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

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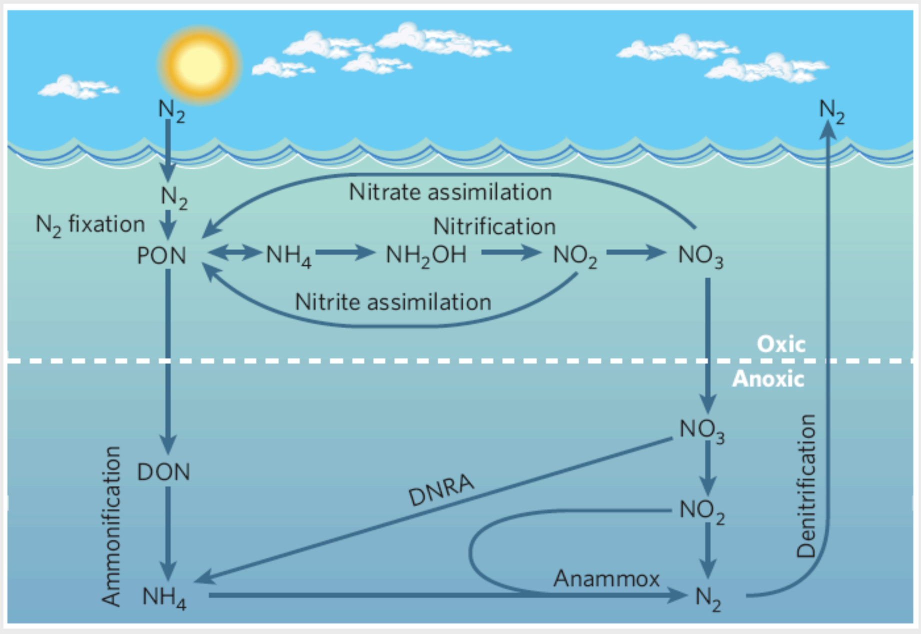
Backgrounds

Nitrogen Cycle in the Ocean

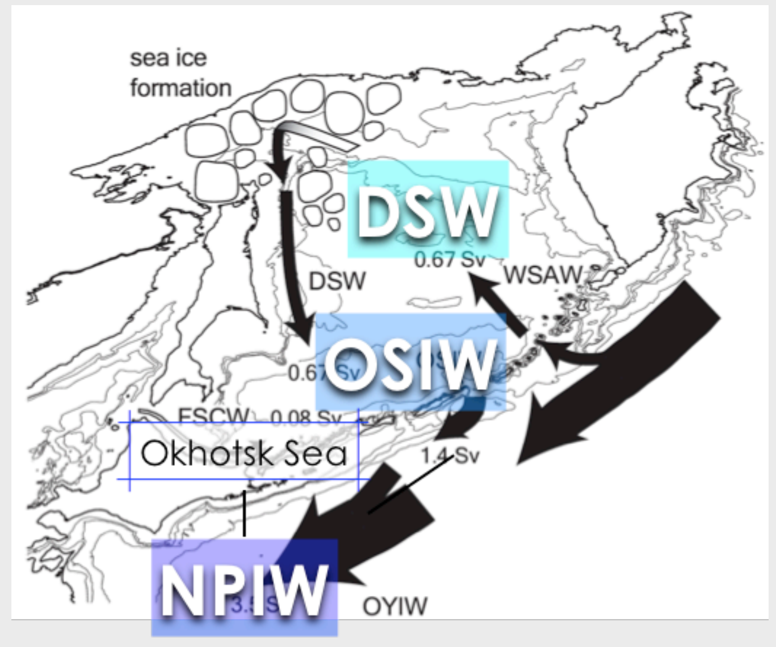
Nitrogen (N) cycle in the ocean balances with biological source (N_2 fixation) and sink (denitirification). Most recent studies suggest that the oceans are, on balance, losing fixed nitrogen, but the magnitude of the net loss is not well quantified [*Codispoti et al.*, 2001, 2007].



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)

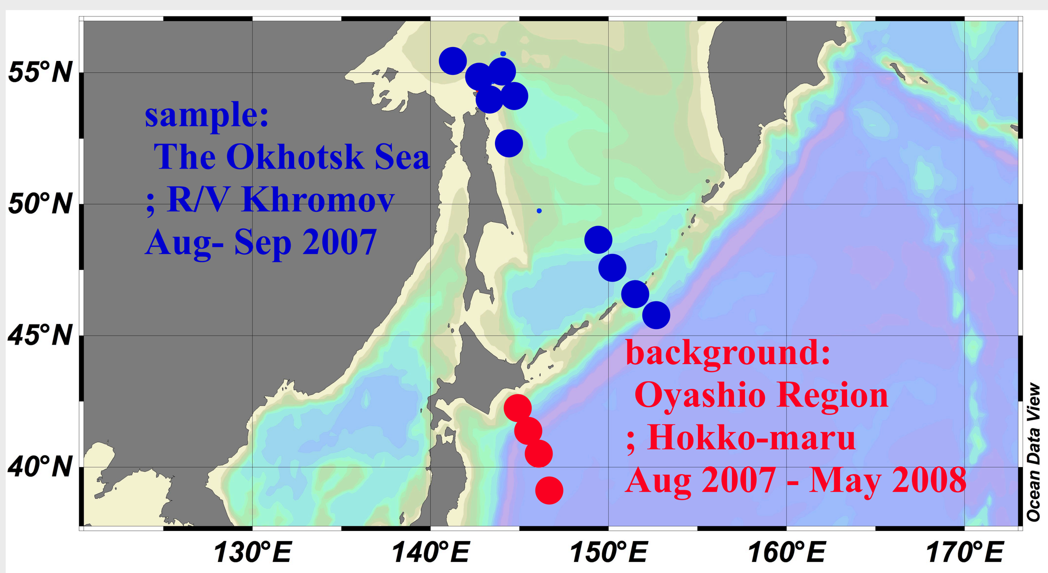
- The Sea of Okhotsk has the same trends as global, which has been caused by weakening of formation/circulation of the NPIW as a response to the reinforcement of ocean stratification (e.g., Watanabe et al., 2001).
- The occurrence of denitrification in benthic water of the western basin by a low N* and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

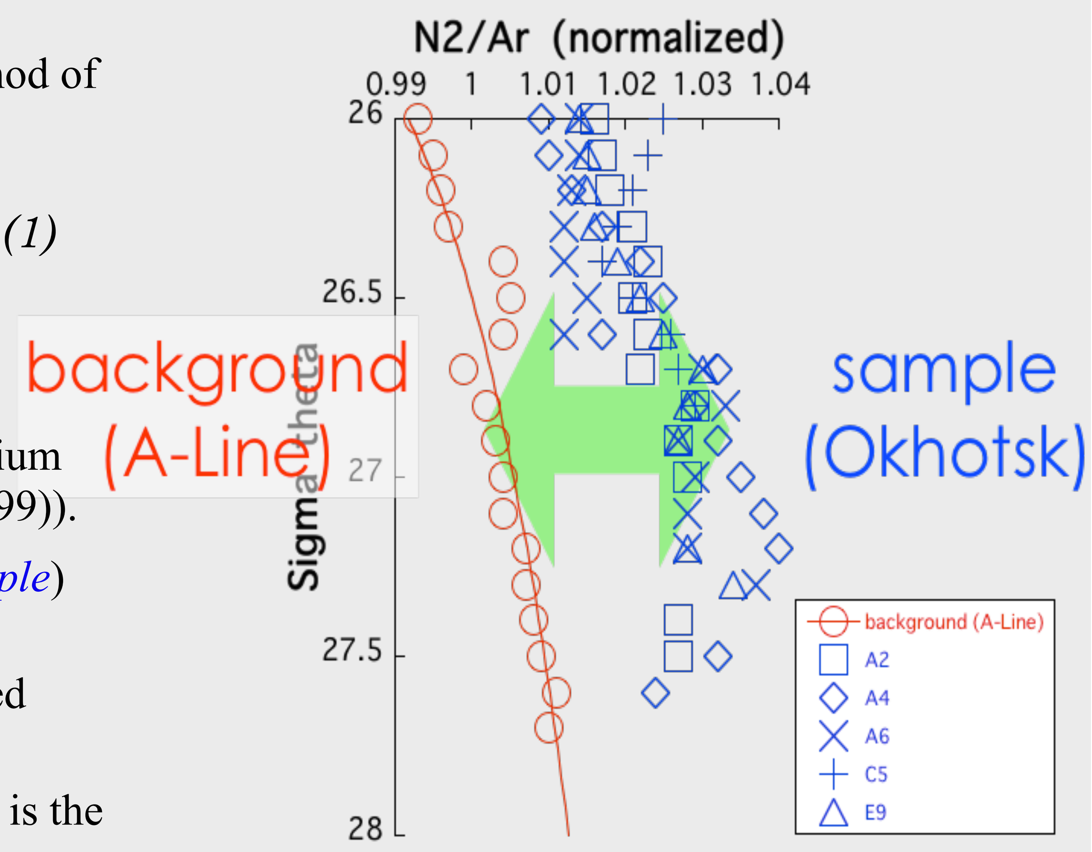
[N]*excess*: the pool of "extra" N_2 resulting from denitrification.

(N₂: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



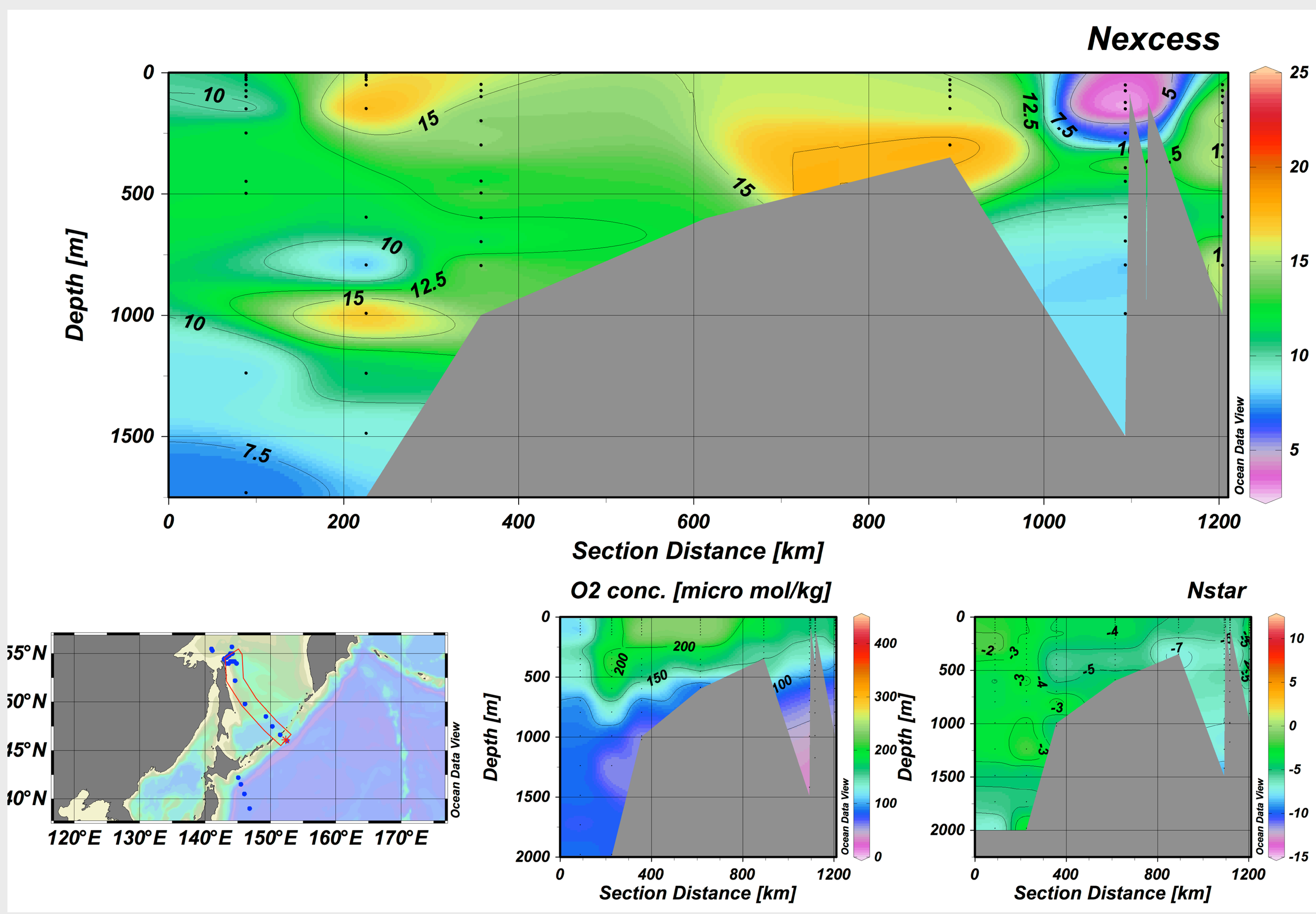
Results and Discussion

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 (1.6×10^{11} ~ 4.2×10^{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