The estimate of the denitrification using nitrogen gas excess in the Sea of Okhotsk

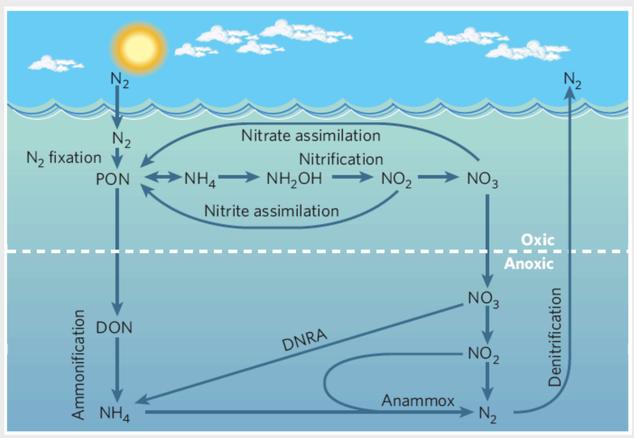
M. Ito[1], Y. W. Watanabe[2], S. S. Tanaka[3], T. Ono[4], J. Nishioka[5], T. Nakatsuka[6]

1. Graduate School of Environmental Science, Hokkaido University, Japan, 2. Faculty of Environmental Earth Science, Hokkaido University, Japan, 3. National Institute for Environmental Studies, Japan, 4. Hokkaido National Fisheries Research Institute, Japan, 5. Institute of Low Temperature Science, Hokkaido University, Japan, 6. Graduate School of Environmental Studies, Nagoya University, Japan

Backgrounds

Nitrogen Cycle in the Ocean

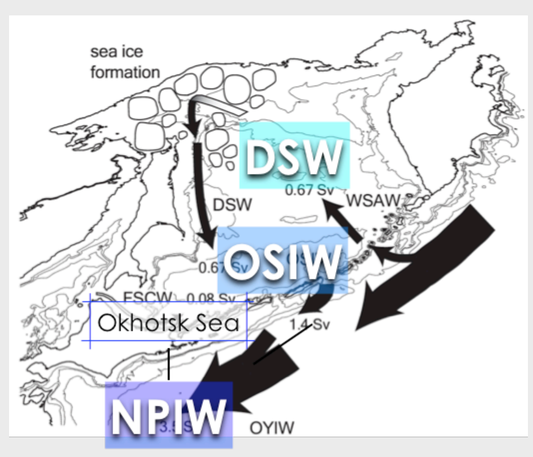
Nitrogen (N) cycle in the ocean balances with biological source (N_2 fixation) and sink (denitirification). Most recent studies suggest that the oceans are, on balance, losing fixed nitrogen, but the magnitude of the net loss is not well quantified [*Codispoti et al.,* 2001, 2007].



The Sea of Okhotsk

Dense shelf water (DSW)
⇒Okhotsk Sea Intermediate Water (OSIW)
⇒North Pacific Intermediate Water(NPIW)
(e.g., Ohshima and Martin, 2004; Yasuda, 1997)

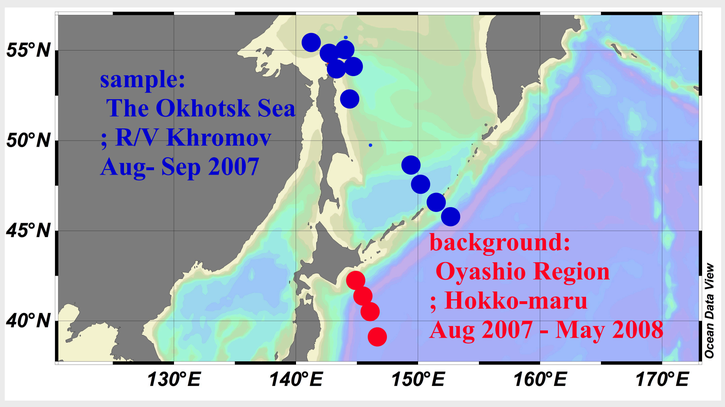
- The Sea of Okhotsk has the same trends as global, which has been caused by weakening of formation/circulation of the NPIW as a response to the reinforcement of ocean stratification (e.g., Watanabe et al., 2001).
- The occurrence of denitrification in benthic water of the western basin by a low N* and a high $\delta^{15}NO_3^-$ (Yoshikawa et al., 2006).



Methods

Study sites and data

We obtained the seawater samples of dissolved gas properties from 10m to bottom depth and determined N_2, Ar and O_2 by using a high accuracy GC method (*Tanaka and Watanabe,* 2007). The analytical precisions of N_2, Ar and O_2 were 0.04%, 0.05%, 0.02%, respectively.

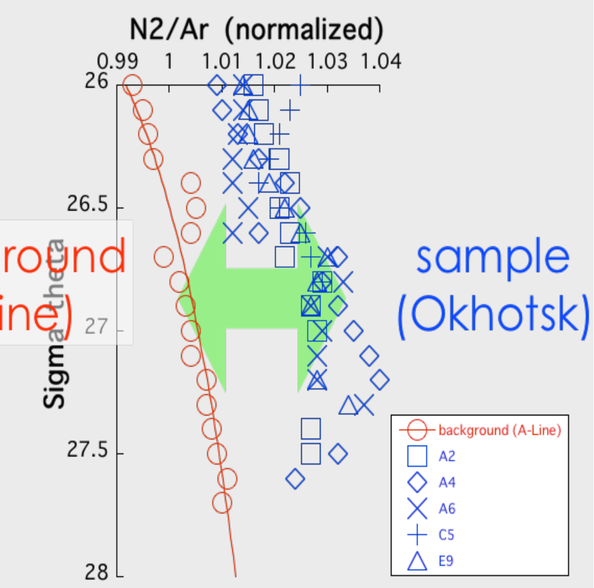


Concept for estimating $N_{2\ excess}$ in the seawater

N_2 inventory by denitirification and its rate by modified method of *Devol et al.* (2006).

$$[N]_{excess} = [(N_2 : Ar)_{sample} - (N_2 : Ar)_{background}] \cdot \alpha \cdot [N]_{(t,\,s)}, \quad (1)$$

where,
$[N]_{excess}$: the pool of "extra" N_2 resulting from denitrification.
$(N_2:Ar)$: the normalized N_2:Ar ratio (1.000 indicates equilibrium by dividing equilibrium saturation values (*Emerson et al.,* 1999)).
sample & *background*: the data within the Sea of Okhotsk (*sample*) and Oyashio (*background*)
$[N]_{(t,s)}$: the atmospheric equilibrium saturation of N_2 calculated from observed temperature and salinity
α: the correction term for the bubble injection process, which is the amount of bubble injection (μmol/kg) in seawater



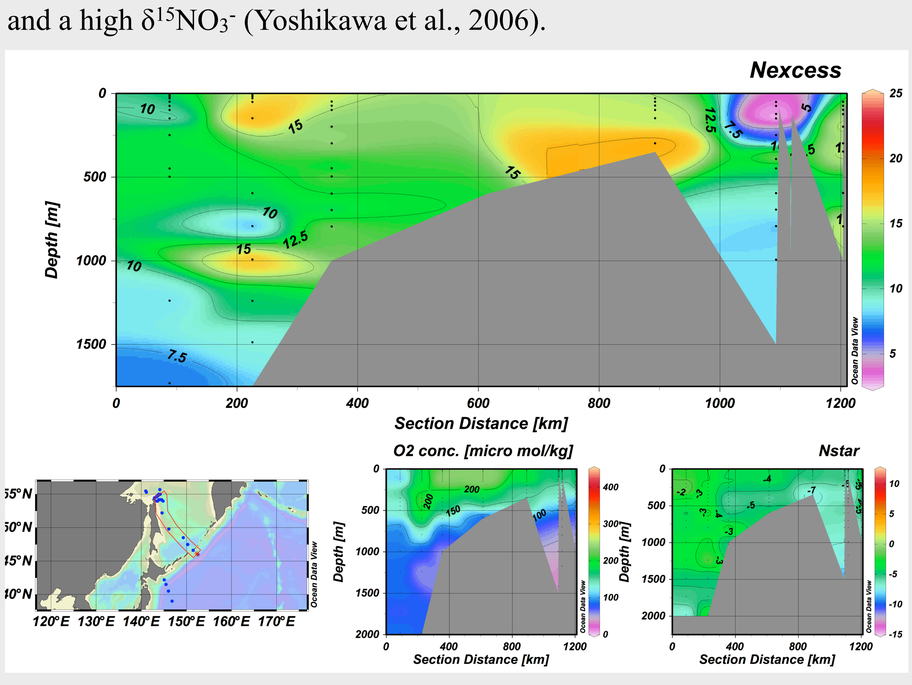
Results and Discussion

N* and O2 concentration profile

- Index of nitrogen fixation-denitrification:

$$N^* = [NO_3]+[NO_2]+[NH_4] - 16 \times [PO_4] + 2.9, \quad (2)$$

- The occurrence of denitrification in benthic water of the western basin by a low N* and a high $\delta^{15}NO_3^-$ (Yoshikawa et al., 2006).



Estimate of the rate of denitrification

$$R = \int_0^{bottom} [N]_{excess} / \sigma \times S \times 1/\tau, \quad (2)$$

where,
R: denitrification rate (mol y^{-1})
$[N]_{excess}$: the amount of excess N_2 gas per density (μmol kg^{-1})
σ: the potential density
S: an area in study site ($1.6 \times 10^{11} \sim 4.2 \times 10^{11}$ m^2 from *Ohshima et al.,* 2006)
τ: a residence time of seawater (1.4 y from *Itoh et al.,* 2003)

	R (T mol y^{-1})	Area (m^2)	R / A (mol m^{-2} y^{-1})
Okhotsk Sea	0.49 ± 0.20 ~ 1.29 ± 0.53	1.6×10^{11} ~ 4.2×10^{11}	3.08 ± 1.26
Arabian Sea	2.92 ± 1.81	1.5×10^{12}	1.95 ± 1.2
Global	32.12	358×10^{12}	0.004 ± 0.002 ~ 0.012 ± 0.005

References

Codispoti et al., 2001, *Scientia Marina* 65, 85-105; Watanabe et al., 2001, *Geophys. Res. Let.*, 28(17), 3289-3292; Watanabe et al., 2009, *Geophys. Res. Let.*, 36, L15606; Tanaka and Watanabe, 2007, *Marine Chemistry*, 106, 516-529; Devol et al., 2006, *Deep-Sea Research I*, 53, 1533-1547; Emerson et al., 1991, *Global Biogeohem. Cycles*, 5(1), 49-69; Ohshima et al., 2006, *J. Meteorol. Soc. Jpn.*, 84(5), 907-919; Ohshima and Martin, 2004, *J. Geophys. Res.*, 109, C09S01; Itoh et al., 2003, *J. Geophys. Res.*, 108, 3258