Toward a simulation of iron circulation from the Okhotsk Sea to the Pacific

Keisuke Uchimoto¹
Tomohiro Nakamura¹, Jun Nishioka¹, Humio Mitsudera¹, Kazuhiro Misumi² and Daisuke Tsumune²

¹: Institute of Low Temperature Science, Hokkaido University, JAPAN
²: Central Research Institute of Electric Power Industry, JAPAN
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Nishioka et al. (2007, JGR)
Presentation Outline

• **Introduction:** Importance of intermediate layer in Okhotsk Sea
• **Ocean model description**
• **Tracer experiment:** DSW on the shelf
• **Simulation of chlorofluorocarbons (CFCs):** intermediate layer ventilation in Okhotsk Sea
• **Iron model description:** Parekh’s model
• **Simulations of iron distribution:** results of preliminary runs
• **Summary**
Introduction

Ventilation of the intermediate layer in the Sea of Okhotsk
Location for ventilation of the North Pacific Intermediate Water (e.g. Talley, 1991)
Sea of Okhotsk

- Two ventilation processes for the intermediate layer
  - brine rejection during sea ice formation
  - tidal mixing along the Kuril Islands

Ventilation Processes Control Fe Transport
suggested by Nishioka et al. (2007, JGR)
brine: high salinity water

Dense Shelf Water (DSW)

polynya

brine

ice
How brine rejection controls Fe transport?

Dense shelf water (DSW) is formed in the northern part of the Sea of Okhotsk.

Fe is transported in the intermediate layer.

Nakatsuka et al. (2004, JGR)

Nishioka et al. (2007, JGR)
Misumi et al. (accepted, JGR) well simulate the Fe distribution in the North Pacific. But their model poorly represents ventilation processes in the Sea of Okhotsk.
An ocean model that can represent the ventilation of the intermediate layer in the Sea of Okhotsk is essential for simulating iron distribution.

- **Tracer experiment**: behavior of DSW
- **CFC simulation**: ventilation of intermediate layer
MODEL

OGCM: Sea Ice-Ocean Model (COCO);
primitive equation model

Resolution:
- horizontally 0.5°
- vertically 51 levels

Forcing: daily climatological atmospheric data (OMIP data)
Tidal mixing parameterization along the Kuril Islands

Vertical diffusion coefficients as tidal mixing effects

CROSSES grids with the increased vertical diffusion as tidal mixing effects
Tracer experiment

Uchimoto et al. (2011, Hydrological Research Letters)

Highest Sea Ice production area

Tracer is injected from Jan. to Apr. at the sea surface (restored to 1.0).

Ice production
Kimura and Wakatsuchi (1999)
Tracer experiments

Vectors:
- annual mean velocity

Concentration of tracer

DSW (σθ > 26.9, T < −1°C) cross-hatching

Nakatsuka et al. (2004, JGR)
CFC simulation
Uchimoto et al. (2011, JGR)
performed according to OCMIP-2 protocols

Ventilation of intermediate layer in the model

- CFC on 26.8 $\sigma_\theta$ and 27.4 $\sigma_\theta$ surfaces
- $\Delta p$CFC along path of DSW
CFC12 on $26.8 \sigma_\theta$, $27.4 \sigma_\theta$

Ventilation owing to dense shelf water (DSW)

Ventilation owing to tidal mixing along Kuril

Sakhalin Island

Color scales are different by a factor of 10.
$\Delta p_{\text{CFC}}$ ( $\Delta$ partial pressure of CFC)

$\Delta p_{\text{CFC}}(\bar{x}, \rho) = p_{\text{CFC}}(\bar{x}, \rho) - p_{\text{CFC}}(\rho)$

at the ref. point

Index of the water ventilated within the Sea of Okhotsk
$\Delta p_{\text{CFC}}$ (\(\Delta\) partial pressure of CFC)

\[ \Delta p_{\text{CFC}}(\bar{x}, \rho) = p_{\text{CFC}}(\bar{x}, \rho) - p_{\text{CFC}}(\rho) \]

at the ref. point
Δ pCFC (Δ partial pressure of CFC)

Two experiments
- without tidal mixing along Kuril Islands
- without brine rejection

Ventilation through brine rejection
Ventilation through tidal mixing

without tidal mixing
without brine rejection
simulation of iron circulation
Iron (biogeochemical) Model description

Model developed by Parekh et al. (2005, GBC)
PO4, DOP (dissolved organic P), and Fe (total dissolved iron)

\[ Fe = Fe' + FeL \]

Fe': free

FeL: complexed (L: ligand)
Phosphorus cycle

\[ \Gamma = \alpha \frac{\text{PO}_4}{\text{PO}_4 + \text{K}_{\text{PO}_4}} \frac{\text{Fe}}{\text{Fe} + \text{K}_{\text{Fe}}} \frac{\text{I}}{\text{I} + \text{K}_I} \]  
(I : light)

Biological uptake
remineralization DOP→PO4

\[ \Gamma \]

PO4

DOP

euphotic

below euphotic

euphotic

below euphotic

euphotic

Biological pool

euphotic layer = 135 m
Iron Cycle
Fe (dissolved)

• Biological uptake
• Remineralization → proportional to those of PO₄.

aeolian dust (Mahowald et al. 2005, GBC)

Fe is 3.5% of dust
solubility 1%

proportional to Fe'
(Fe=Fe'+FeL)
total ligand conc. = 1.2 nM

Scavenging
euphotic
down
below

sediments
1 μmol/m²/d
(shelf shallower than 300 m)
Fe distribution in the model

Fe on 26.80σ

26.8 σθ

18/07/03

[ nM ]

0.0 1.3 2.6

experiment without sedimentary Fe

Nishioka et al. (2007)
Fe distribution in the model

- Color scale is different by a factor of 2 only in this figure.
Fe distribution in the model

greens: observed in Okhotsk
Nishioka et al. (2007, JGR)

Max. concentration around 27 $\sigma_\theta$

27.0
26.8
Summary

• We have constructed an ocean model that can represent well the circulation and ventilation in the intermediate layer.
  – tracer experiment, CFC simulation

• Combined with Parekh’s model, the model represents iron flows in the intermediate layer, although still in a preliminary stage.
Thank you for your attention!

acknowledgement:

• This work has been supported by the New Energy and Industrial Technology Development Organization (NEDO).
• Aeolian dust data were provided by Dr. Mahowald.