Present and Future Changes in the Okhotsk Sea waters

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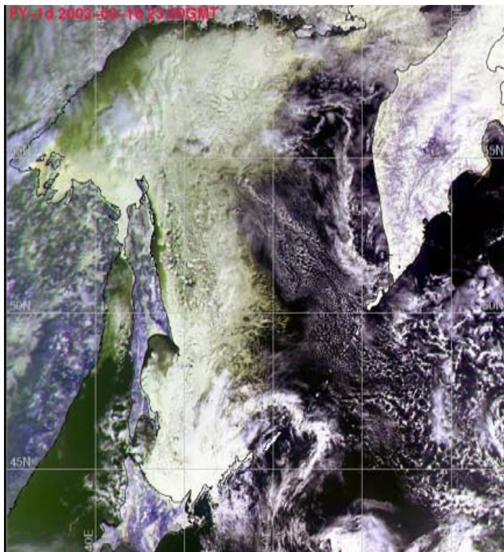
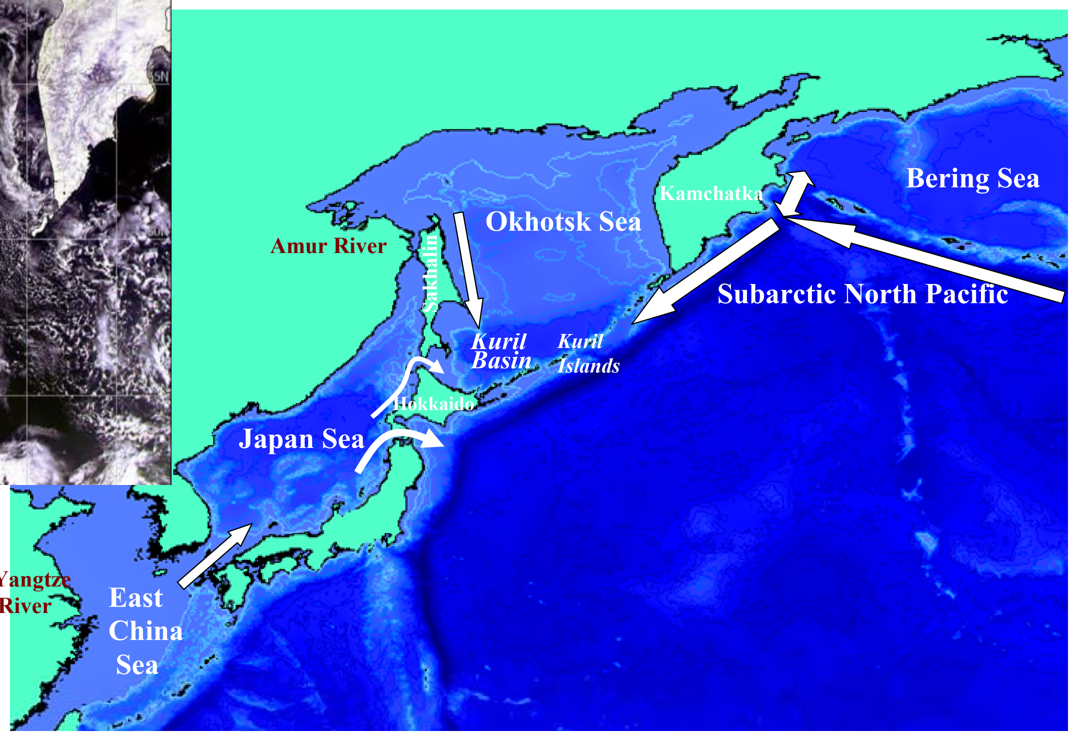
• Recent changes in the intermediate and surface waters of the Kuril Basin

• Main features of the CNP fluxes and biological productivity. Future changes of the CNP fluxes

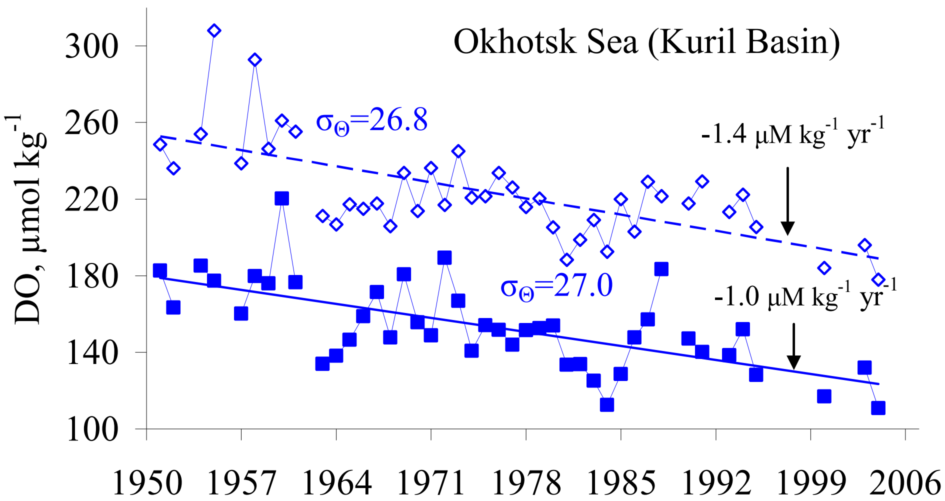
• Impact of the East-China Sea waters

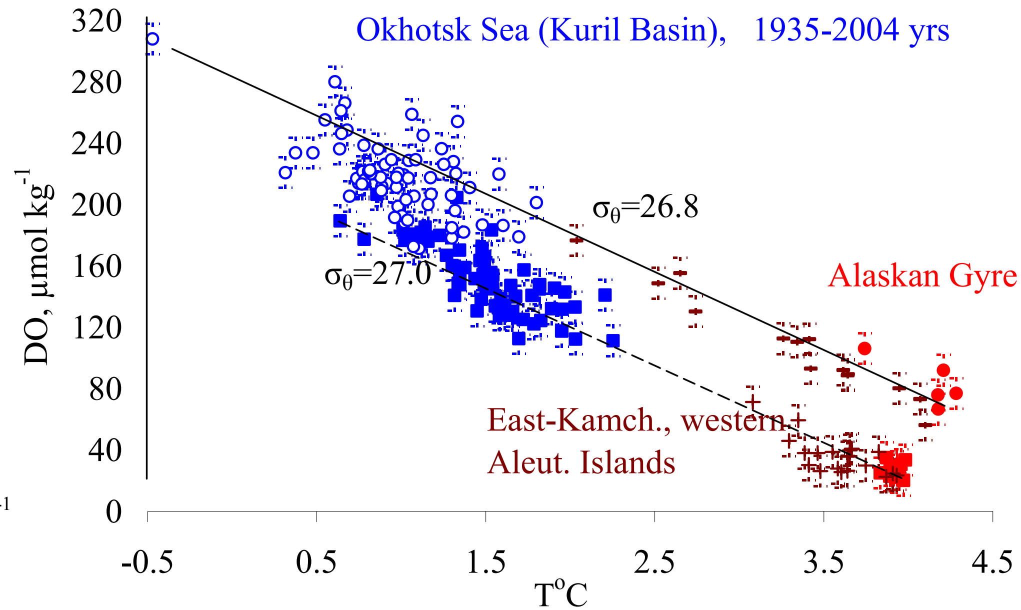
• Seawater acidification and excess carbonate dissolution

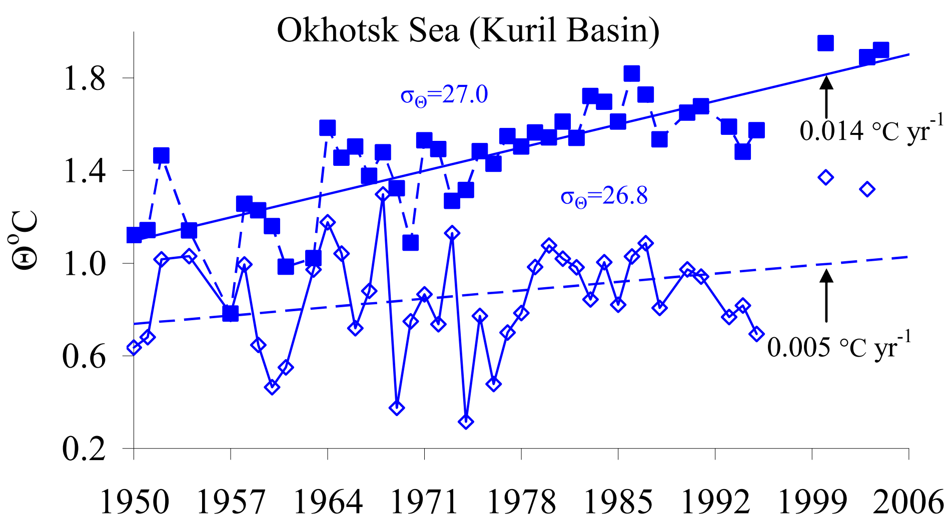




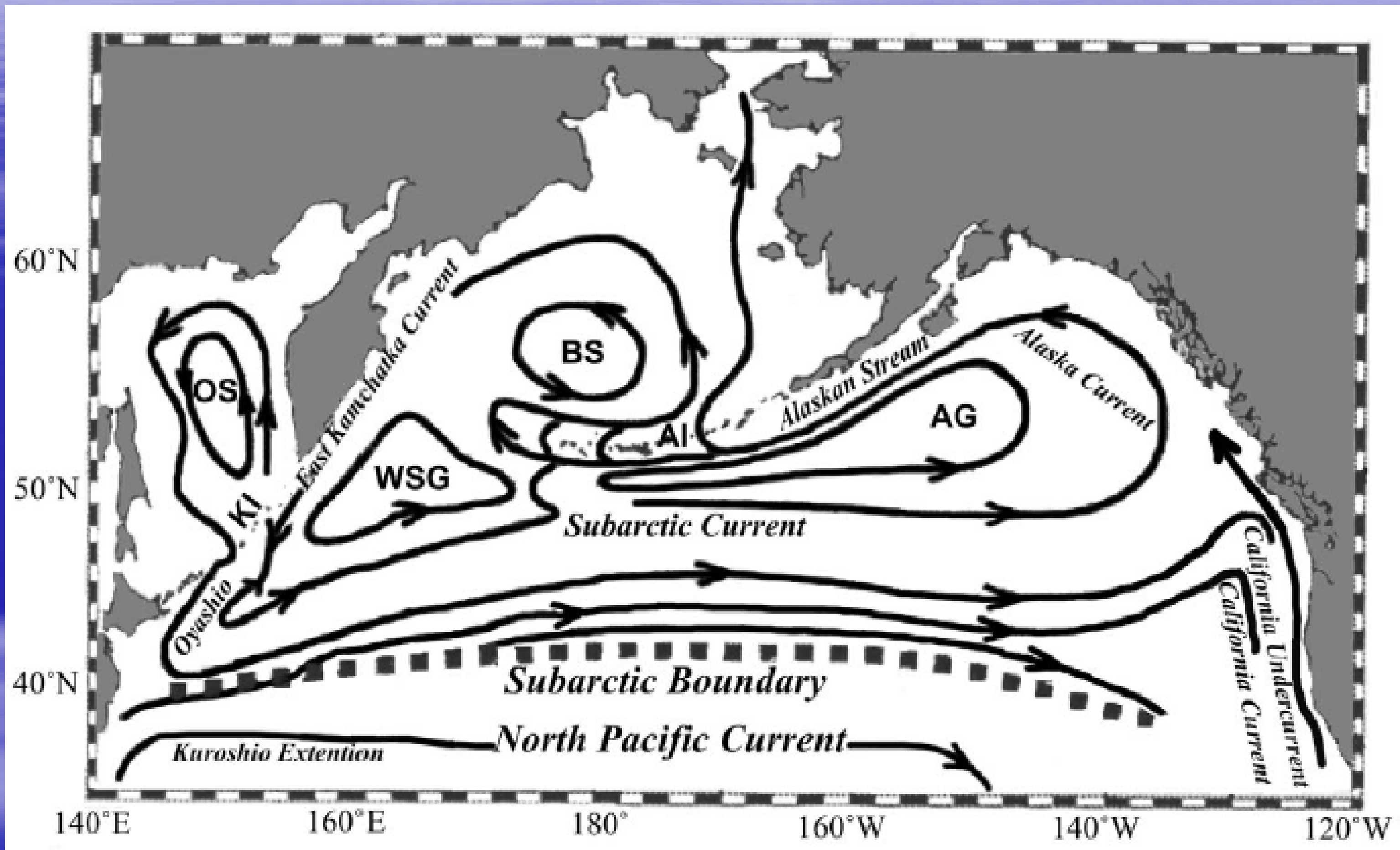
Okhotsk Sea. Intermediate waters.





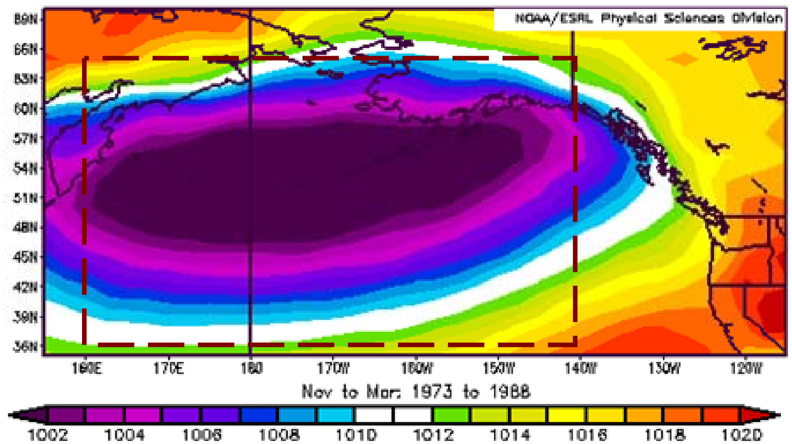


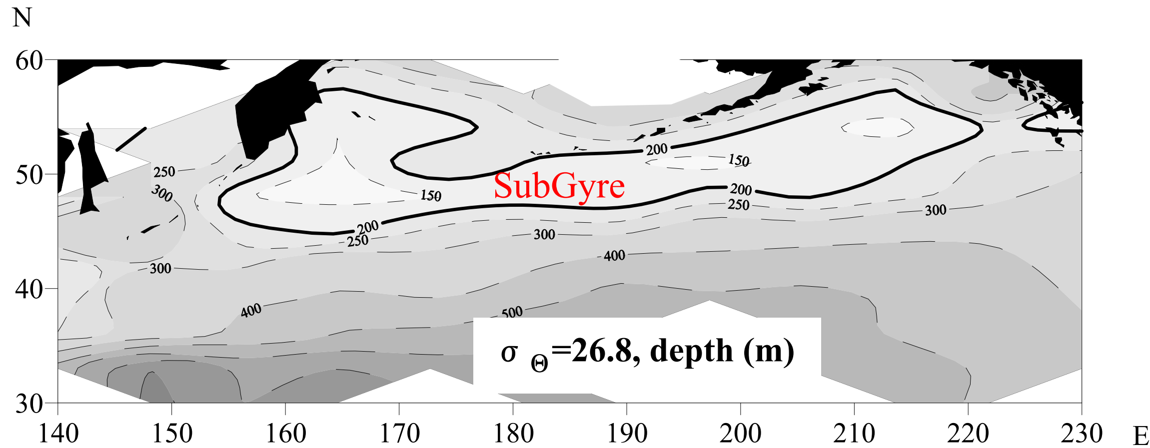
Northern North Pacific. Circulation pattern.

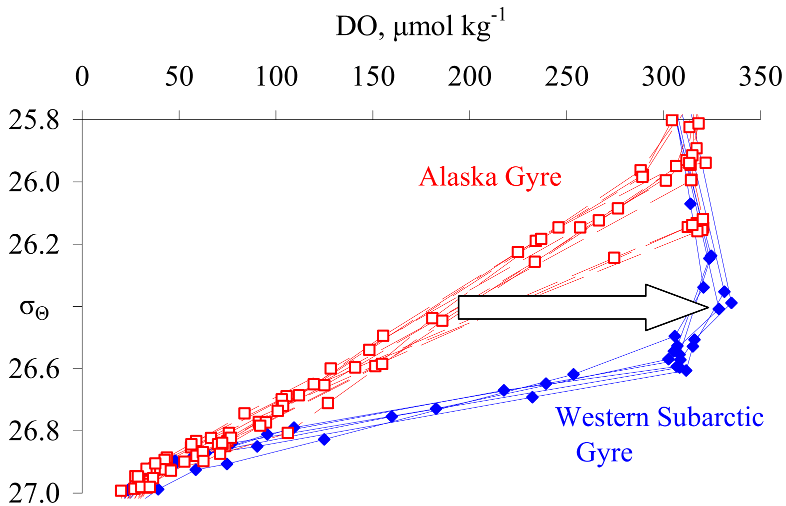


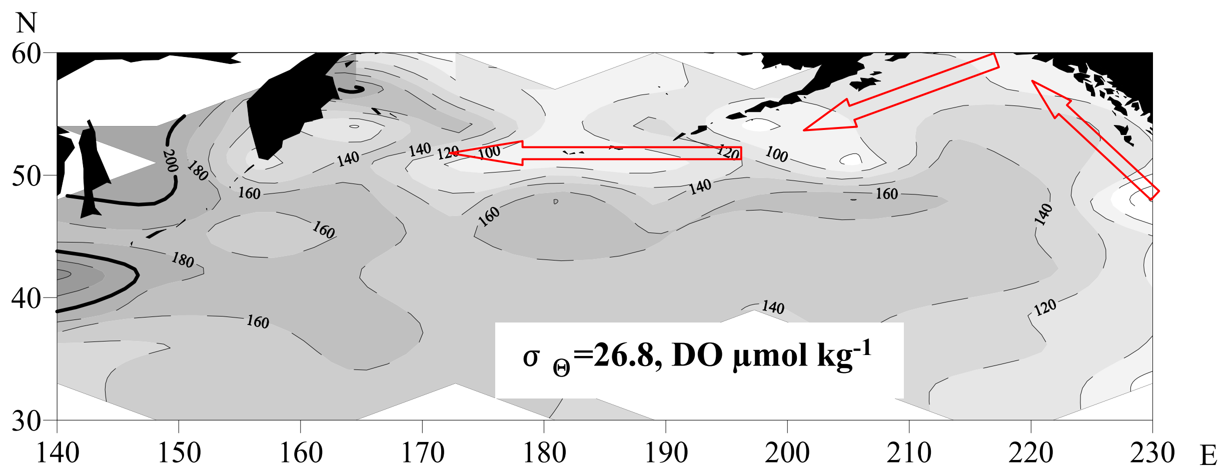
Northern North Pacific

Sea level pressure, mbar, November-March



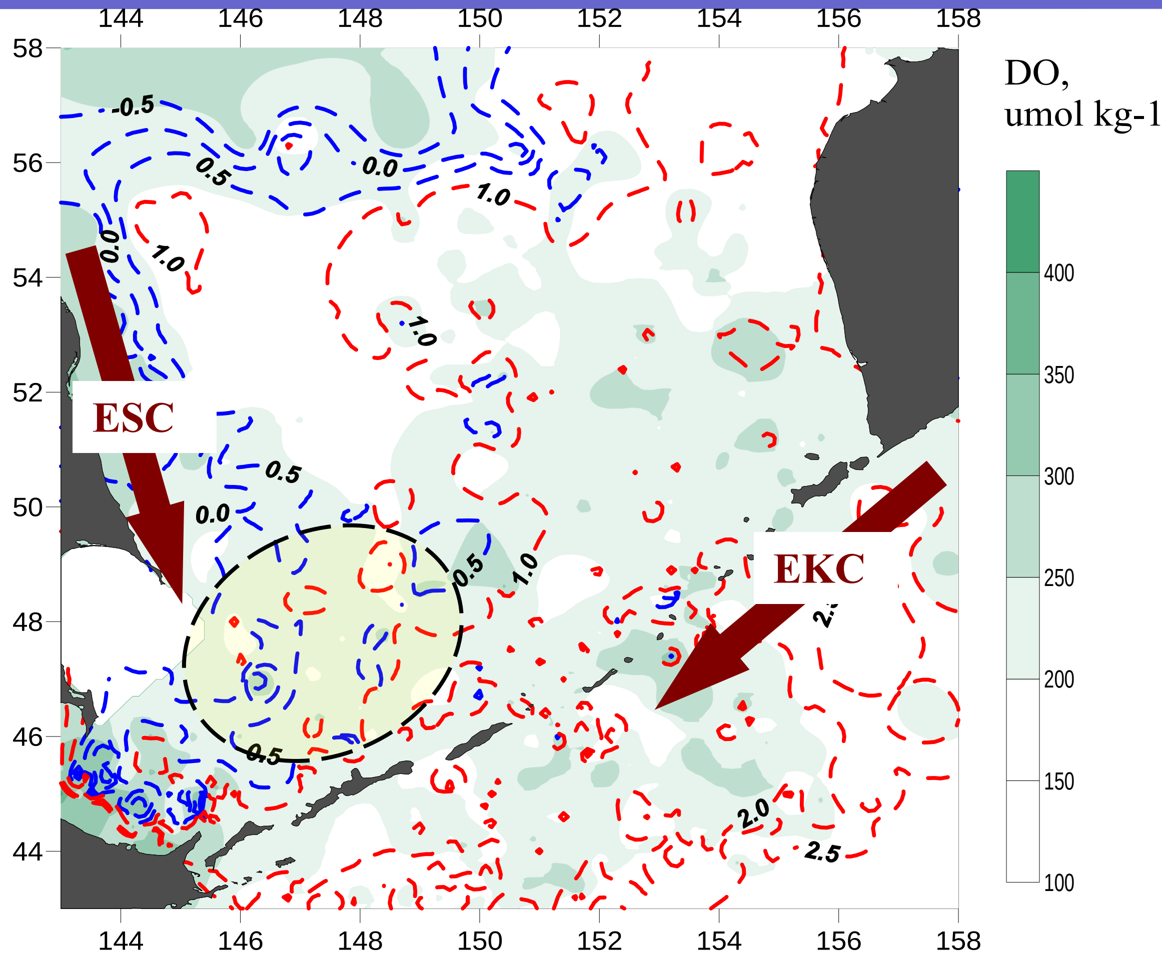




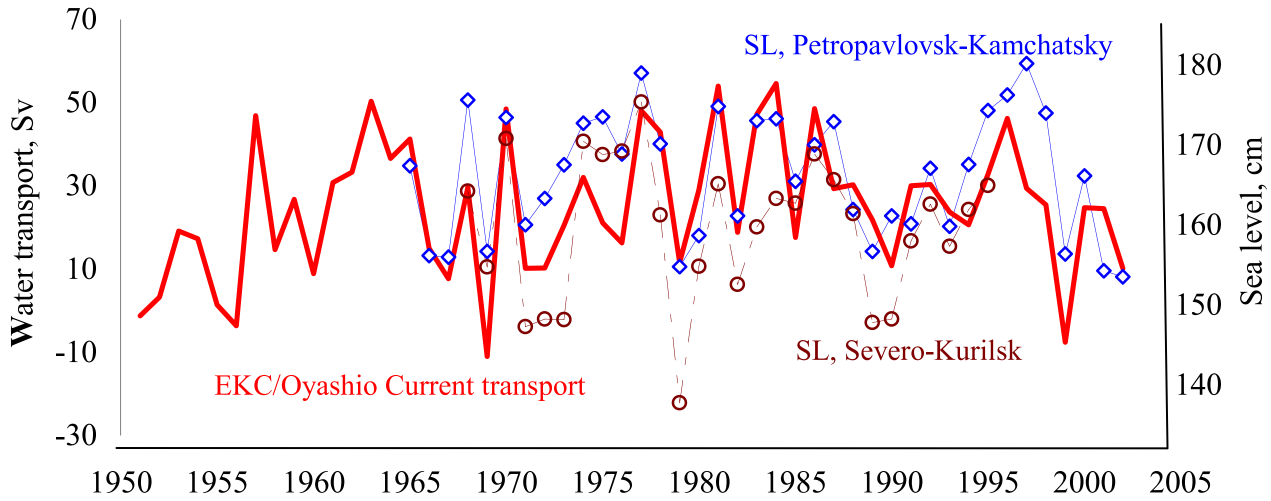


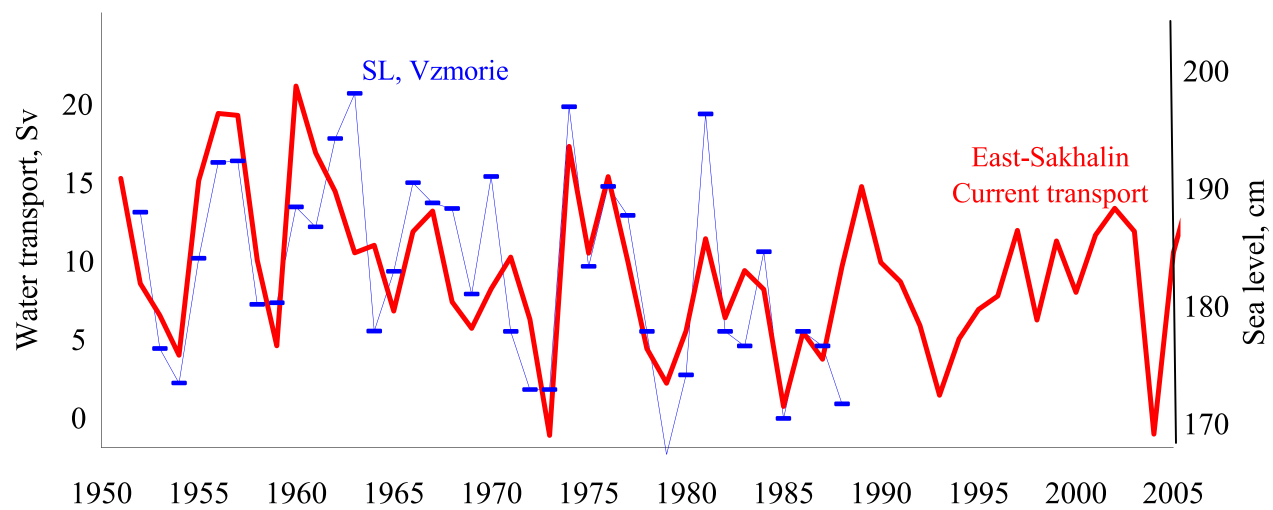
Okhotsk Sea

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

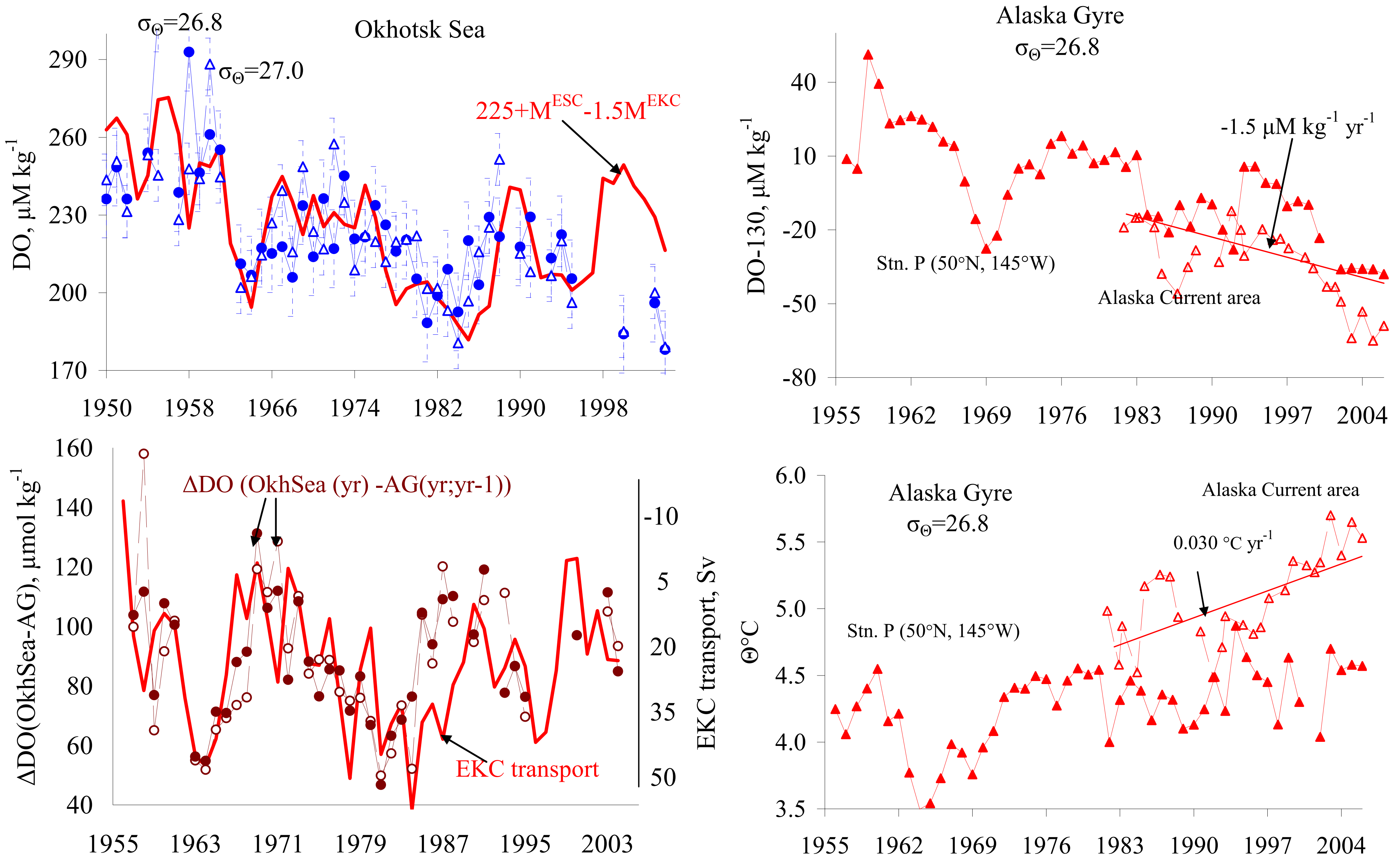


East-Kamchatka/Oyashio and East-Sakhalin Current volume transport

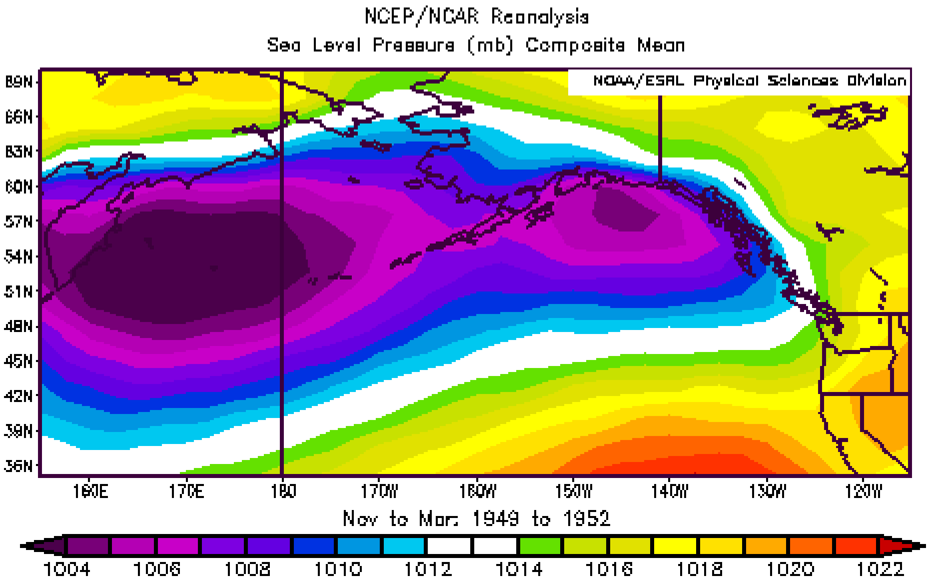


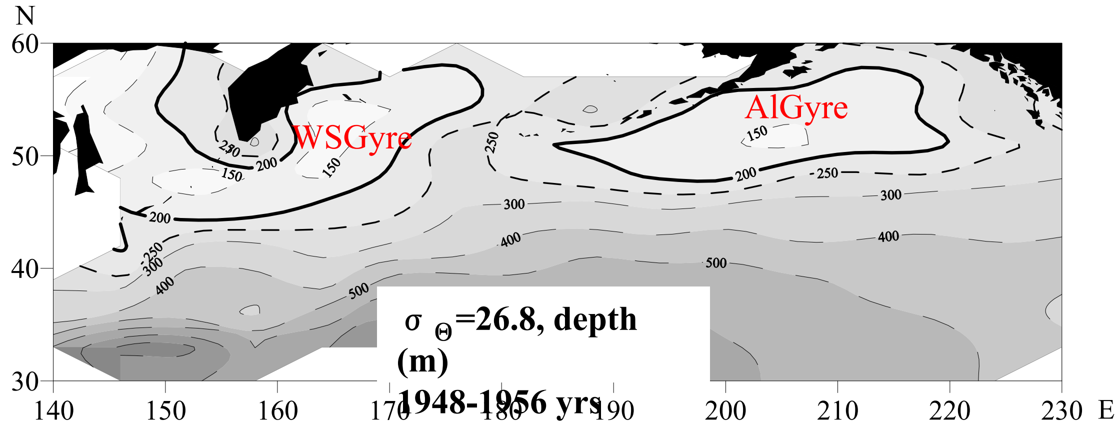


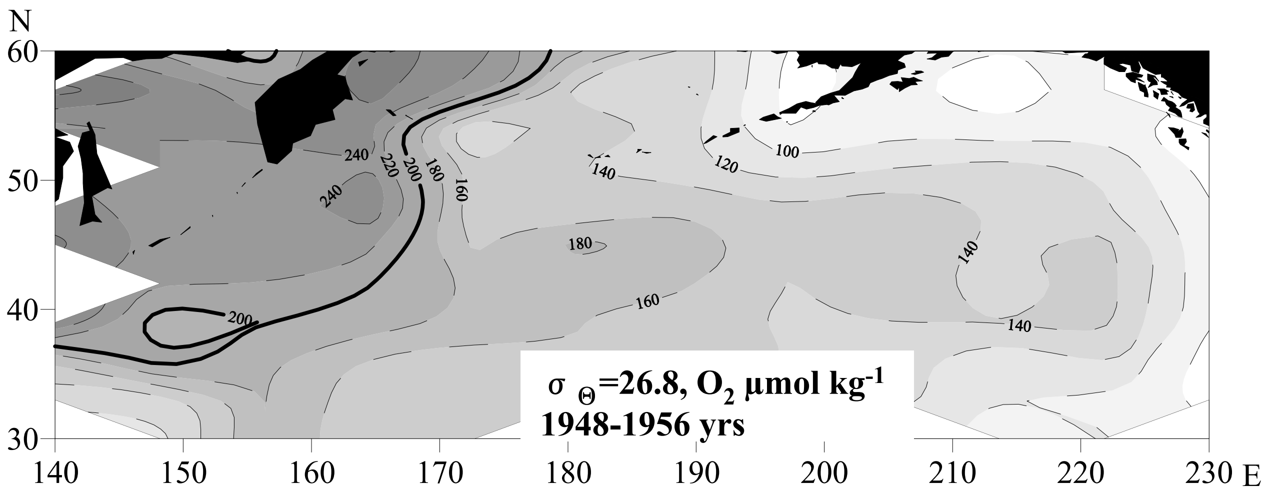
Okhotsk Sea and Alaska Gyre. Intermediate waters.



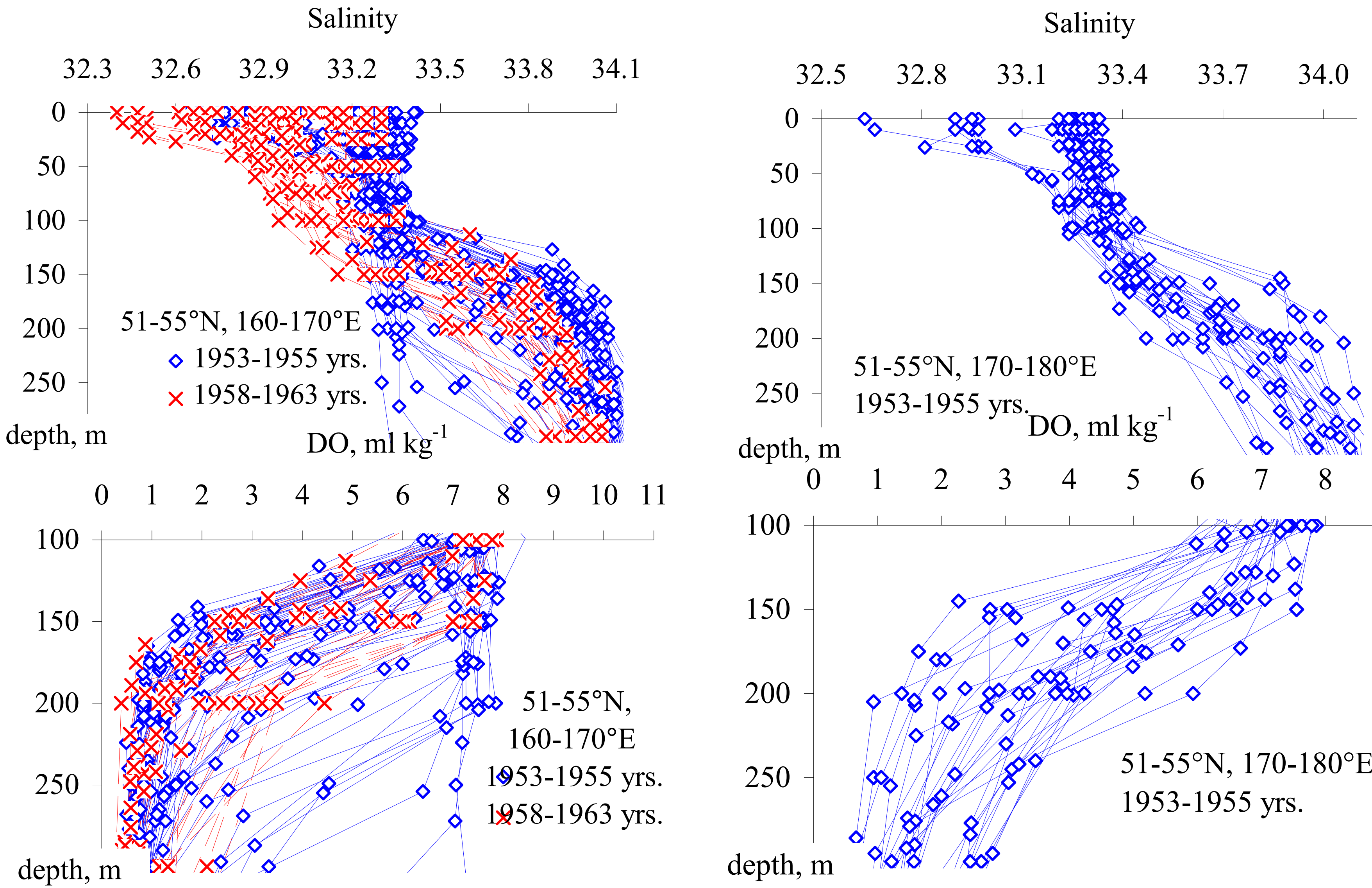
Northern North Pacific







Bering Sea


Salinity
32.3
32.6
32.9
33.2
33.5
33.8
34.1
0
50
100
150
200
250
depth, m
51-55°N, 160-170°E
1953-1955 yrs.
1958-1963 yrs.
DO, ml kg-1
Salinity
32.5
32.8
33.1
33.4
33.7
34.0
0
50
100
150
200
250
51-55°N, 170-180°E
1953-1955 yrs.
DO, ml kg-1
depth, m
0
1
2
3
4
5
6
7
8
9
10
11
100
150
200
250
depth, m
51-55°N,
160-170°E
1953-1955 yrs.
1958-1963 yrs.
0
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100
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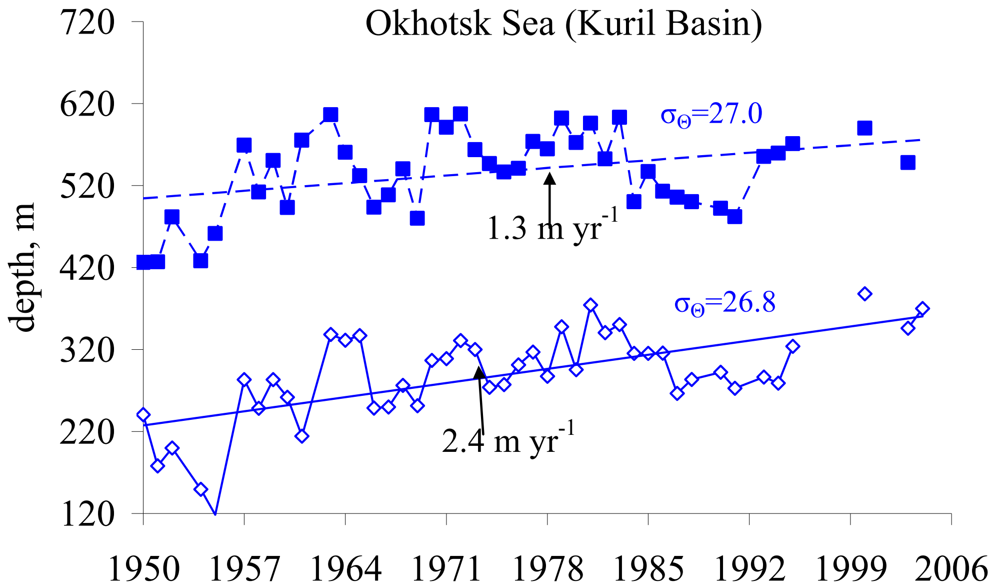
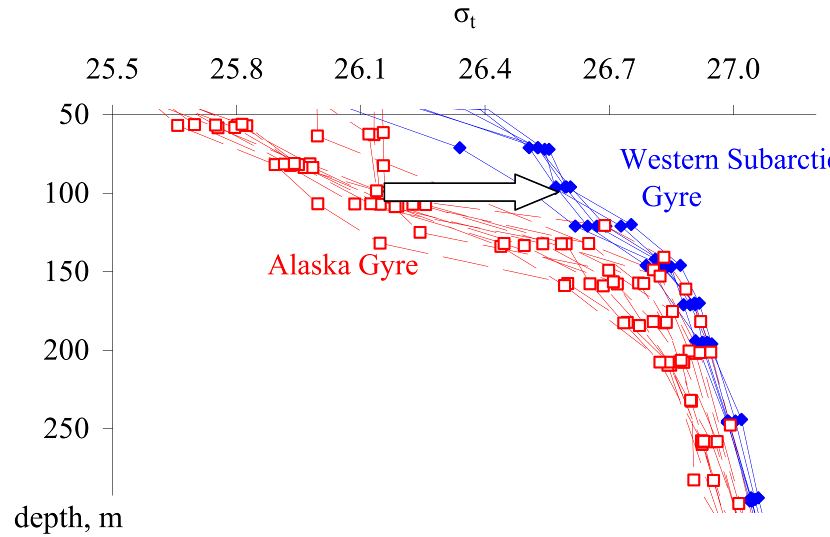
200
250
51-55°N, 170-180°E
1953-1955 yrs.
depth, m

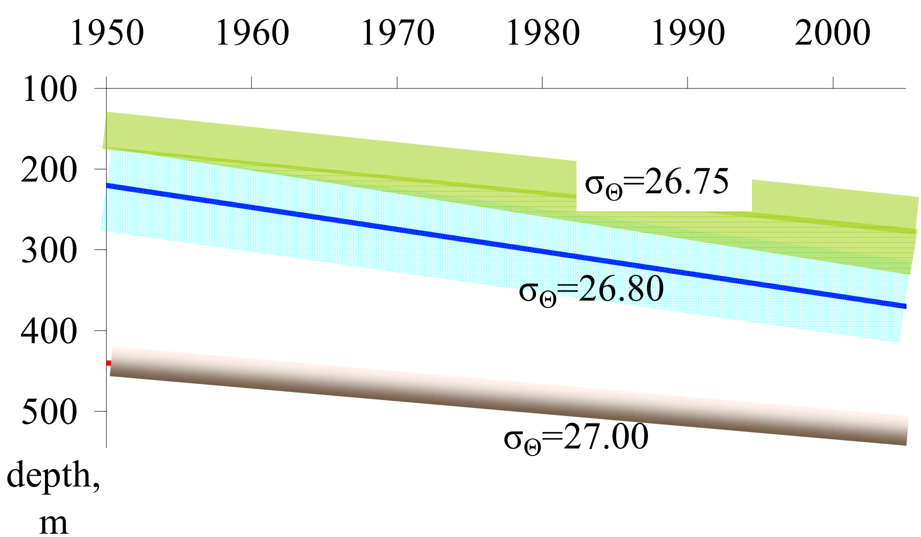
Difference in temperature and chemical parameters between the eastern subarctic Pacific (Alaska Gyre) and the Okhotsk Sea (Kuril Basin region) on isopycnals of $26.8\sigma_\Theta$ and $27.0\sigma_\Theta$

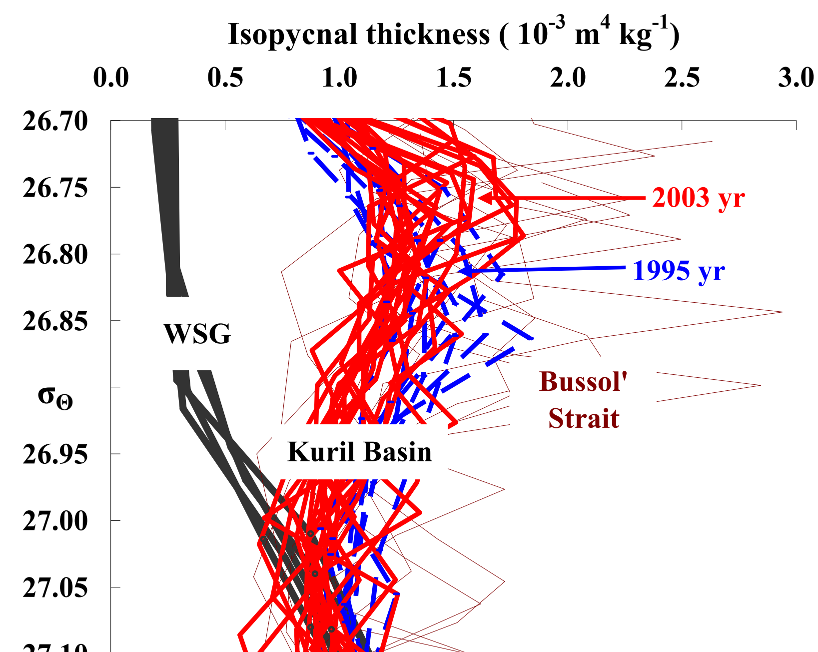
Parameter	**Alaska Gyre-Okhotsk Sea**	**Accuracy of measurements**
Temperature (C)	3.0	± 0.001-0.005
Dissolved oxygen (μM)	-150	± 2-4
Dissolved inorganic carbon (μM)	50	± 2-3
Nitrate (μM)	6	± 0.2-0.6
Phosphate (μM)	0.4	± 0.02-0.06

Okhotsk Sea. Intermediate waters.

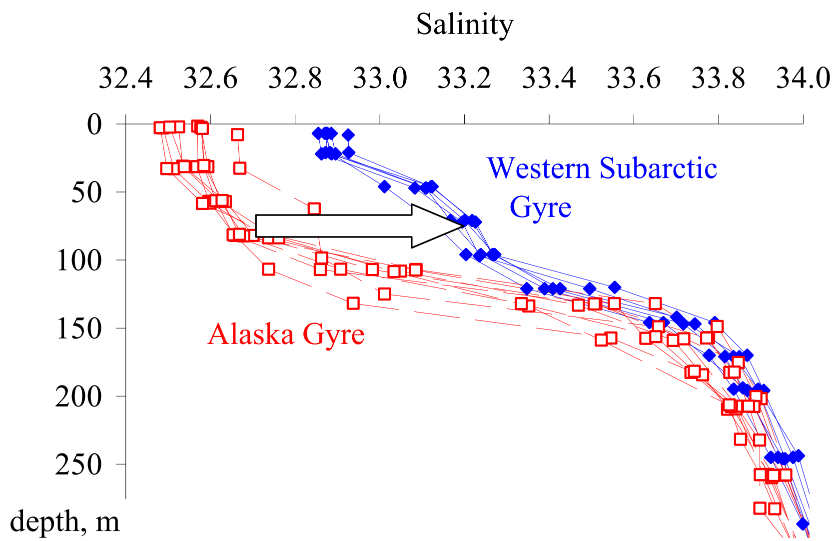


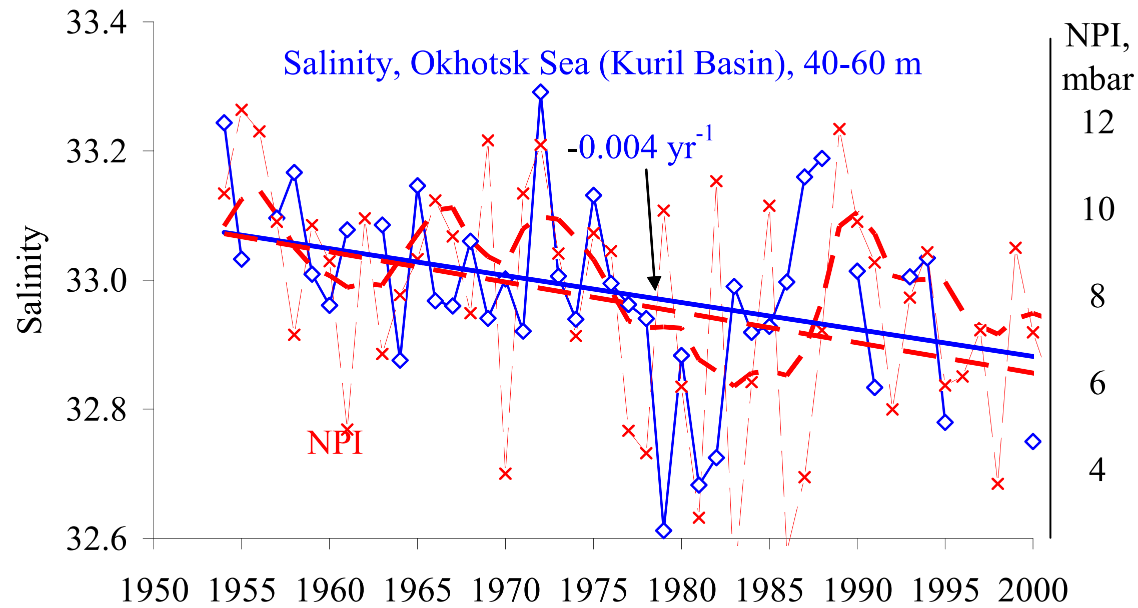


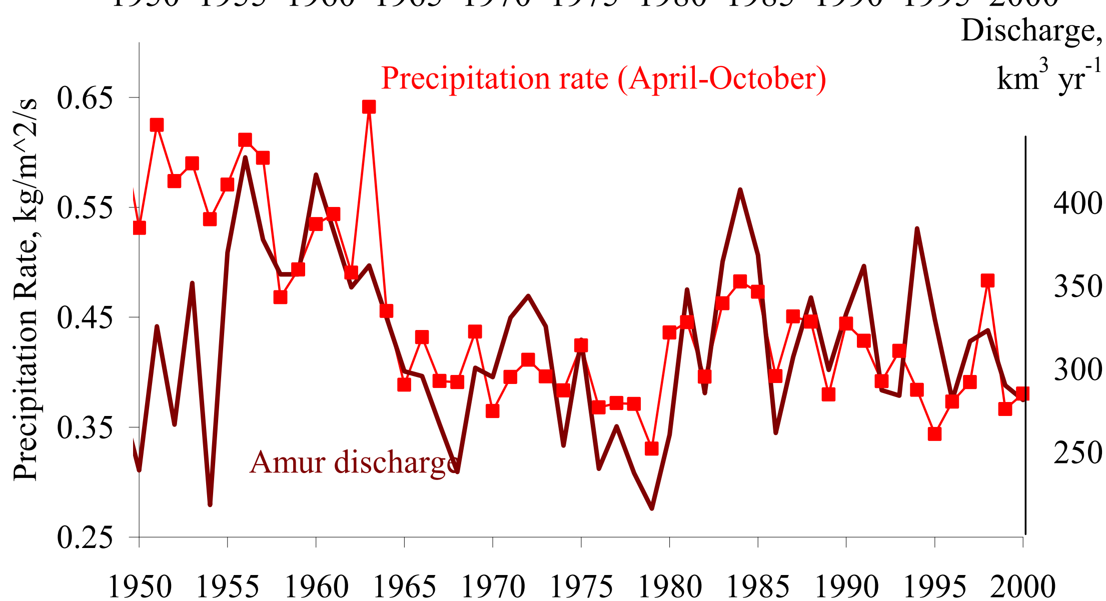




Okhotsk Sea. Surface waters







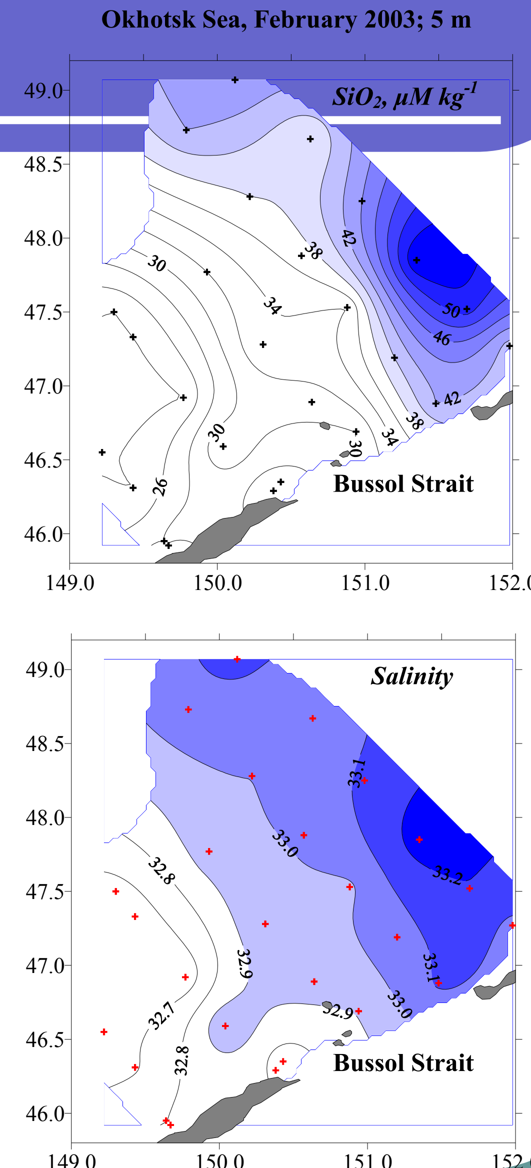
Okhotsk Sea. Intermediate and surface waters. Future changes

- 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.

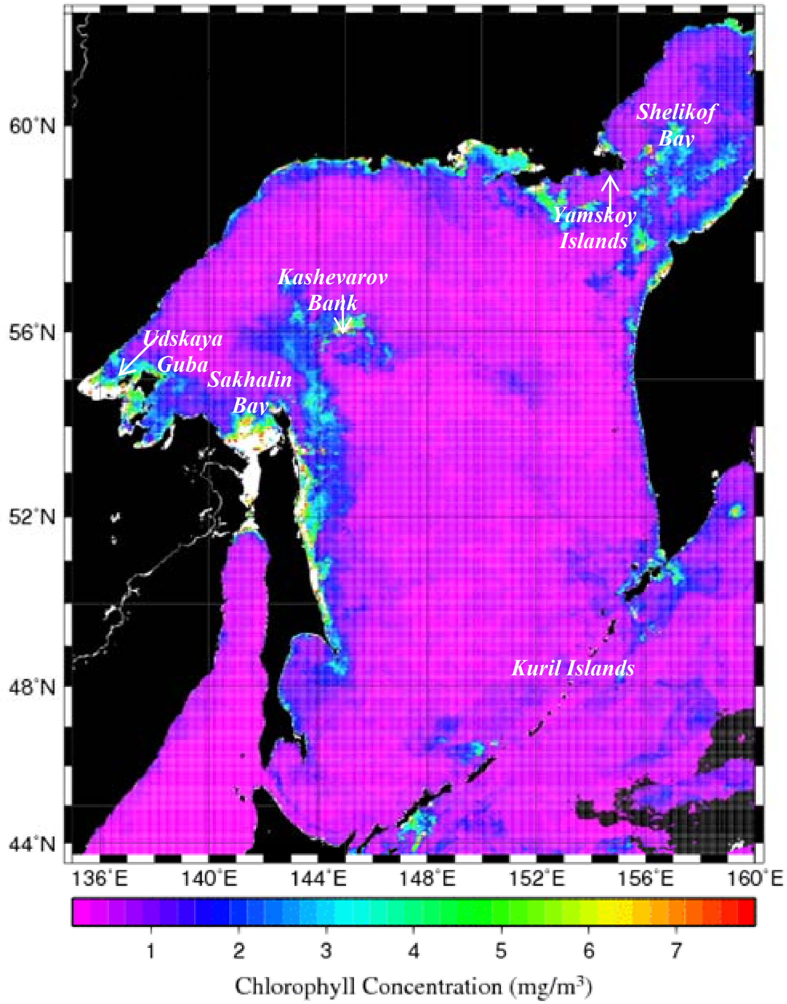
CNP fluxes and biological productivity

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 CO_2 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



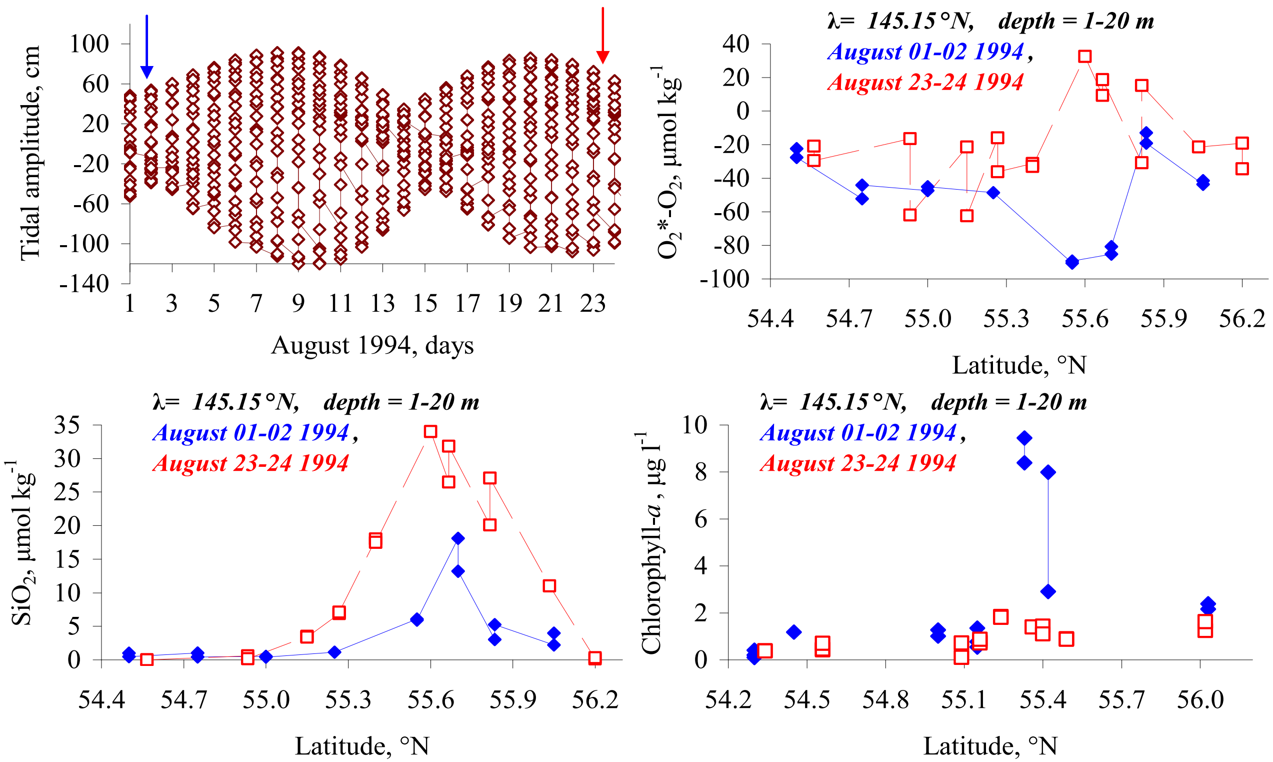
CNP fluxes and biological productivity



- 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 gC m^{-2} day^{-1}. The utilization of nutrients supplied at the Kashevarov Bank may provide production of ~$1.8 \cdot 10^{14}$ gC yr^{-1}, which is more than one-third of the annual production of the Okhotsk Sea (Arzhanova and Zubarevich, 1997).

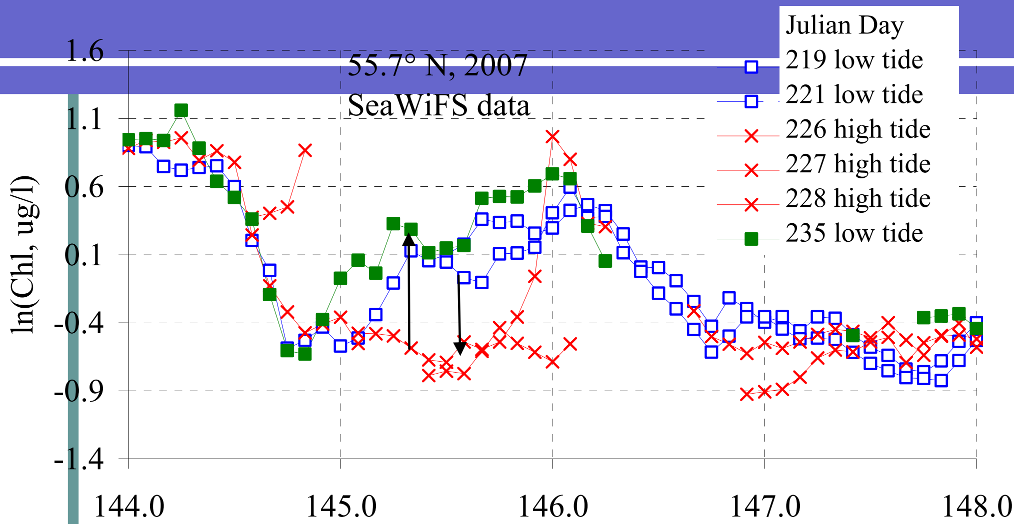
CNP fluxes and biological productivity

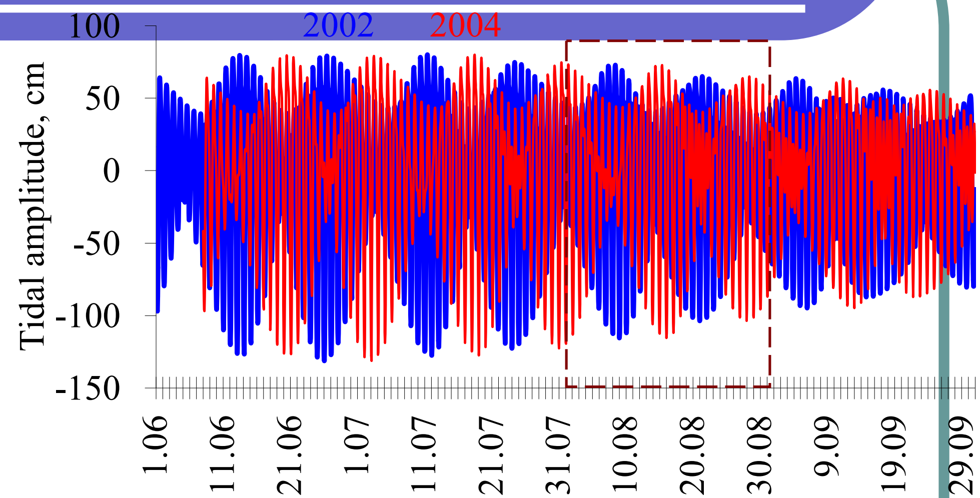
Okhotsk Sea. Kashevarova Bank area.

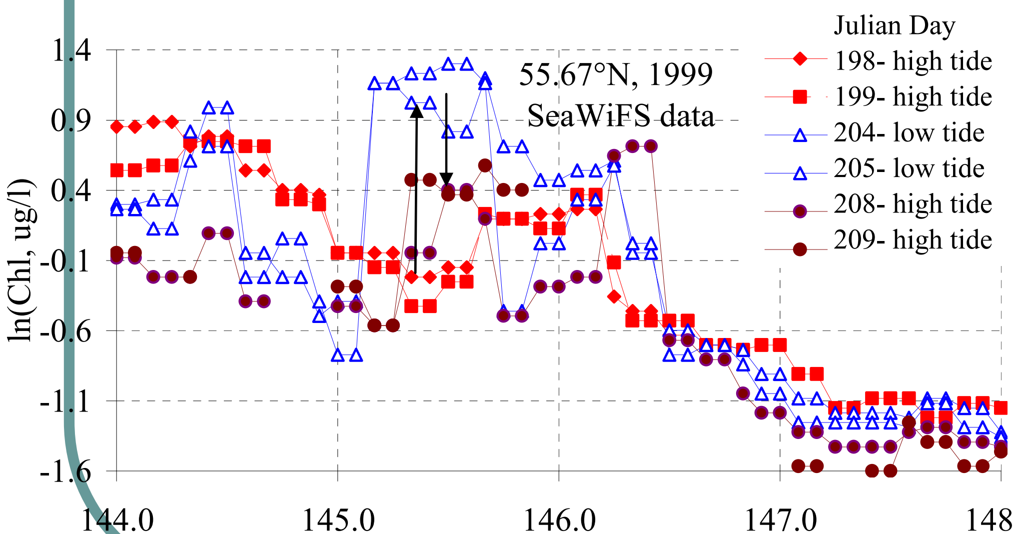


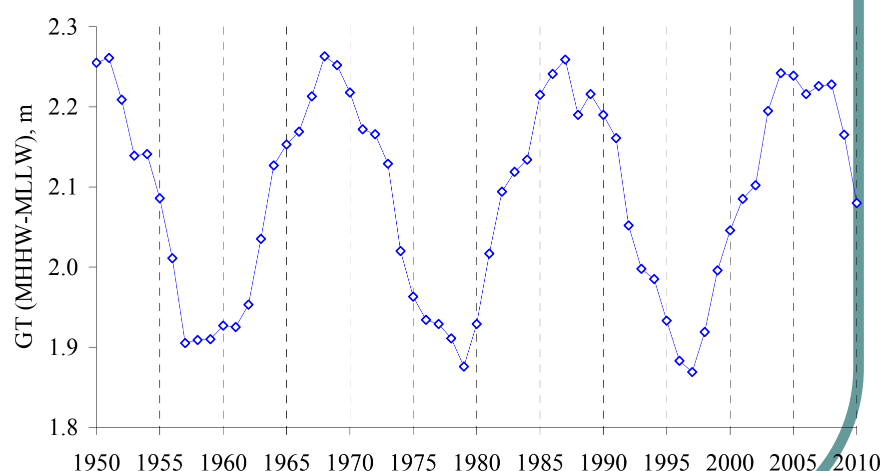
CNP fluxes and biological productivity

Okhotsk Sea. Kashevarova Bank area.









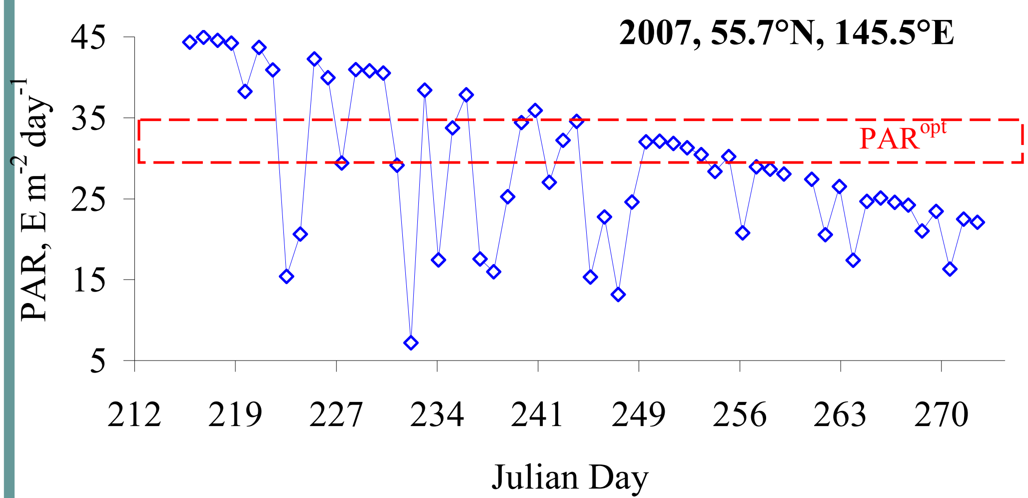
CNP fluxes and biological productivity

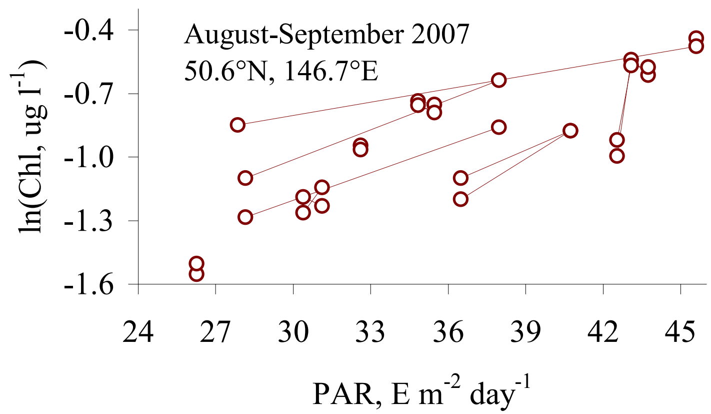
Okhotsk Sea

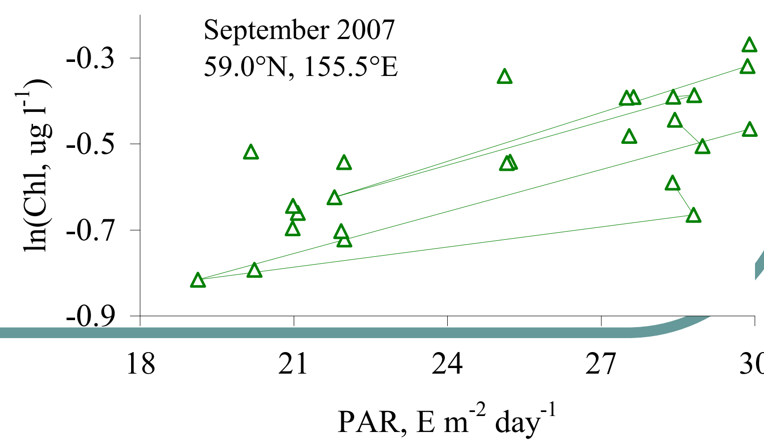
$\Delta(\text{Phyt\_Biomass})/(\text{Phyt\_Biomass}) \approx \Delta Chl/Chl \sim \psi^T \cdot I/I^{opt} \exp(1 - I/I^{opt}) \cdot f([NO_3], K_N, [SiO_2], K_{Si}) - \lambda^P$,

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.

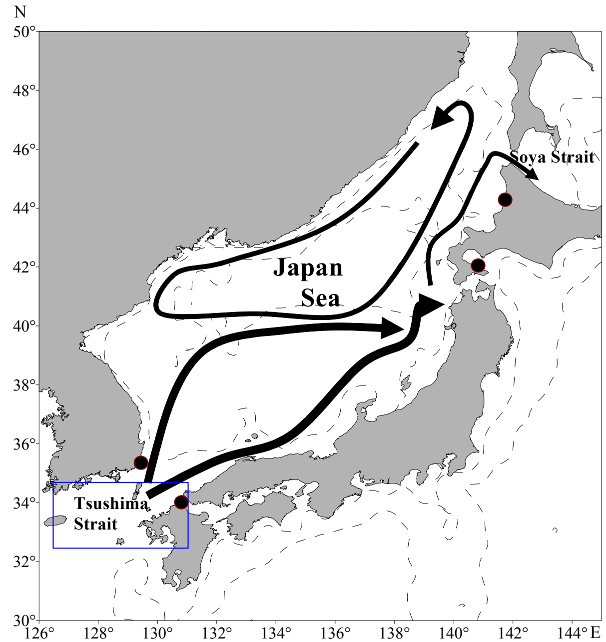
$PAR \leq PAR^{opt}$, $\Delta Chl/Chl \ \{\Delta \ln(Chl)\} \sim k \cdot \Delta PAR$

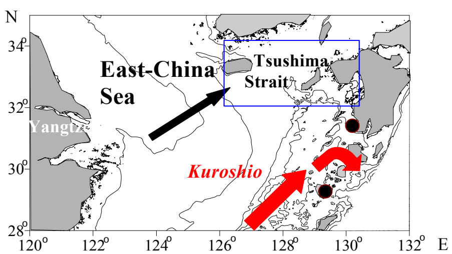


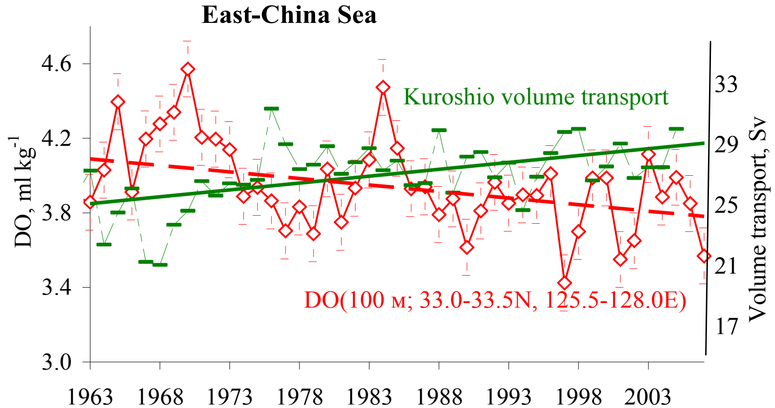


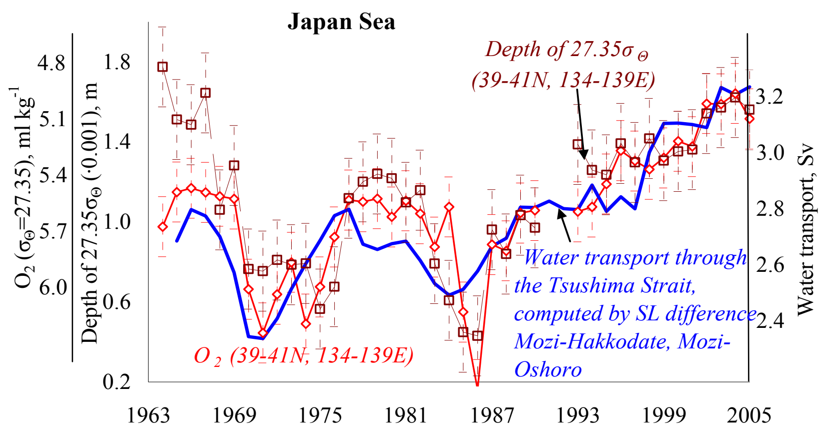


Impact of the East-China Sea waters

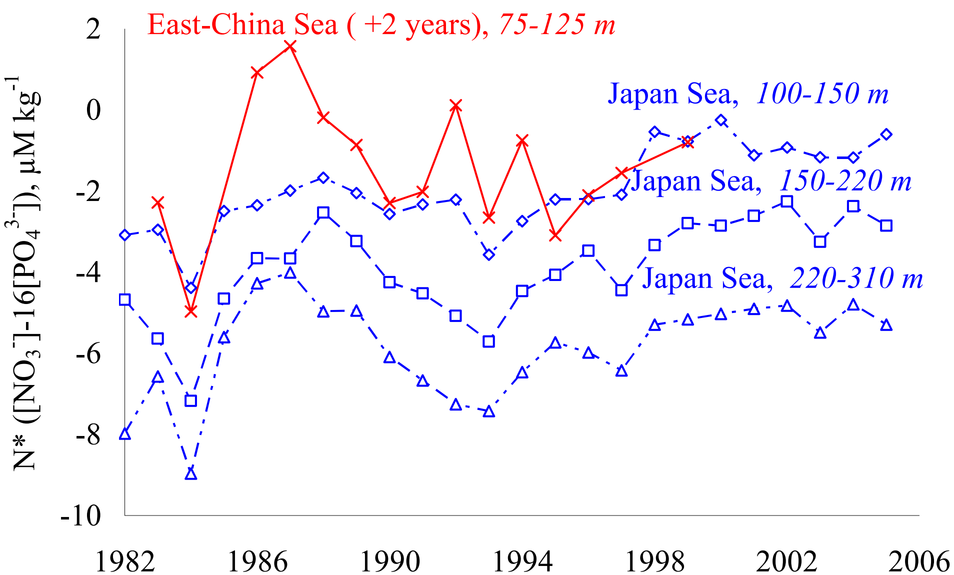








Impact of the East-China Sea waters



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

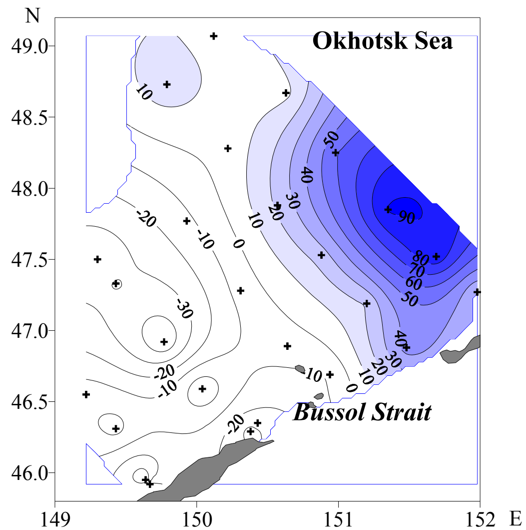
▪**Amur River** discharge ~ 320 km^3 yr^{-1}

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

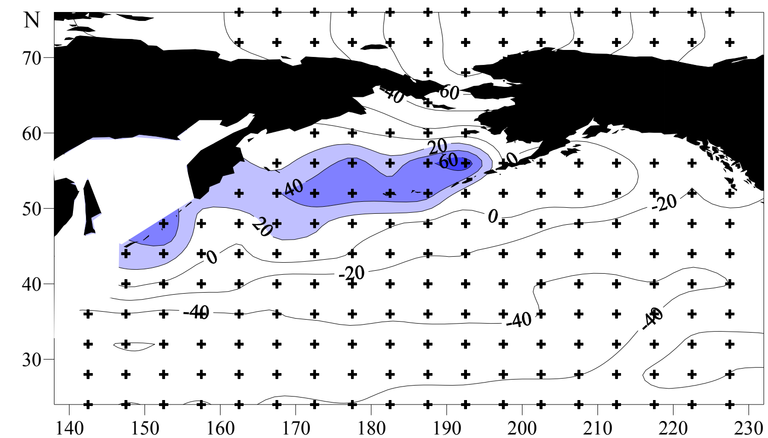
▪Dam construction led to decreased **Yangtze** sediment discharge and seawater SiO_2 (East-China and Japan Seas)

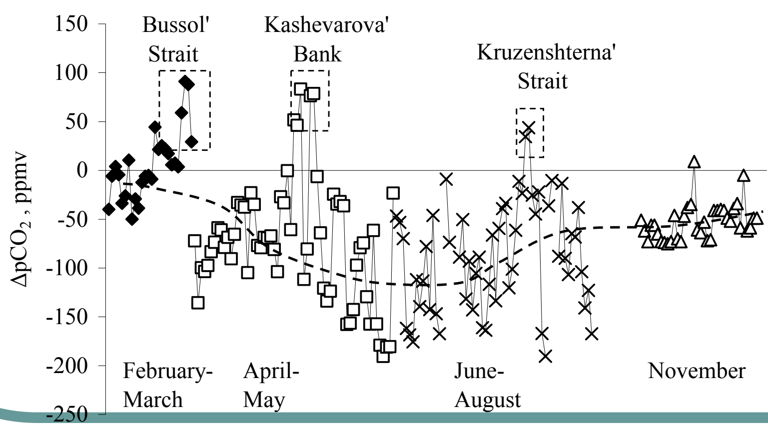
CNP fluxes and biological productivity
North Pacific and Okhotsk Sea. Atmosphere-ocean CO_2 flux

pCO_2^{sw}-pCO_2^{air}, ppmv; February 2003

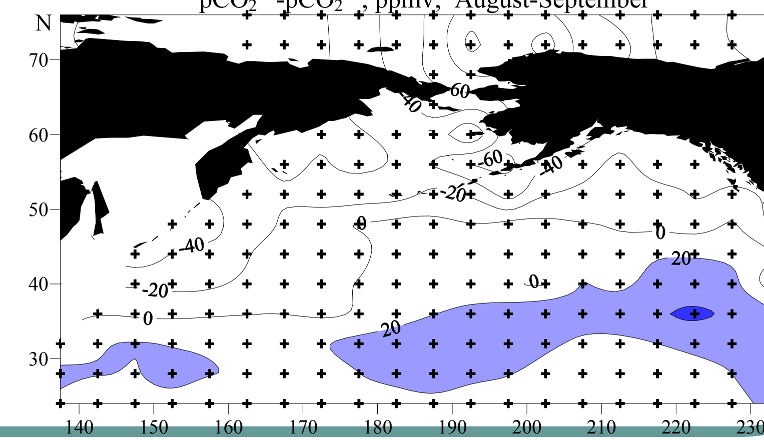


pCO_2^{sw}-pCO_2^{air}, ppmv; February-March



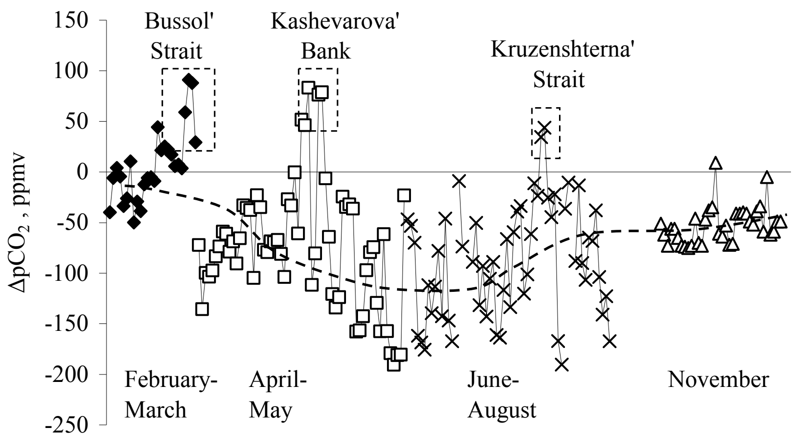


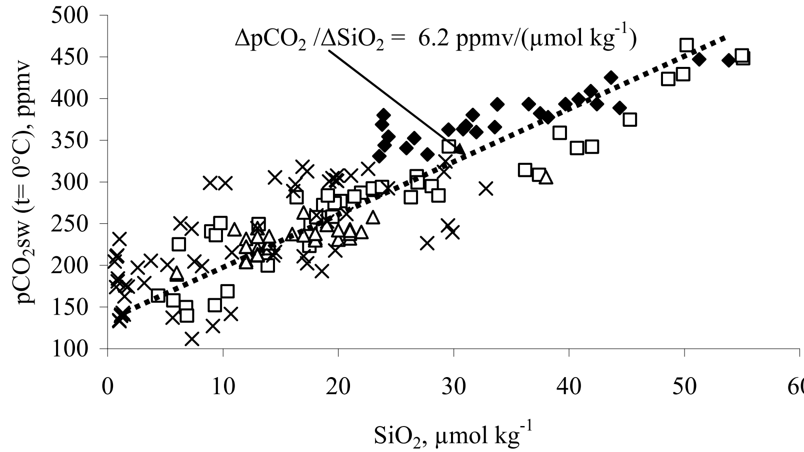
pCO_2^{sw}-pCO_2^{air}, ppmv; August-September



CNP fluxes and biological productivity

Okhotsk Sea. Atmosphere-ocean CO_2 flux

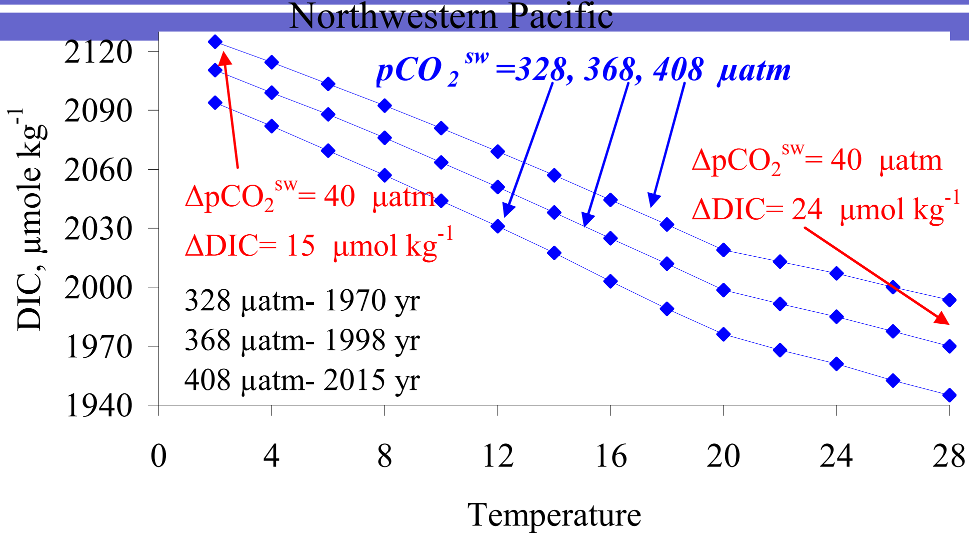


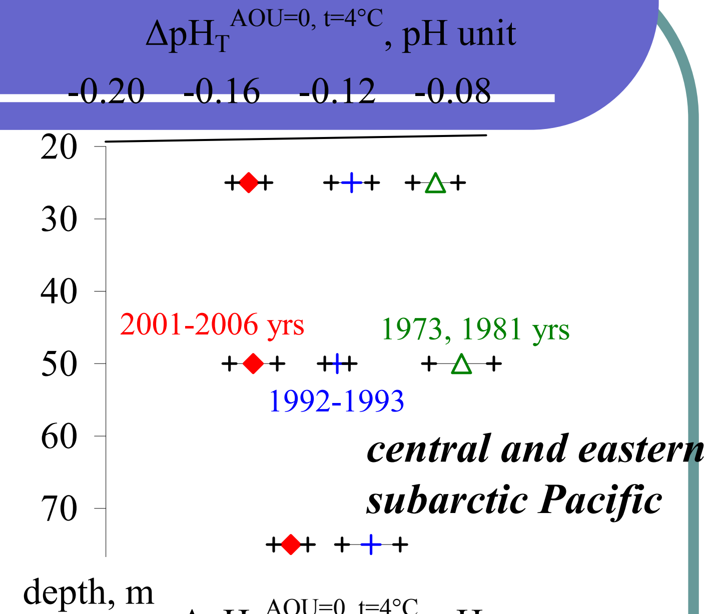


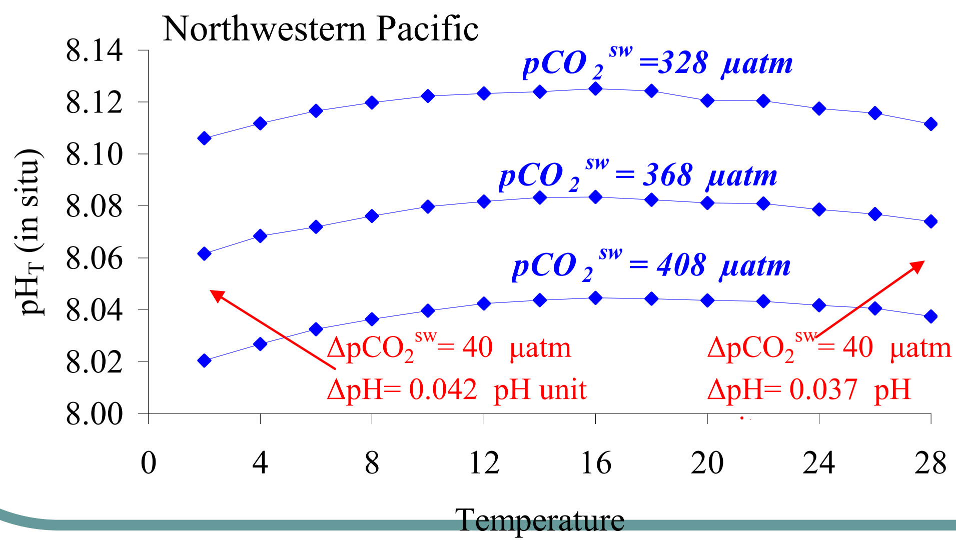
CNP fluxes and biological productivity Okhotsk Sea. Future changes.

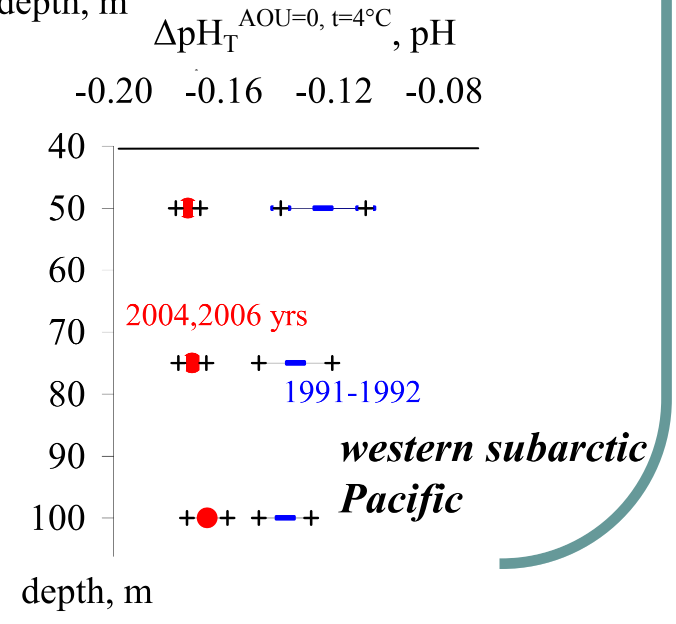
- Climate change will suppress vertical mixing by thermal stratification and decreases in surface salinity in the subpolar regions (i.e. Manabe, Stouffer, 1993; Manabe, Stouffer, 2000). These changes would lead to the decreased of the autotrophic phytoplankton biomass (expressed by chlorophyll concentrations) 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 CO_2 will be significantly decreased.

Seawater acidification and excess carbonate dissolution
Subarctic North Pacific

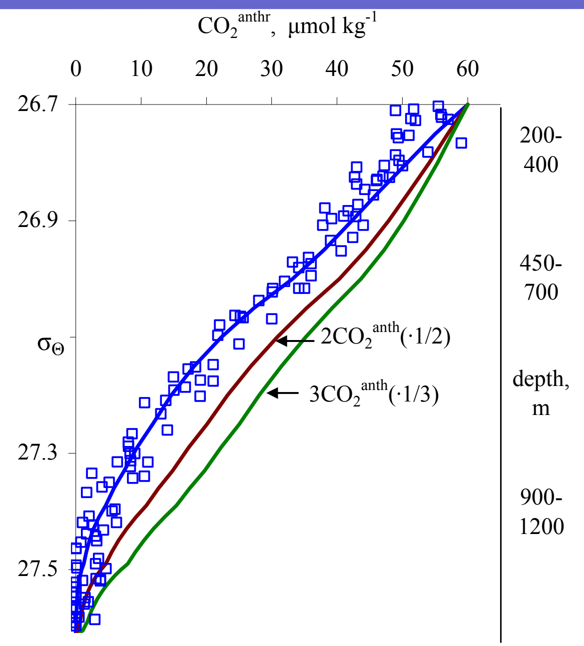


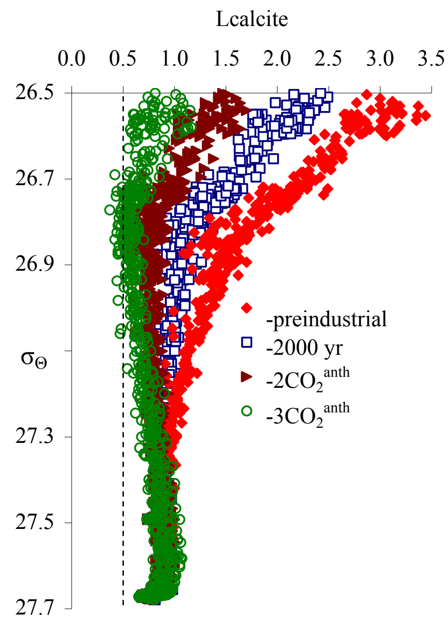


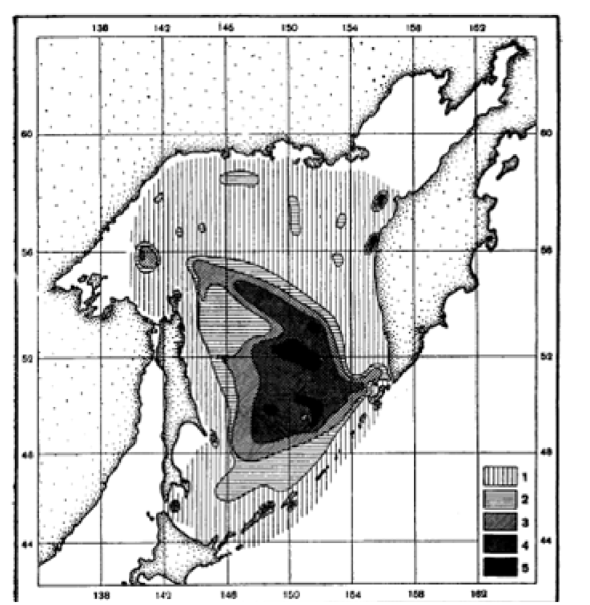




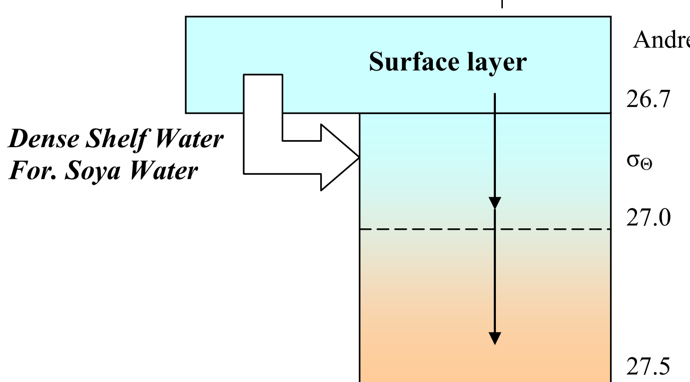
Seawater acidification and excess carbonate dissolution
Okhotsk Sea







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



Andreev et al., 1998

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 CO_2 supply into the seawater.

Thank you!