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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 (N₂ 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) \Rightarrow 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 N₂, Ar and O₂ by using a high accuracy GC method (Tanaka and Watanabe, 2007). The analytical precisions of N₂, Ar and O₂ were 0.04%, 0.05%, 0.02%, respectively.



Concept for estimating N_{2 excess} in the seawater

N₂ inventory by denitirification and its rate by modified method of *Devol et al.* (2006).

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

where,

[N]_{excess}: the pool of "extra" N_2 resulting from denitrification. (N₂:Ar): the normalized N₂:Ar ratio (1.000 indicates equilibrium $(A-Line)_{27}$ 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 N₂ 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:

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

 $R = \int_{0}^{bottom} [N]_{excess} / \sigma \times S \times 1/\tau, (2)$

where, *R*: denitrification rate (mol y⁻¹) $[N]_{excess}$: the amount of excess N₂ gas per density (µmol kg⁻¹)



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