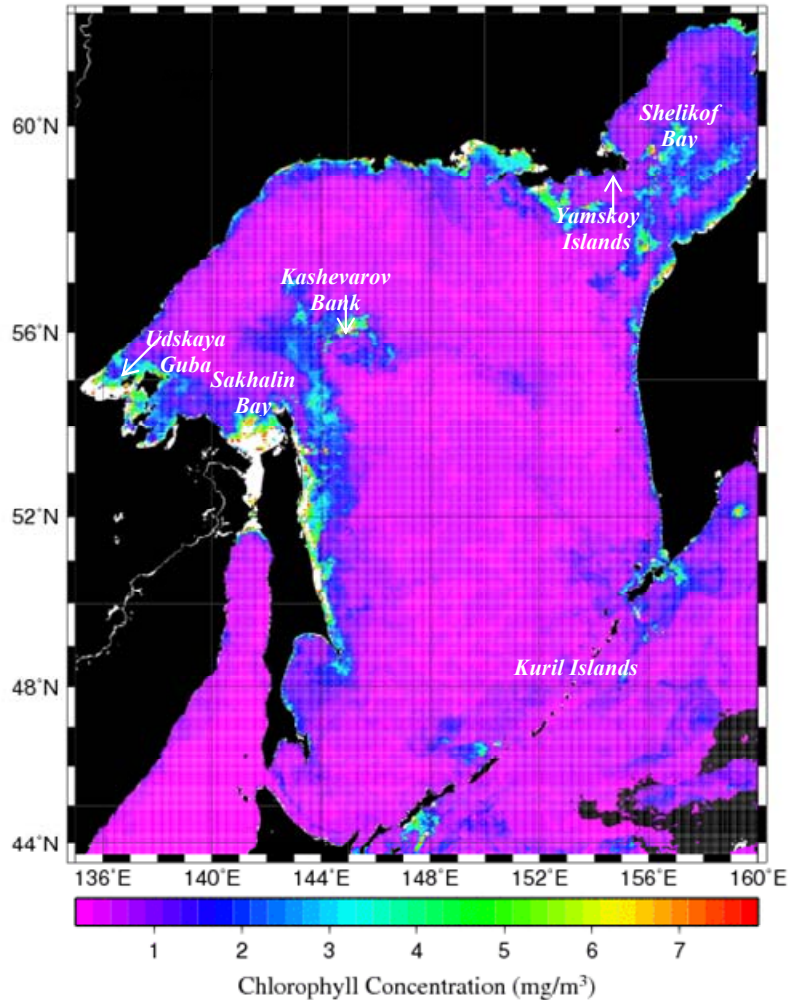
Salt, dissolved inorganic phosphorus (DIP), nitrogen (DIN), and carbon (DIC) fluxes (10^{12} , yr^{-1}) and primary production (10^{12} , yr^{-1}) for the Okhotsk Sea. The water mass exchange (Q) is reported in Sverdrup (Sv)

	Salt	DIP	DIN	DIC
Pacific –Okhotsk Sea, Q =5 Sv	20±3 kg of salt	0.04±0.01 mole	1.0± 0.1 mole	4.1± 0.7 mole
Japan Sea –Okhotsk Sea, Q=0.6 Sv	7± 4 kg of salt	-0.04± 0.01 mole	-0.6± 0.1 mole	-5.4 ± 2 mole
Riverine and (P- E), 0.026 ± 0.05 Sv	-27± 5 kg of salt	<0.001 mole	<0.01 mole	0.16± 0.03 mole
Sea- air CO₂ flux				4.5±1.5 mole
Residual	0 ± 7 kg of salt	0.0±0.02 mole	0.4 ± 0.2 mole	3.4 ± 3 mole
Total Primary Production				60 mole

Okhotsk Sea, February 2003; 5 m



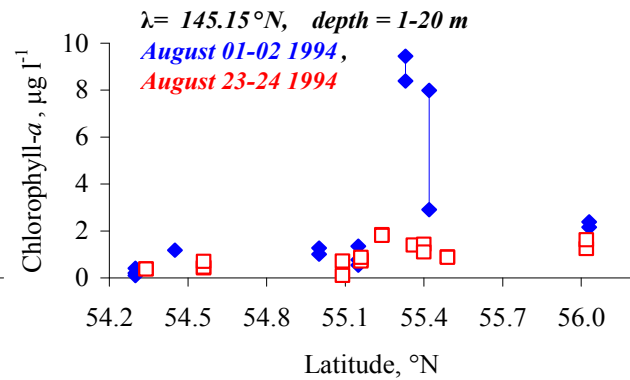
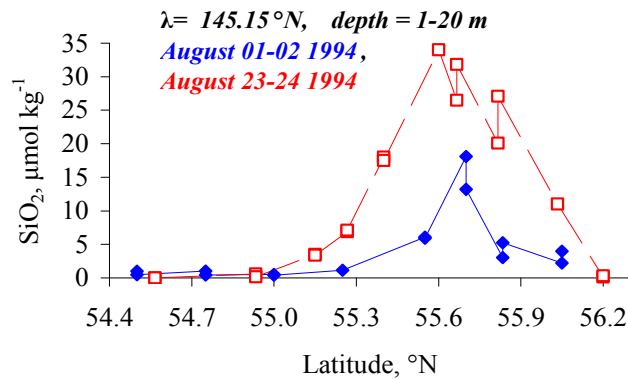
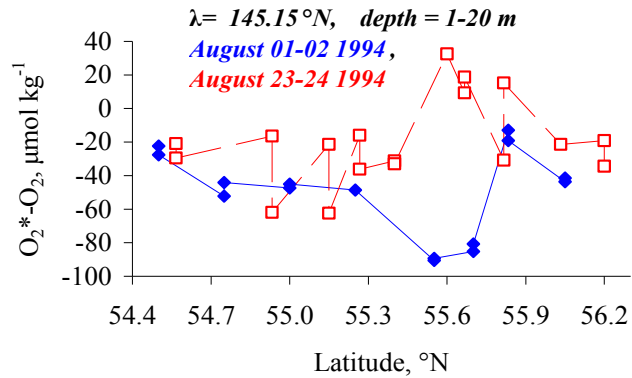
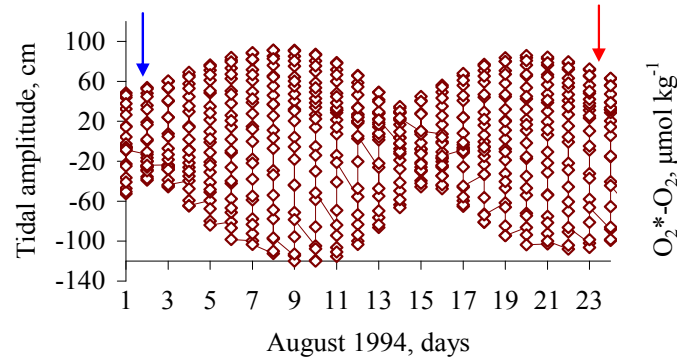
CNP fluxes and biological productivity



- 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, Utskaya 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 $3\text{--}4 \text{ gC m}^{-2} \text{ day}^{-1}$. 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).

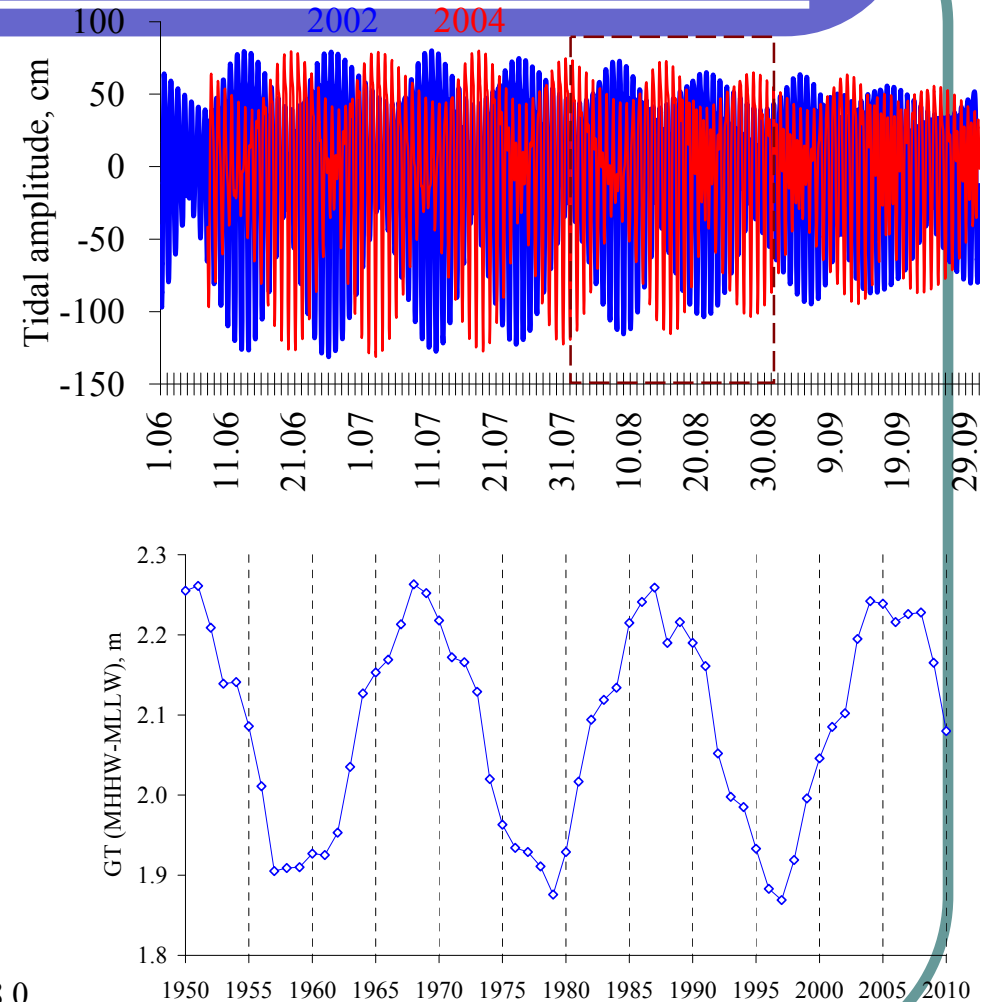
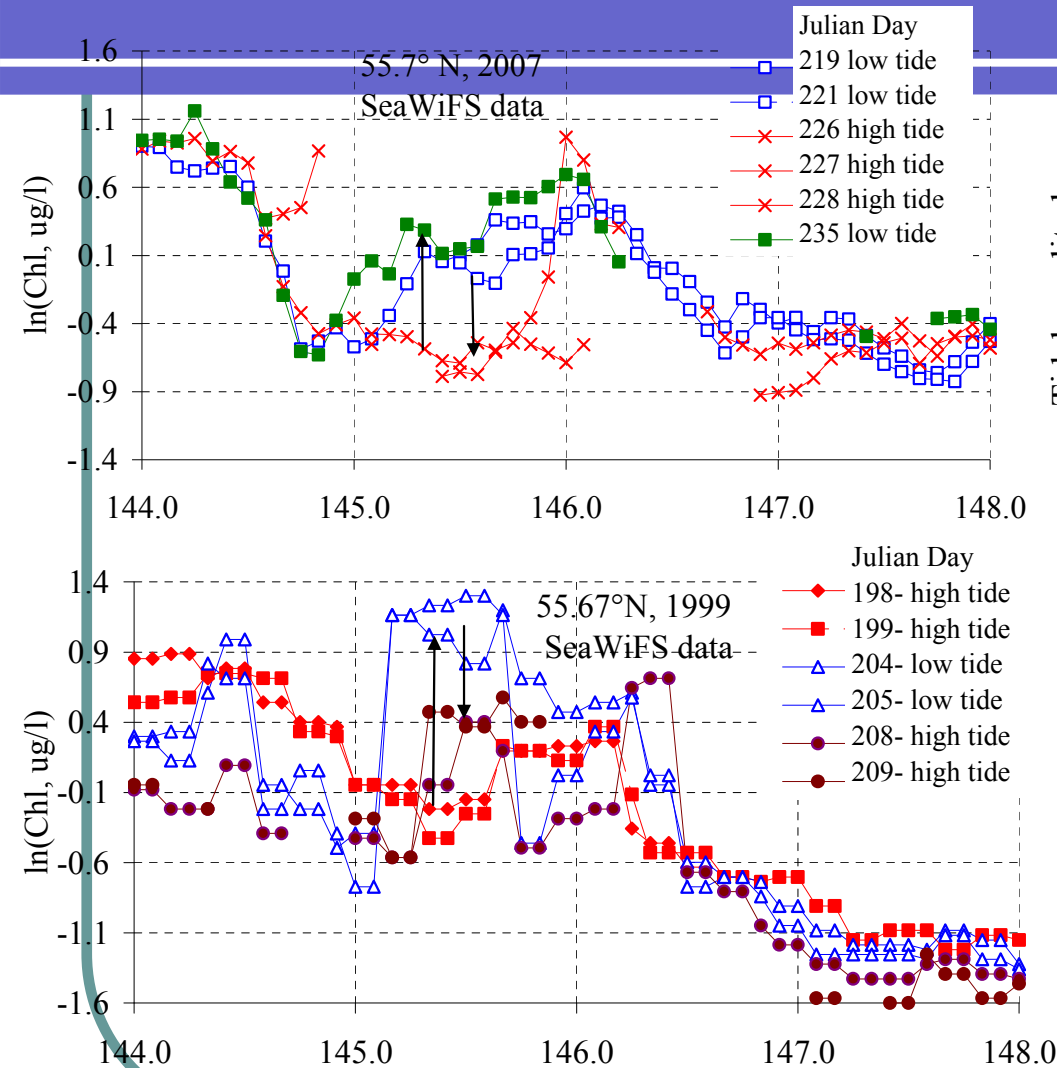
CNP fluxes and biological productivity

Okhotsk Sea. Kashevarova Bank area.



CNP fluxes and biological productivity

Okhotsk Sea. Kashevarova Bank area.

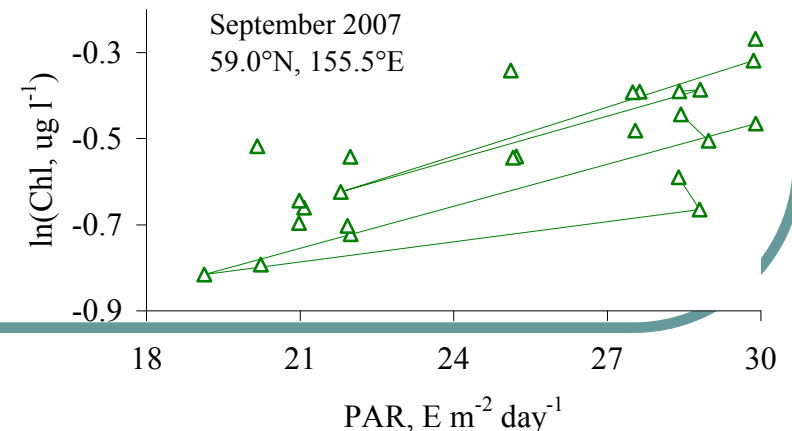
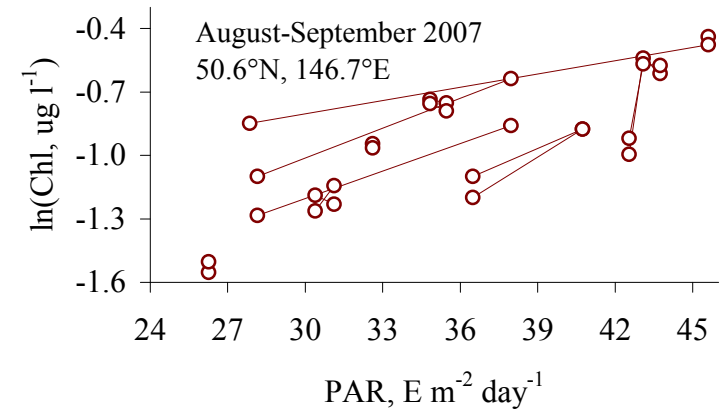
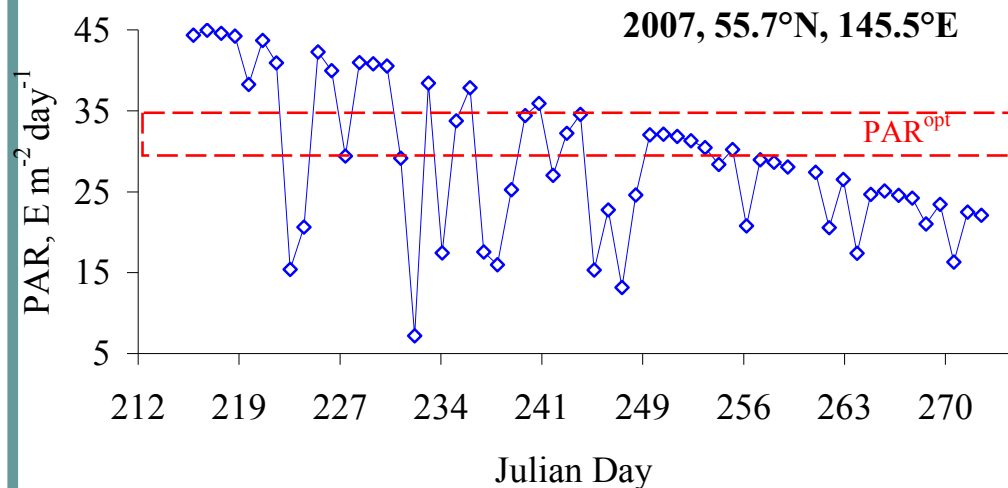


CNP fluxes and biological productivity

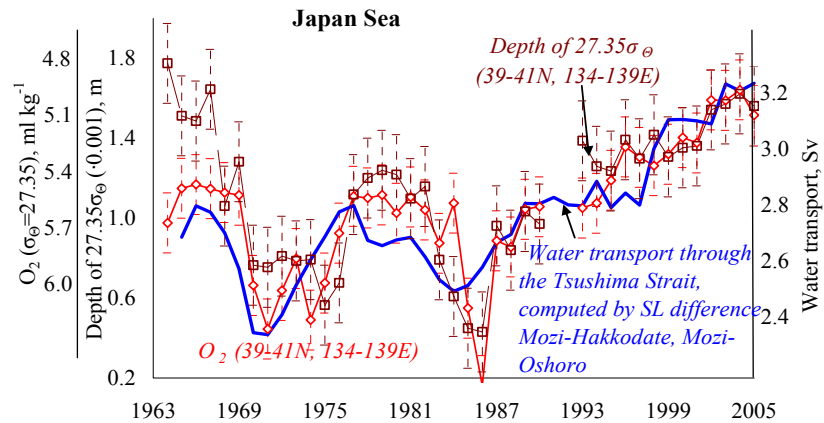
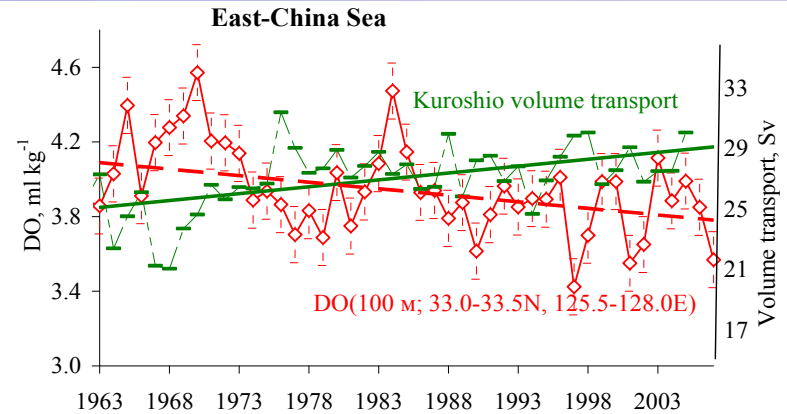
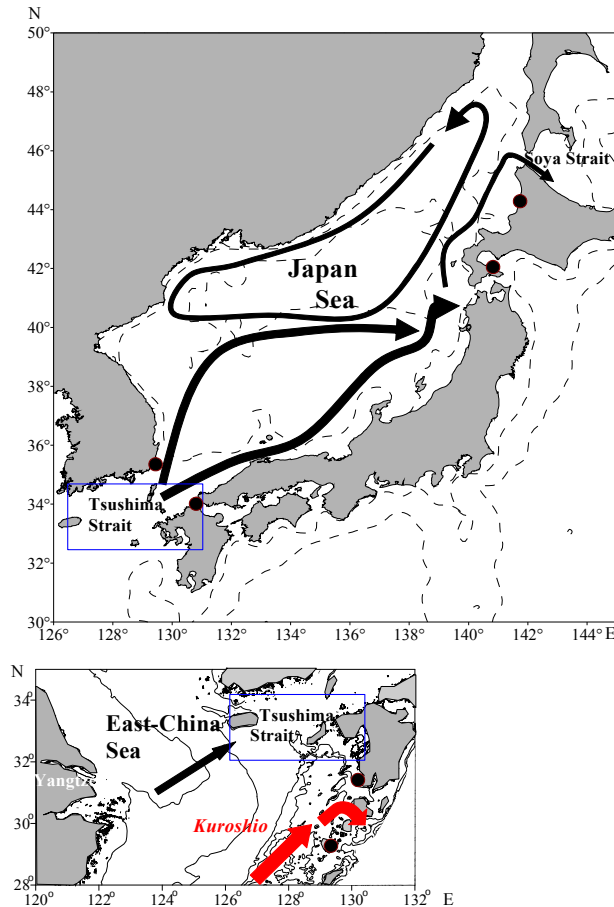
Okhotsk Sea

$\Delta(\text{Phyt_Biomass})/(\text{Phyt_Biomass}) \approx \Delta\text{Chl}/\text{Chl} \sim \psi^T \cdot I/I^{\text{opt}} \exp(1 - I/I^{\text{opt}}) \cdot f([\text{NO}_3], K_N, [\text{SiO}_2], K_{\text{Si}}) - \lambda^P$,
 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.

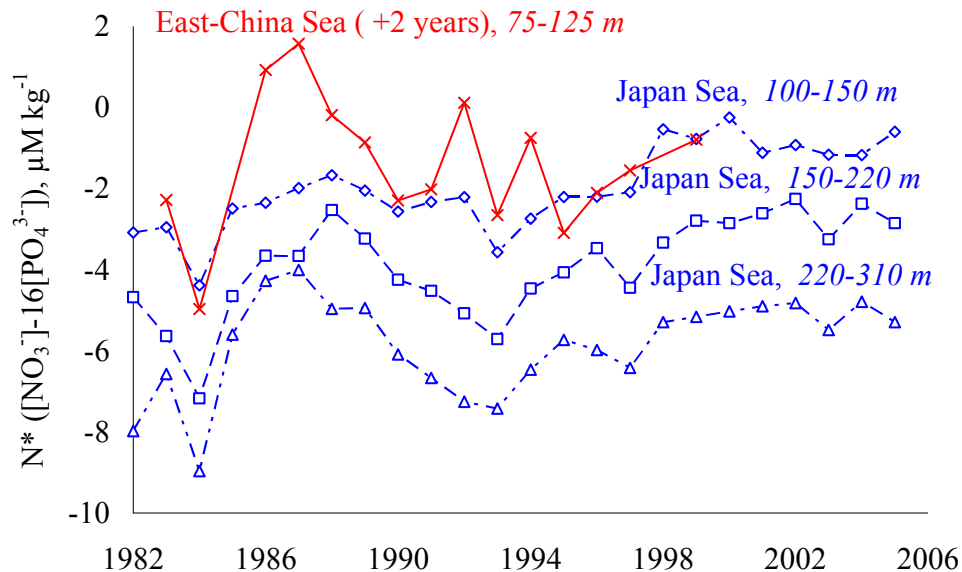
$$\text{PAR} \leq \text{PAR}^{\text{opt}}, \quad \Delta\text{Chl}/\text{Chl} \{\Delta\ln(\text{Chl})\} \sim k \cdot \Delta\text{PAR}$$



Impact of the East-China Sea waters



Impact of the East-China Sea waters



- **Yangtze River** discharge $\sim 900 km^3 yr^{-1}$; Okhotsk Sea is getting $\sim 0.8 Sv$ (Soya volume transport)/ $3 Sv$ (volume transport through Tsushima Strait) $\cdot 900 km^3 yr^{-1} \sim 240 km^3 yr^{-1}$

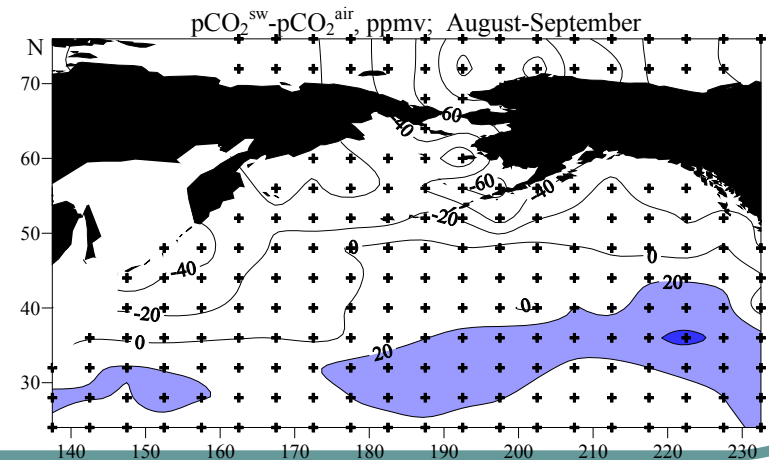
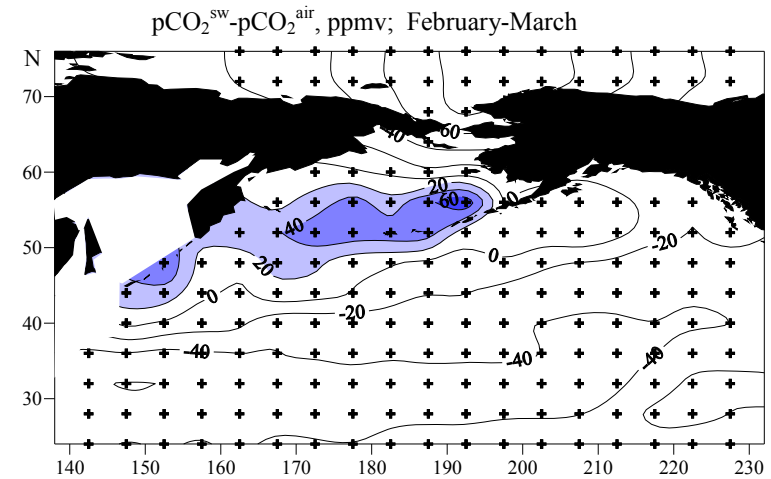
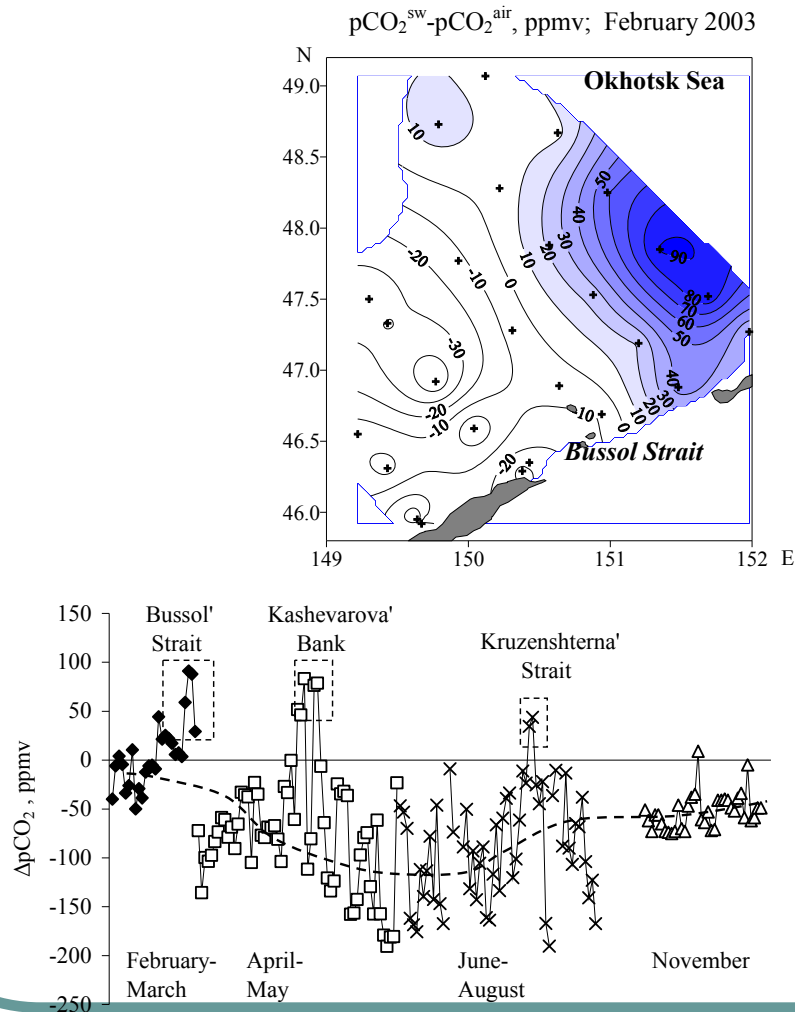
- **Amur River** discharge $\sim 320 km^3 yr^{-1}$

- **Yangtze River** (per year) $\rightarrow$ dissolved organic carbon ($1.2 \cdot 10^7$ tones), nitrogen ($5.4 \cdot 10^5$ tones), toxic elements (arsenic-1600 tones, thallium), organic pollution.

- Dam construction led to decreased **Yangtze** sediment discharge and seawater SiO_2 (East-China and Japan Seas)

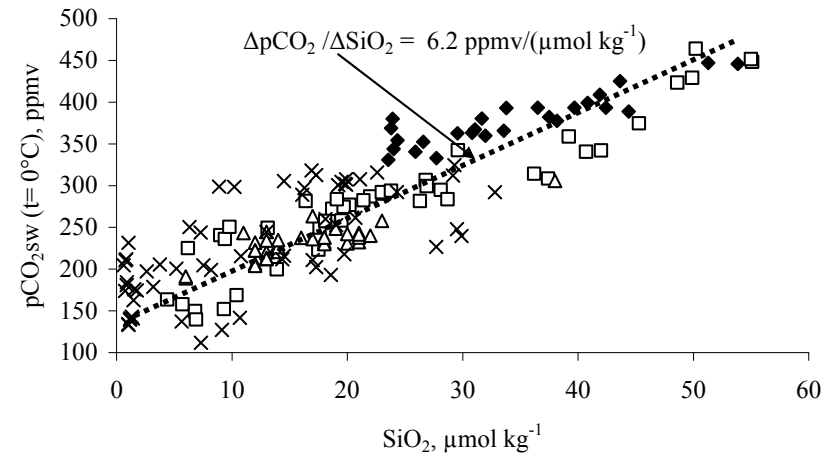
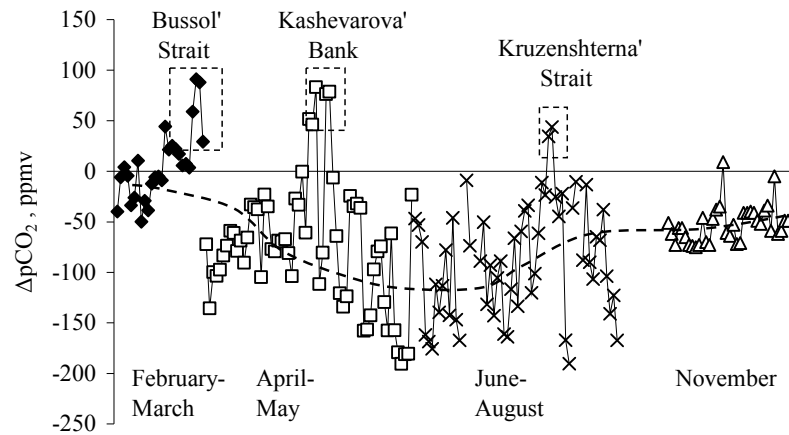
CNP fluxes and biological productivity

North Pacific and Okhotsk Sea. Atmosphere-ocean CO₂ flux



CNP fluxes and biological productivity

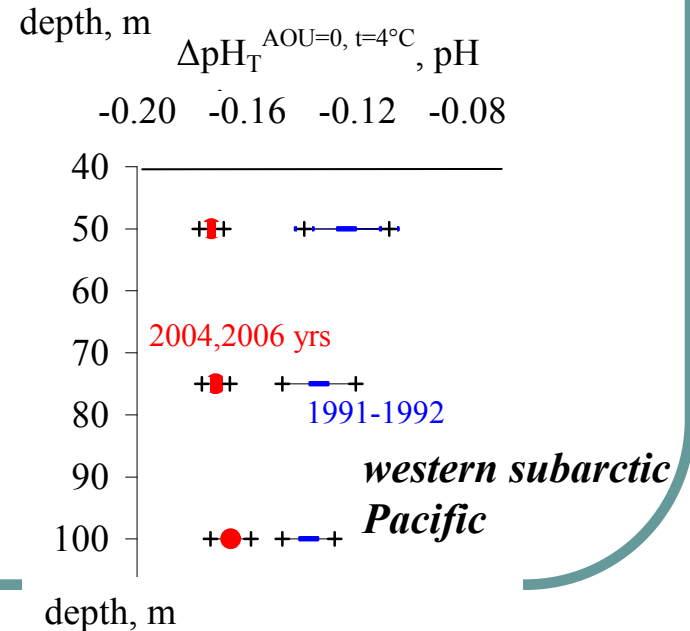
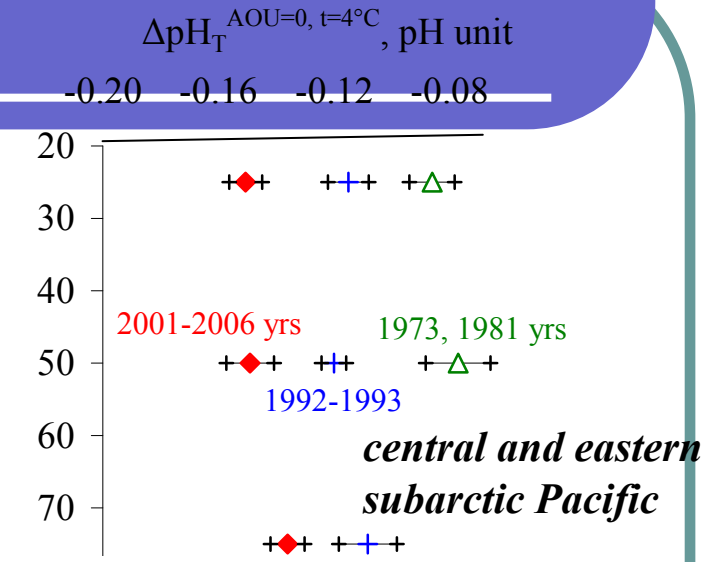
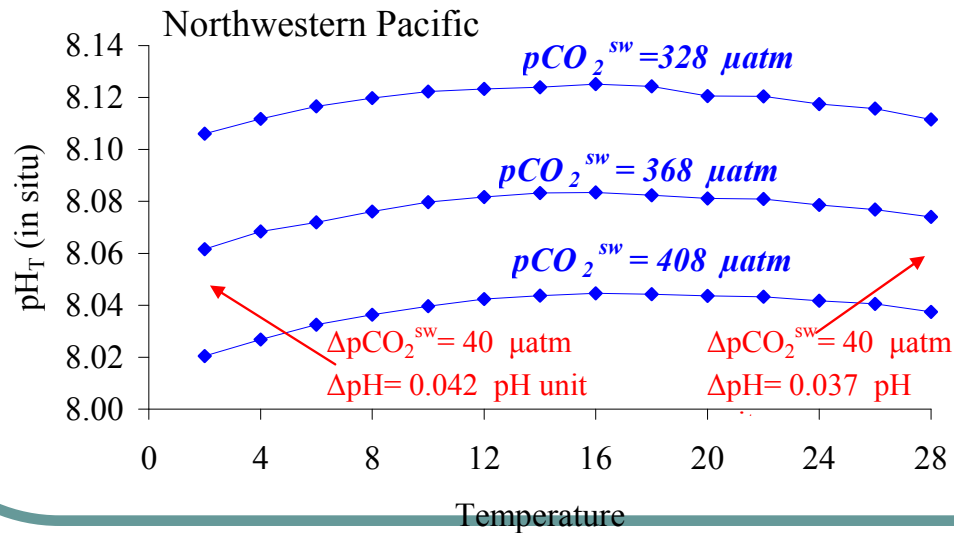
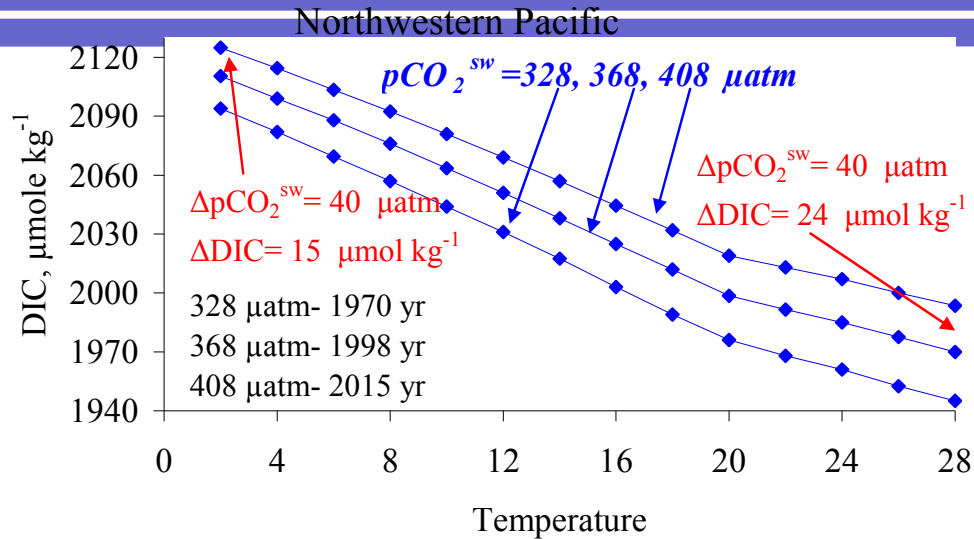
Okhotsk Sea. Atmosphere-ocean CO₂ flux



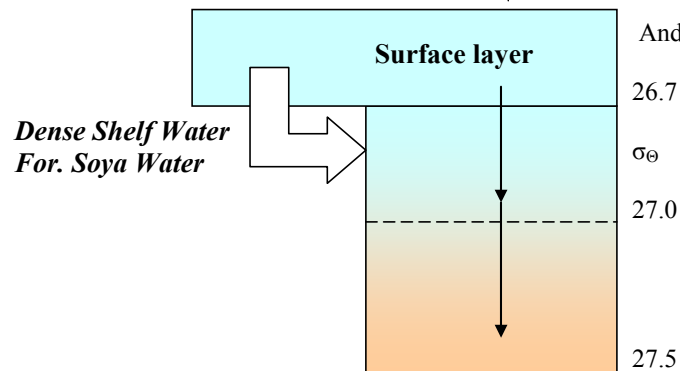
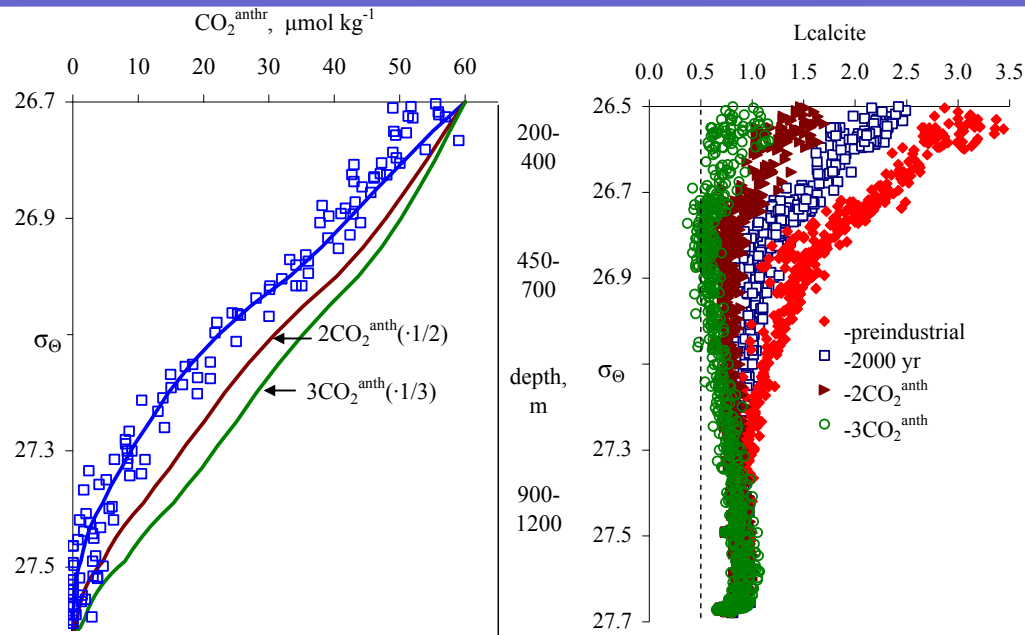
CNP fluxes and biological productivity Okhotsk Sea. Future changes.

- 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.

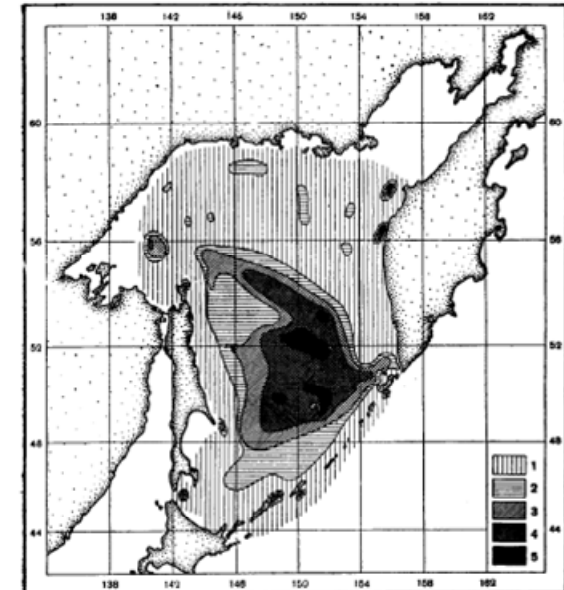
Seawater acidification and excess carbonate dissolution Subarctic North Pacific



Seawater acidification and excess carbonate dissolution Okhotsk Sea



Andreev et al., 1998



Surface sediment carbonate (%)
1-<1.0; 2-1.0-2.0; 3-2.0-5.0; 4-5.0-7.0; 5->7.0

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!