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

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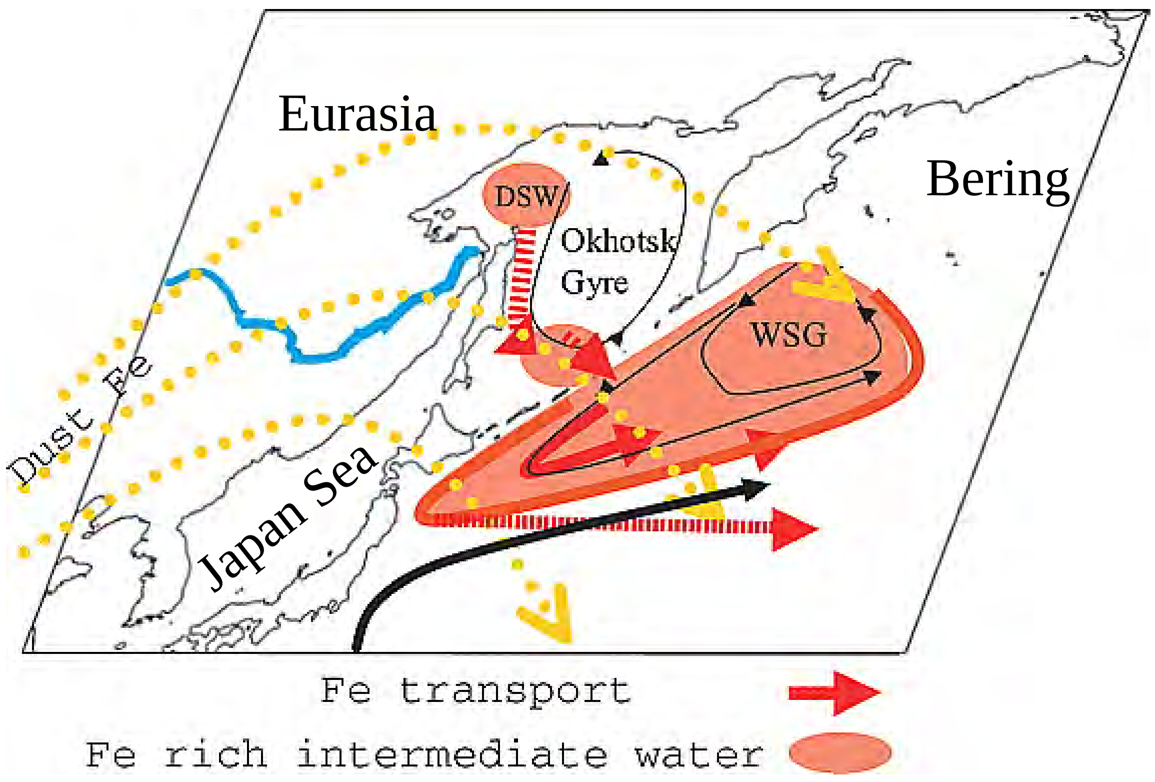
Toward a simulation of iron circulation from the Okhotsk Sea to the Pacific



Nishioka et al. (2007, JGR)

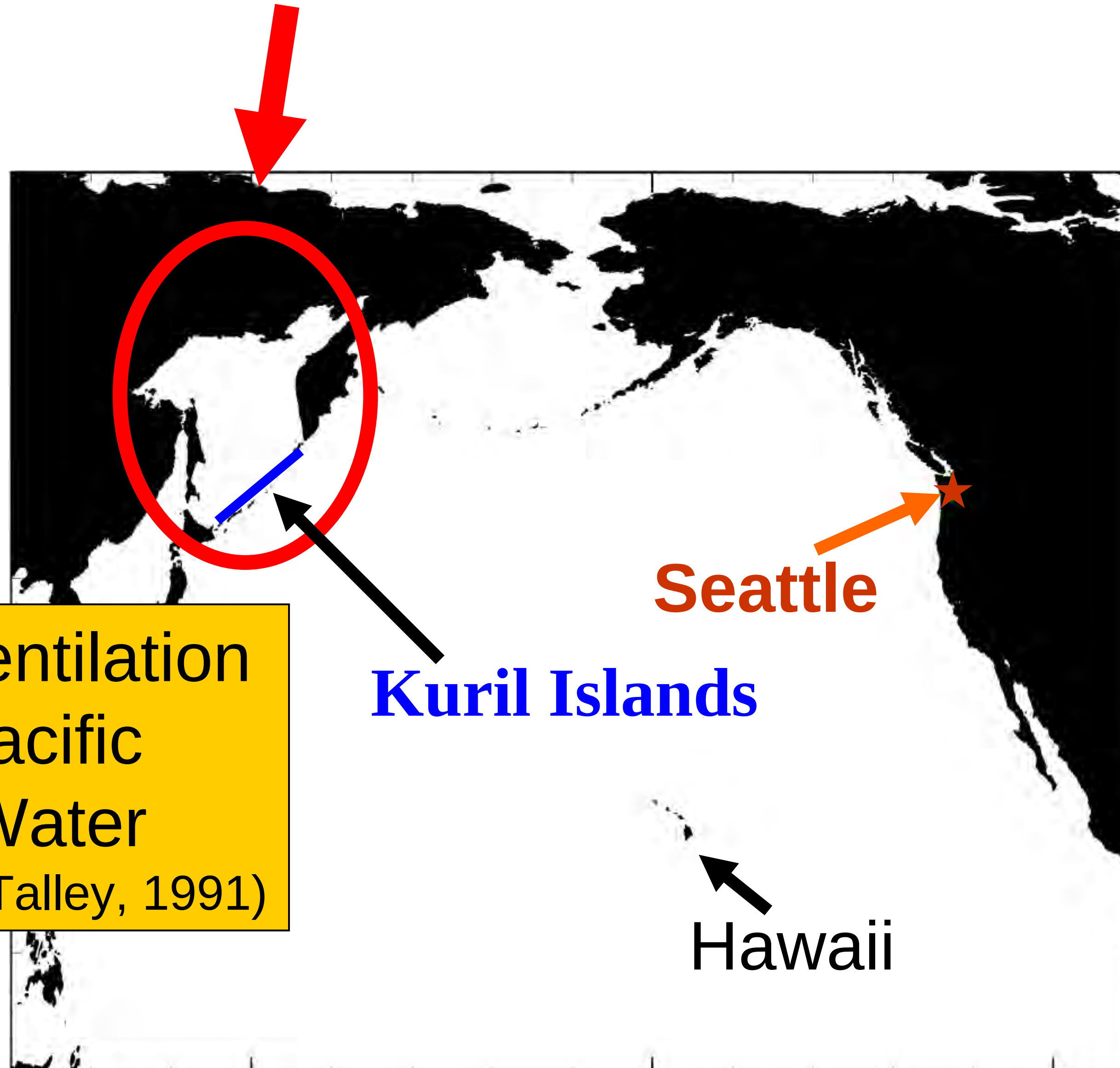
Presentation Outline

- **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

Sea of Okhotsk

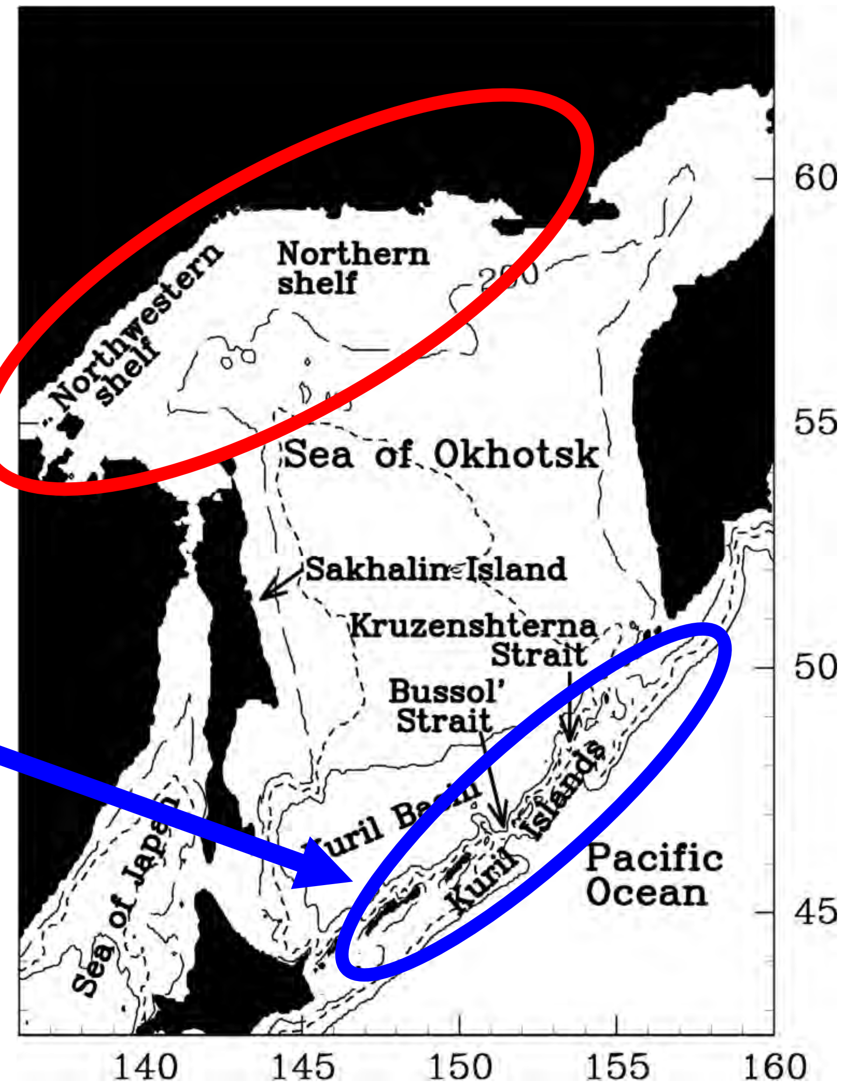


Location for ventilation of the North Pacific Intermediate Water

(e.g. Talley, 1991)

Sea of Okhotsk

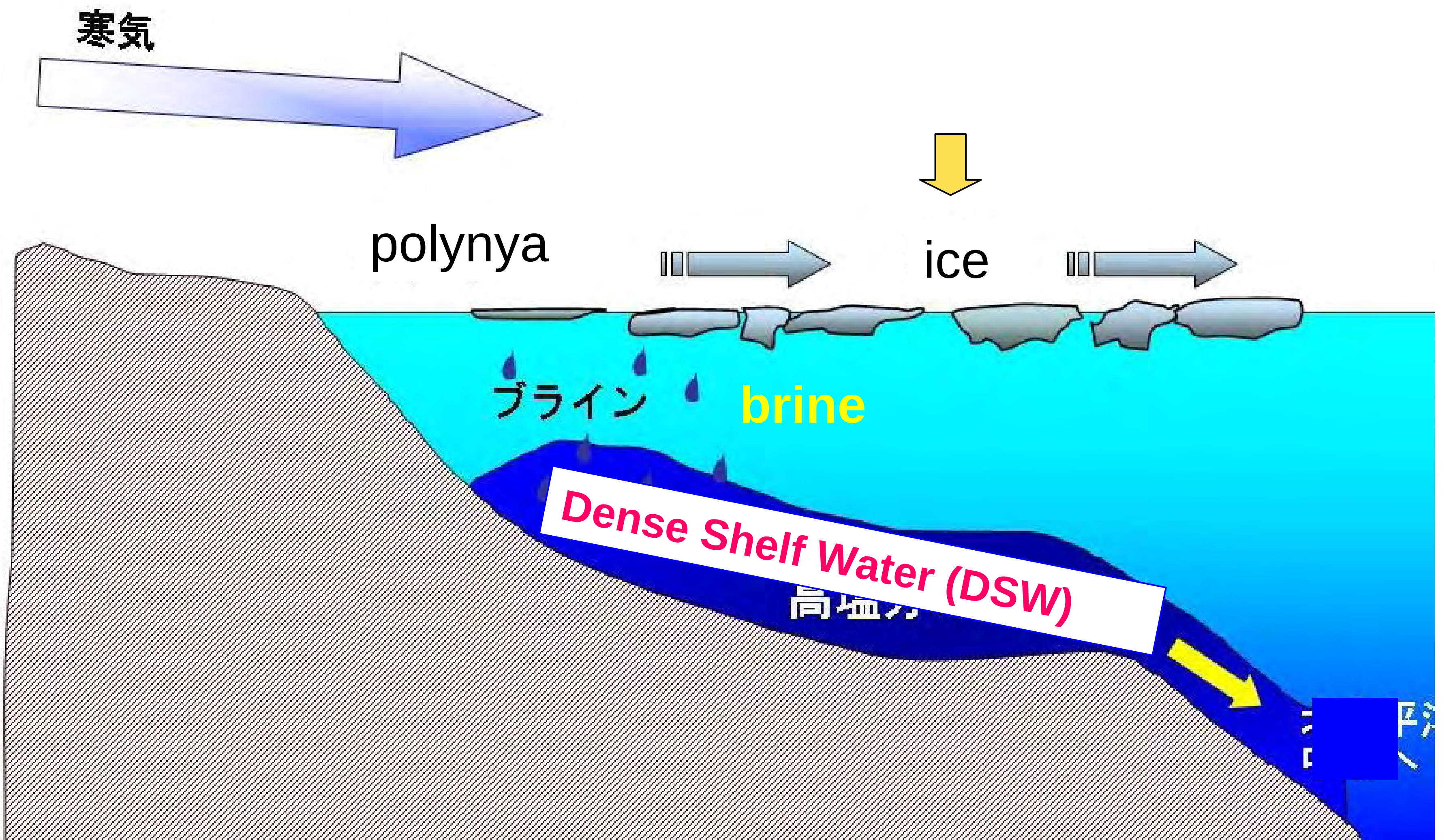
- Two ventilation processes for the intermediate layer
  - brine rejection during sea ice formation
  - tidal mixing along the Kuril Islands



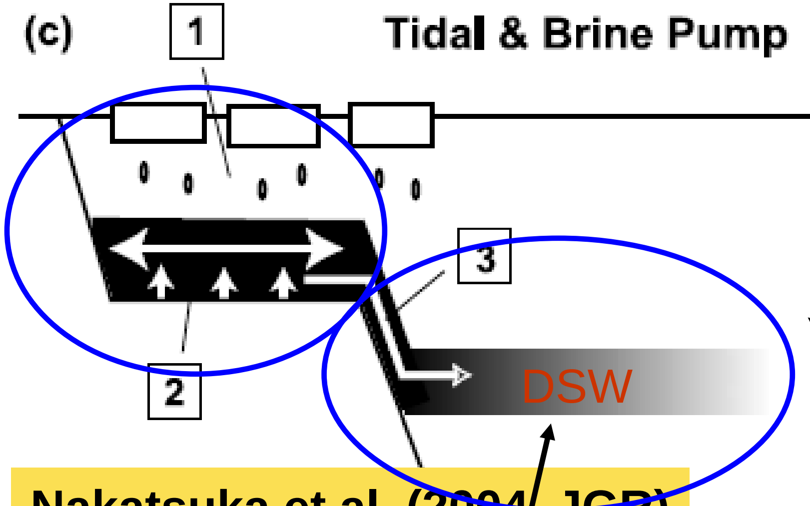
Ventilation Processes Control Fe Transport

suggested by Nishioka et al. (2007, JGR)

brine: high salinity water



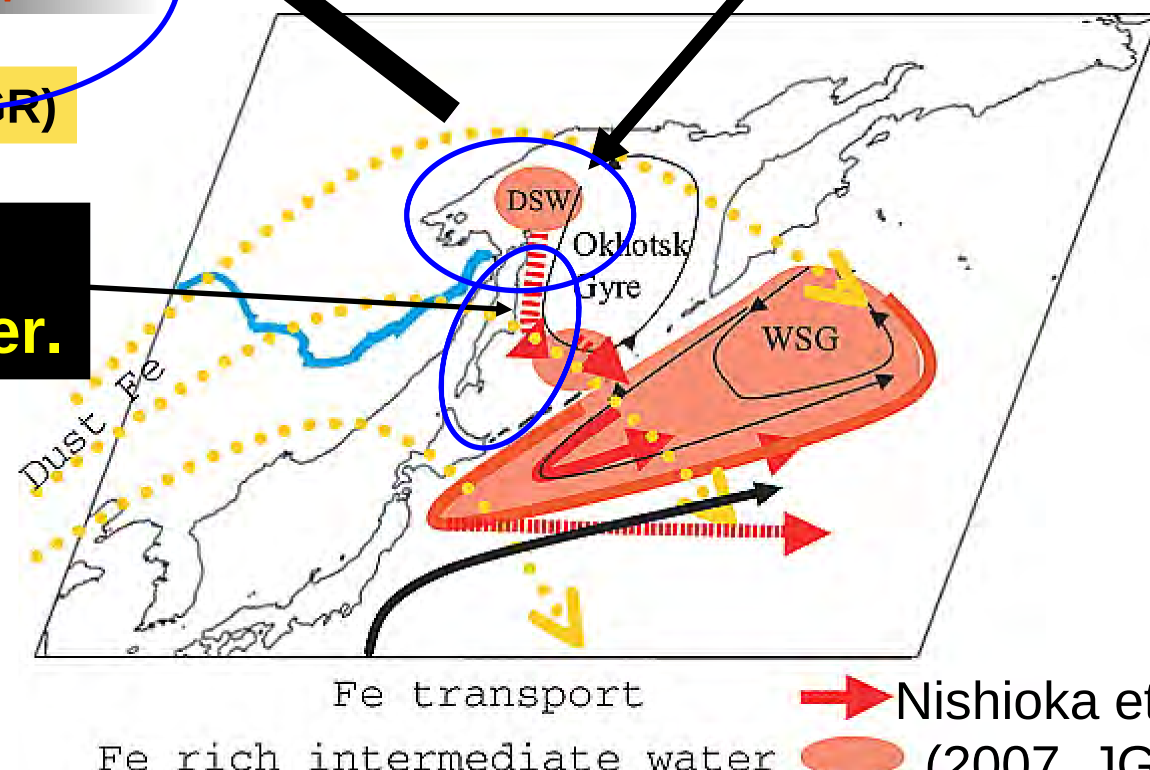
How brine rejection controls Fe transport?



Nakatsuka et al. (2004, JGR)

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

Fe is transported in the intermediate layer.



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

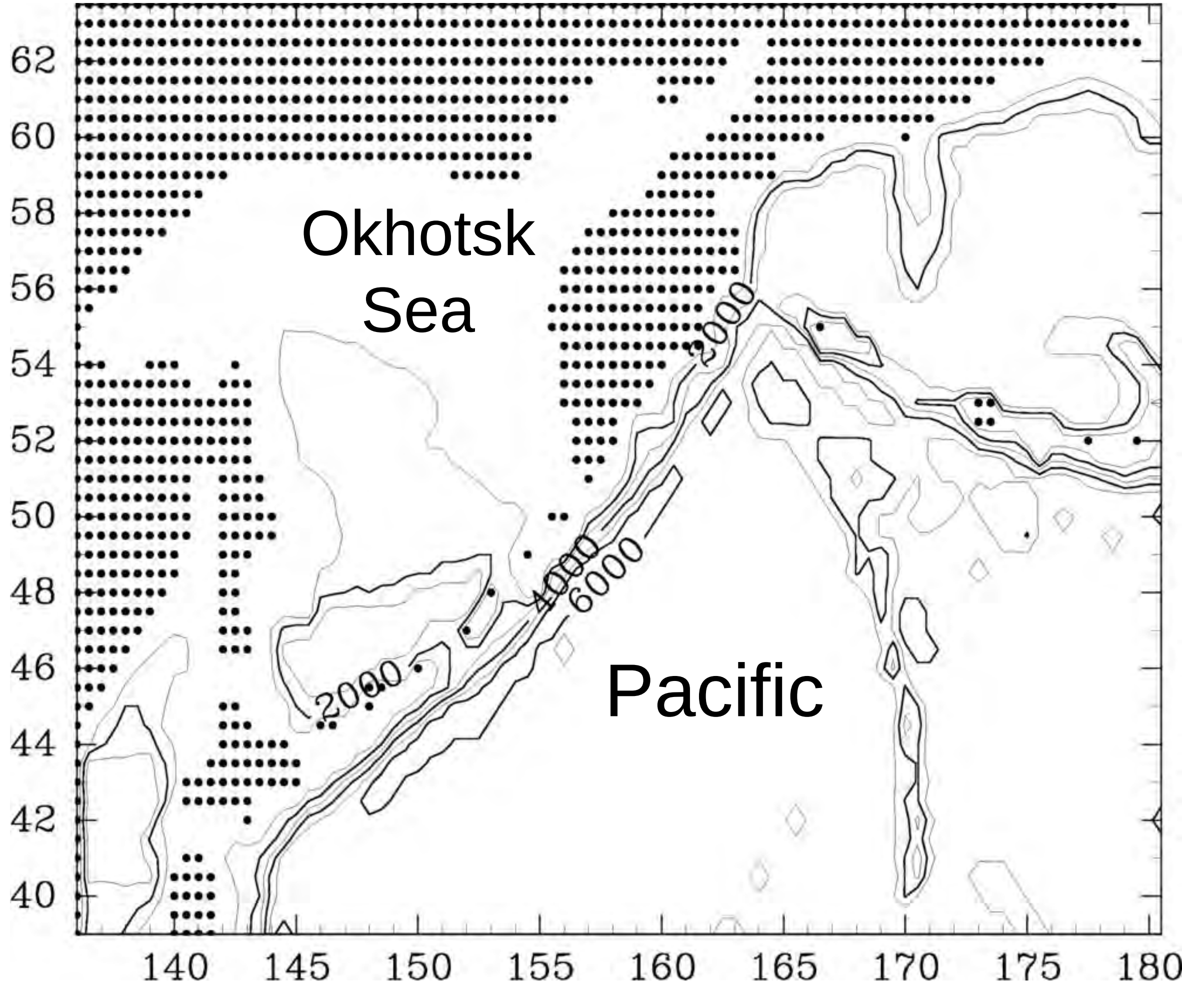
OGCM: **Sea Ice-Ocean Model** (COCO); primitive equation model

Resolution:

horizontally 0.5°

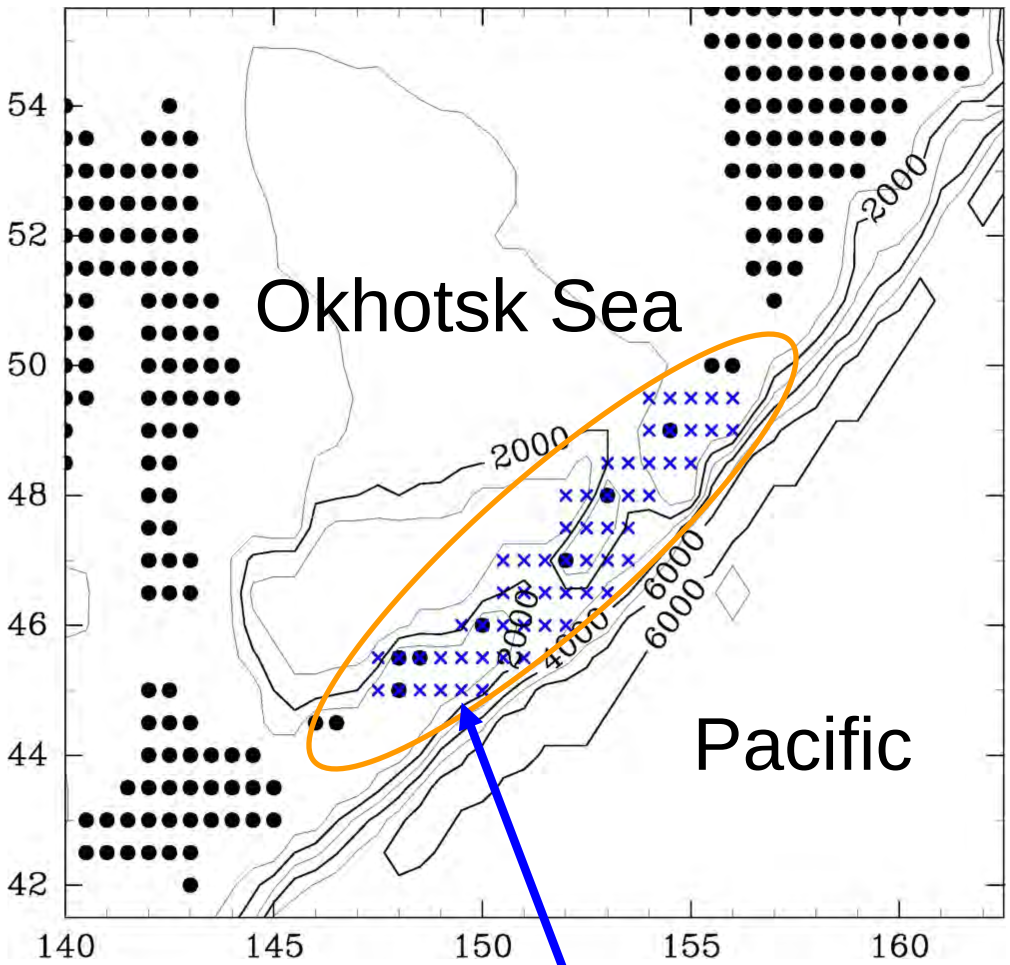
vertically 51 levels

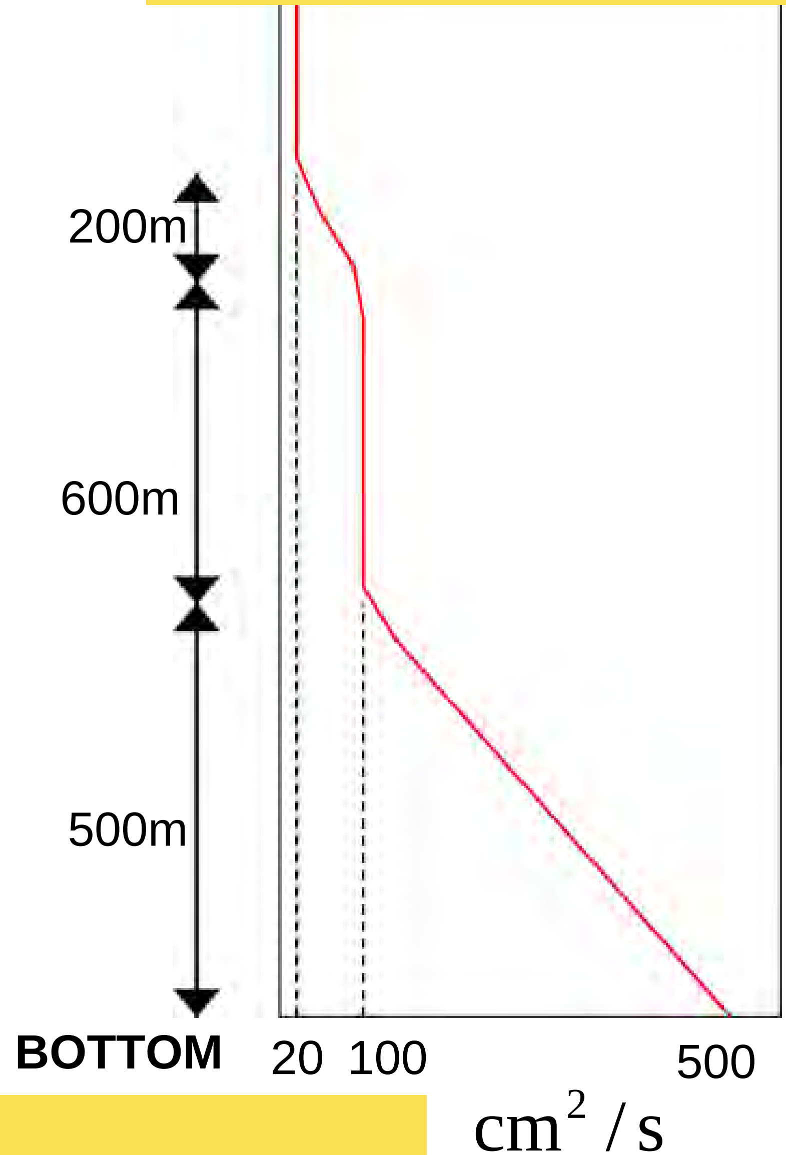
Forcing: **daily climatological atmospheric data** (OMIP data)



Tidal mixing parameterization along the Kuril Islands

Vertical diffusion coefficients as tidal mixing effects





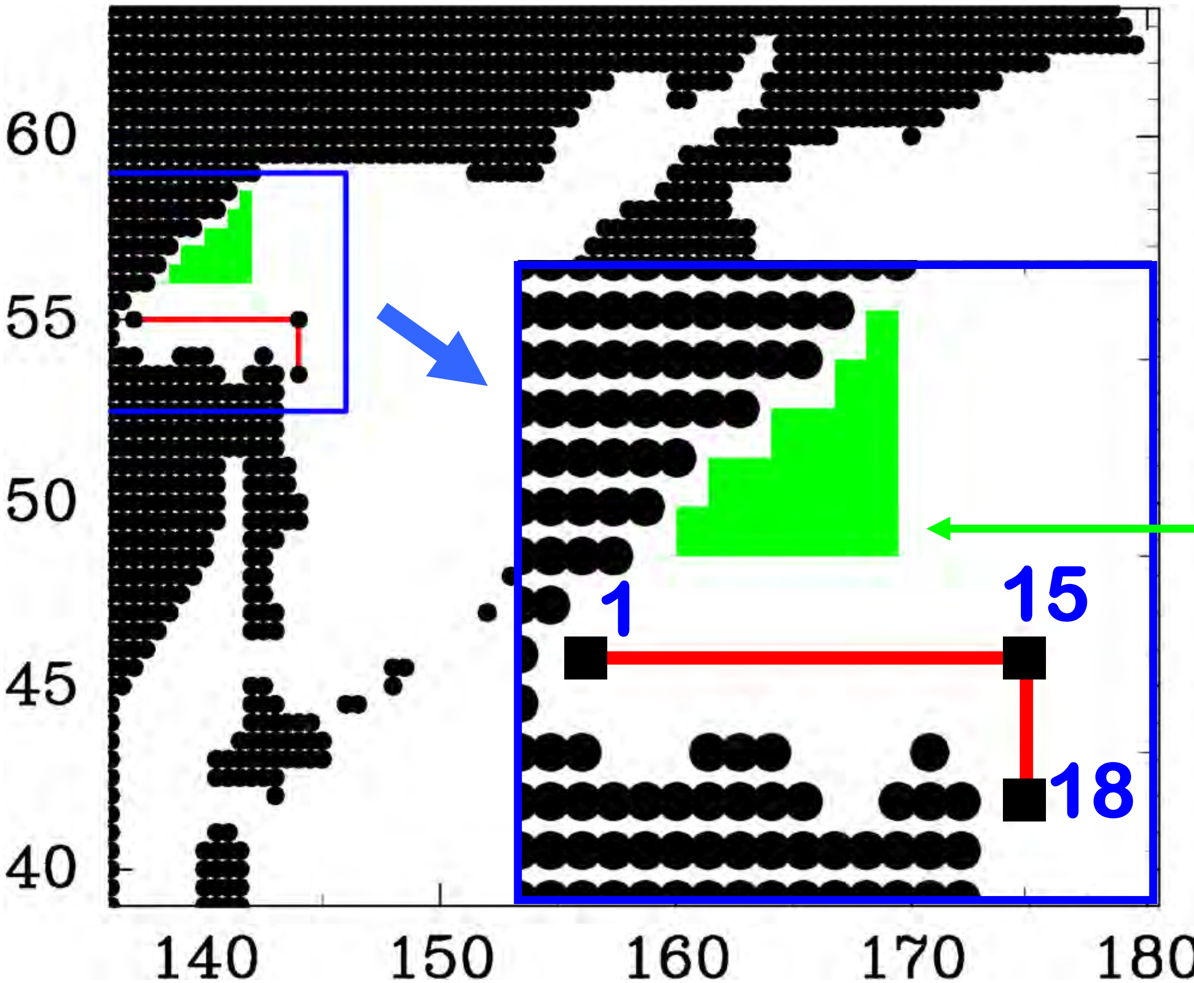
CROSSES

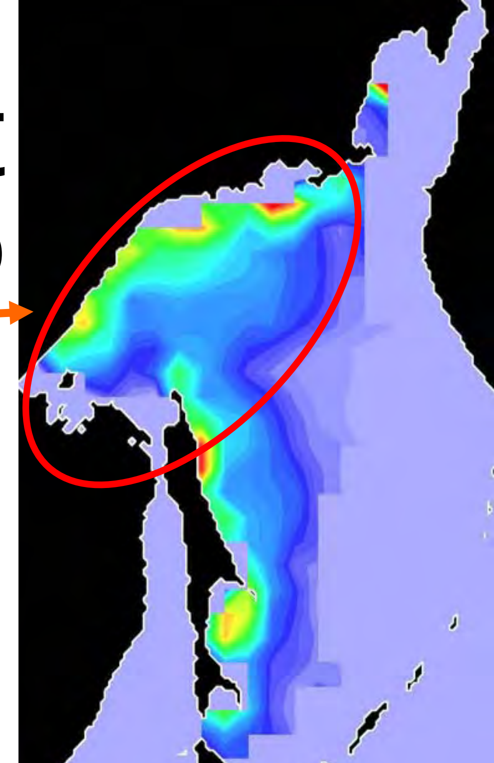
grids with the increased vertical diffusion as tidal mixing effects

Tracer experiment

Uchimoto et al. (2011, Hydrological Research Letters)

Highest Sea Ice production area

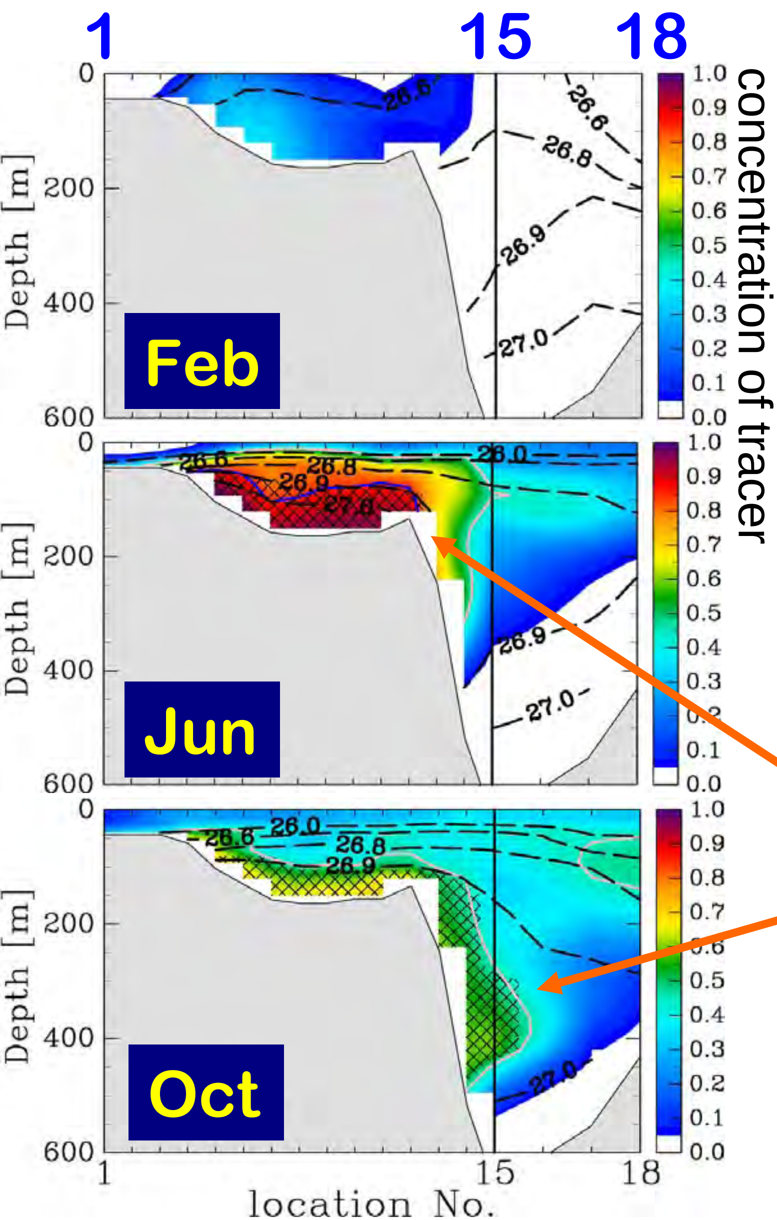


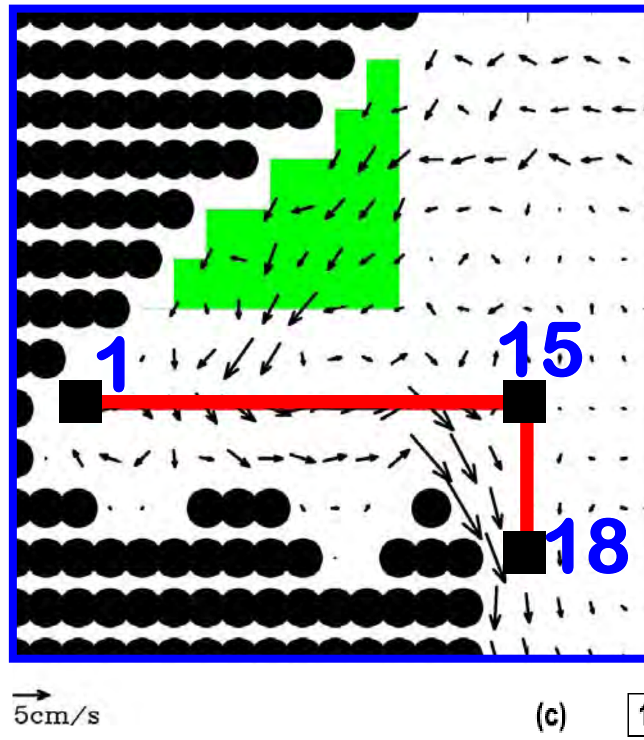


Ice production
Kimura and Wakatsuchi (1999)

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

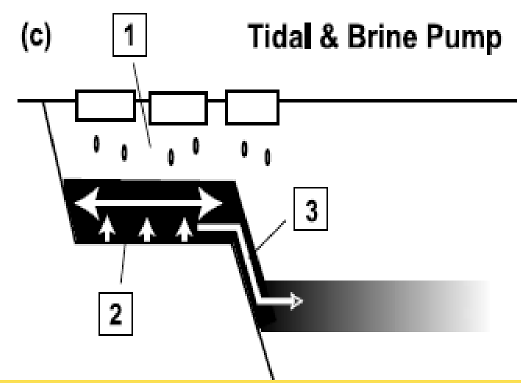
Tracer experiments





Vectors:
annual mean velocity

DSW (σ_θ>26.9, T<−1℃)
cross-hatching



Nakatsuka et al. (2004, JGR)

CFC simulation

Uchimoto et al. (2011, JGR)

performed according to OCMIP-2 protocols

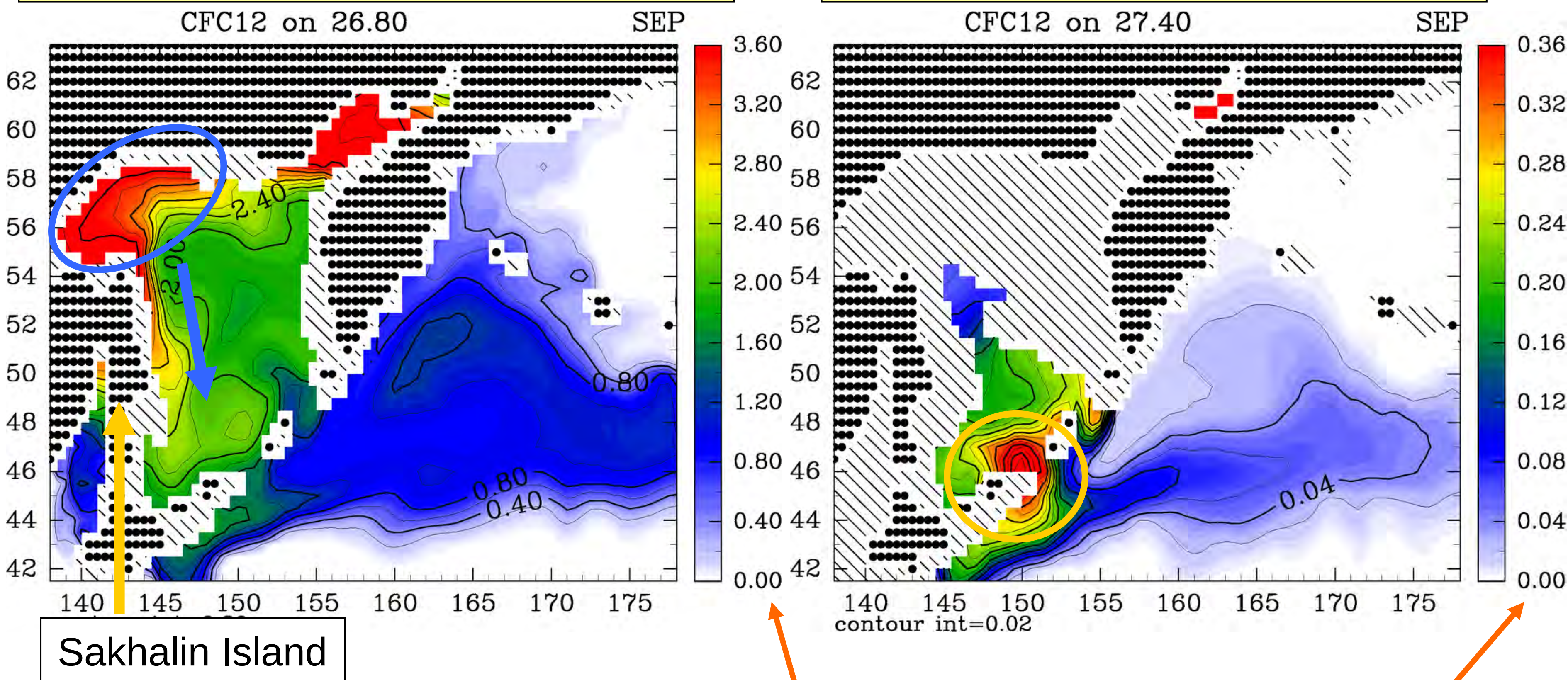
Ventilation of intermediate layer in the model

- CFC on 26.8σ_{θ} and 27.4σ_{θ} surfaces
- ΔpCFC along path of DSW

CFC12 on 26.8 σ_θ, 27.4 σ_θ

Ventilation owing to dense shelf water (DSW)

Ventilation owing to tidal mixing along Kuril



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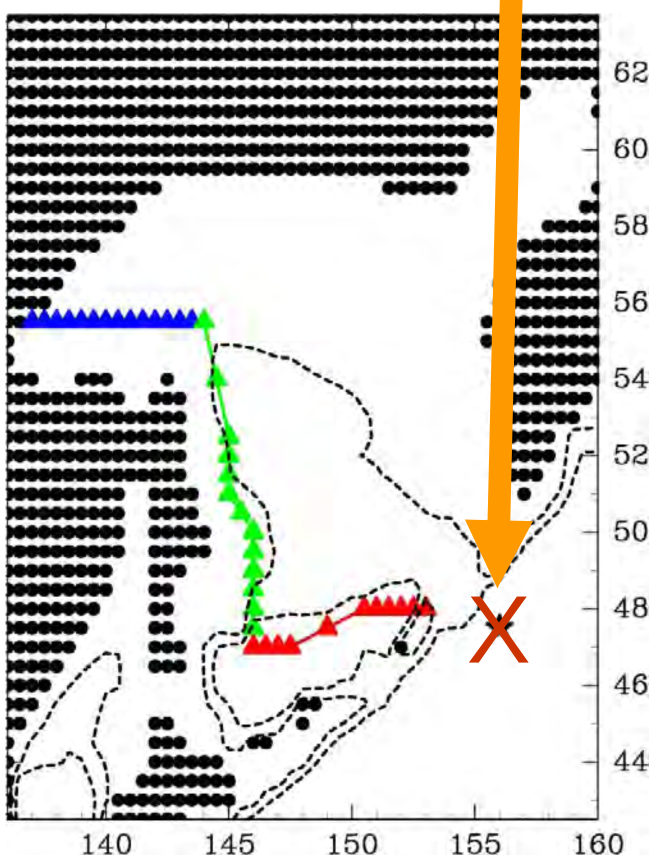
Δ pCFC (Δ partial pressure of CFC)

$$\Delta \mathrm{pCFC}(\vec{\mathrm{x}}, \rho) = \mathrm{pCFC}(\vec{\mathrm{x}}, \rho) - \mathrm{pCFC}(\rho)$$

at the ref. point

Index of the water ventilated within the Sea of Okhotsk



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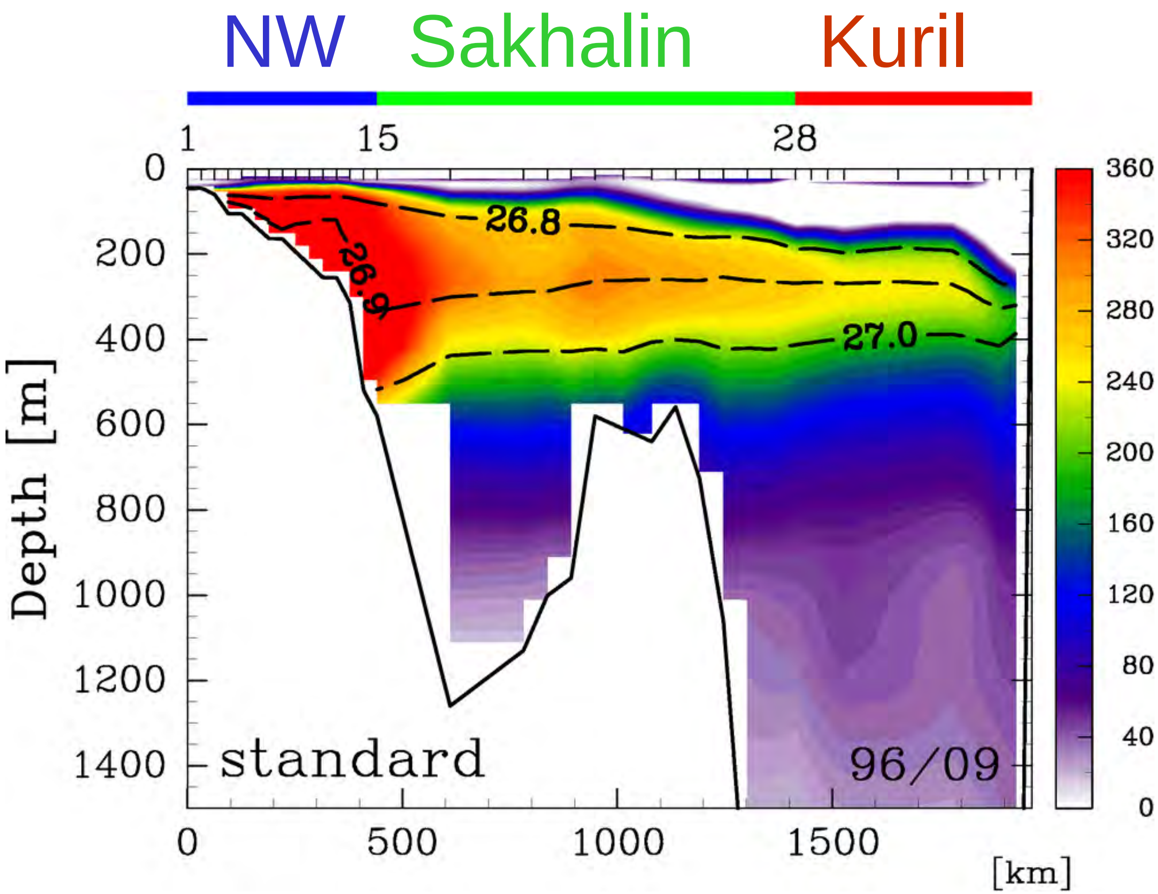
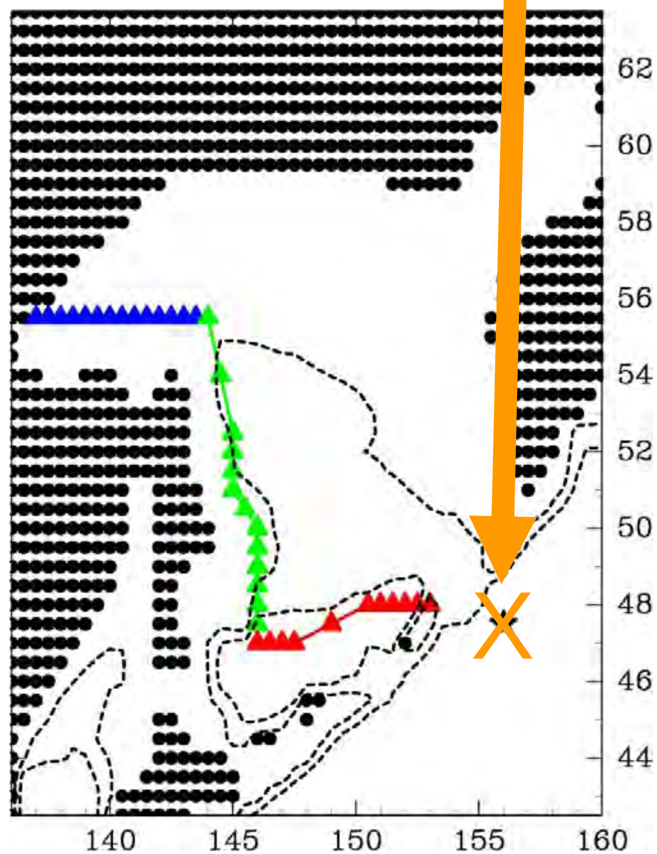
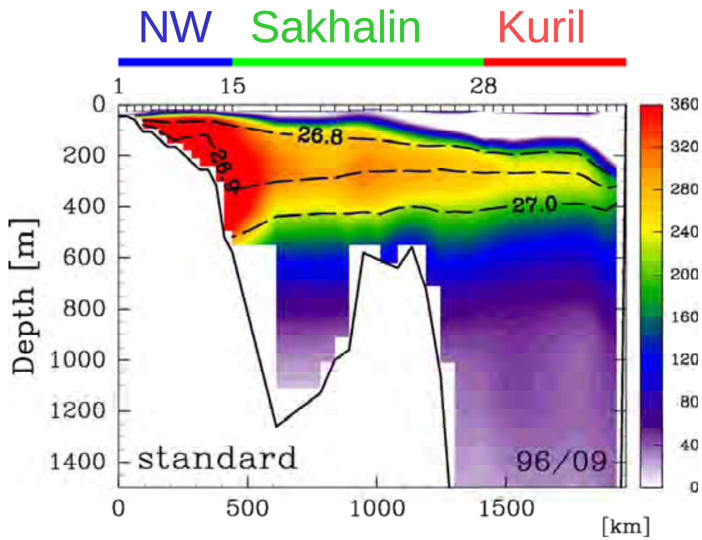
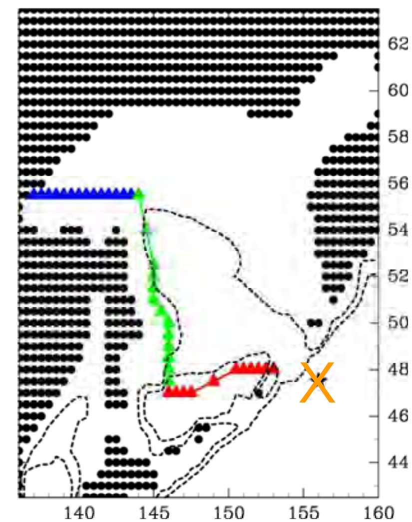




Δ pCFC (Δ partial pressure of CFC)



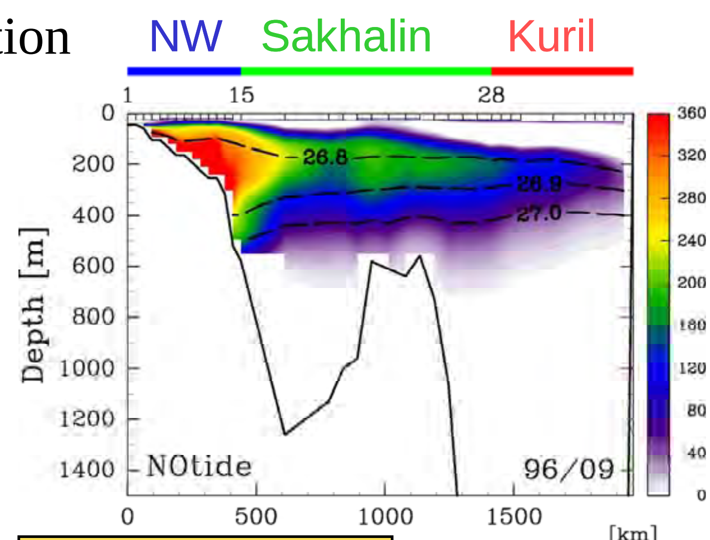


Two experiments

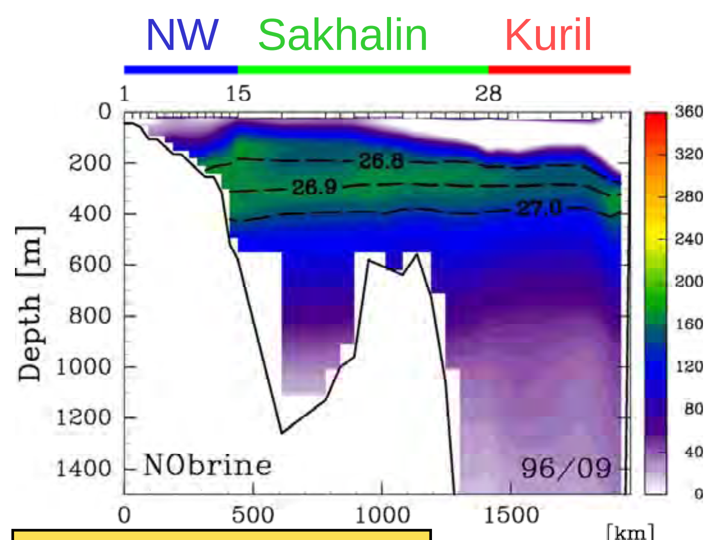
- without tidal mixing along Kuril Islands
- without brine rejection

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)

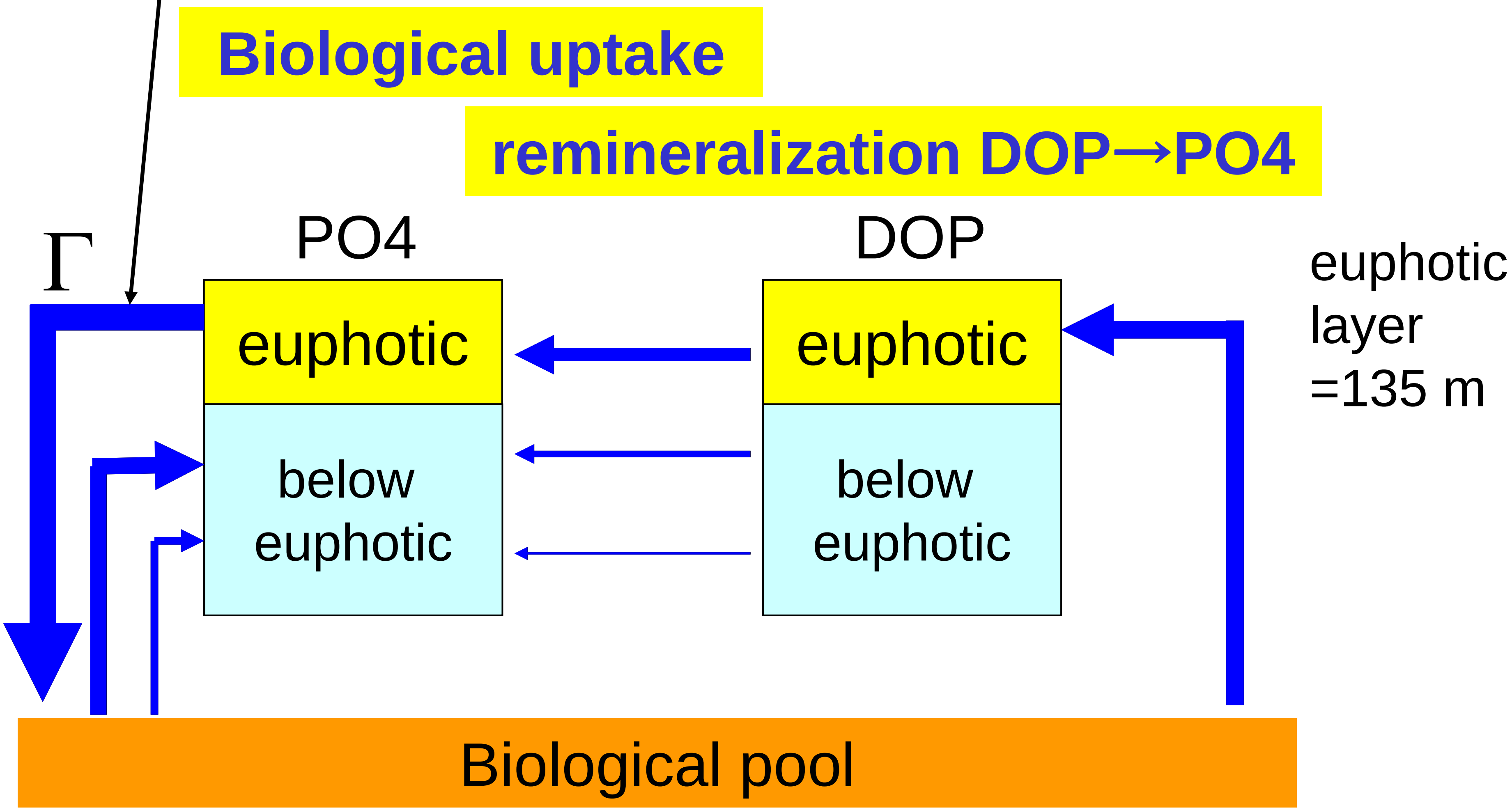
$$\mathrm{Fe} = \mathrm{Fe}' + \mathrm{FeL}$$

$$\mathrm{Fe}' : \mathrm{free}$$

$$\mathrm{FeL} : \mathrm{complexed} \quad (\mathrm{L} : \mathrm{ligand})$$

Phosphorus cycle

$$\Gamma = \alpha \frac{PO_4}{PO_4 + K_{PO_4}} \frac{Fe}{Fe + K_{Fe}} \frac{I}{I + K_I} \quad (I : \text{light})$$



Iron Cycle

Fe (dissolved)

- Fe is 3.5% of dust
- solubility 1%

- Biological uptake
- Remineralization

→proportional to those of PO4.

aeolian dust (Mahowald et al. 2005, GBC)

euphotic

below euphotic

Scavenging

proportional to Fe’

(Fe=Fe’+FeL)

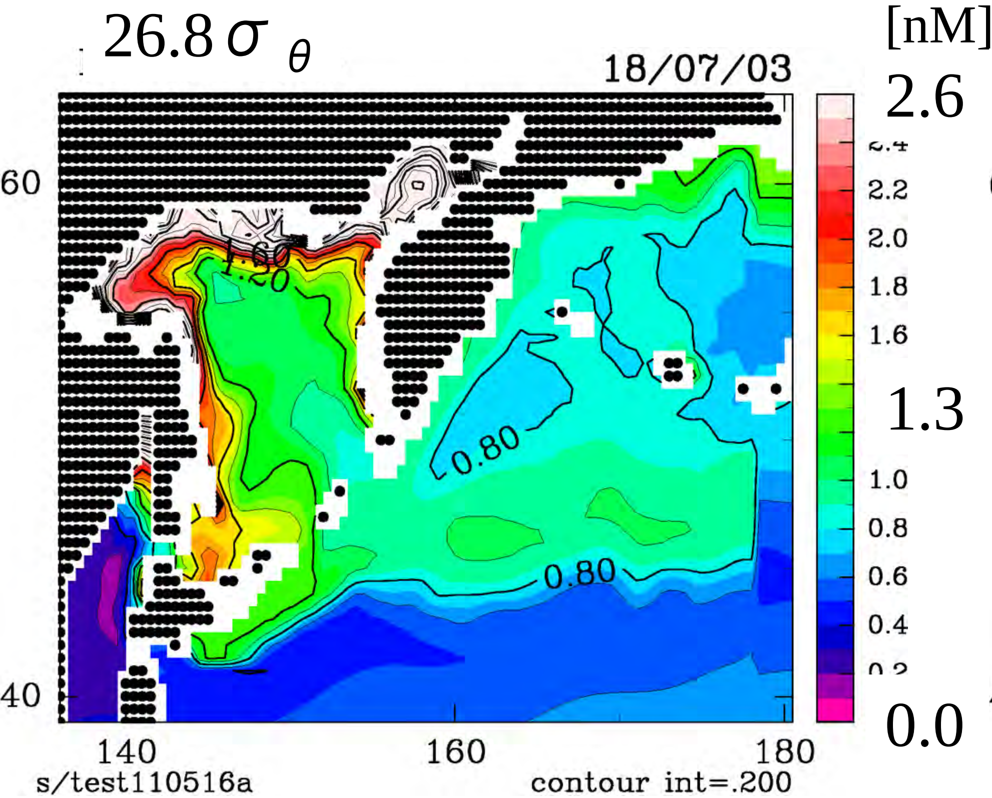
total ligand conc.=1.2 nM

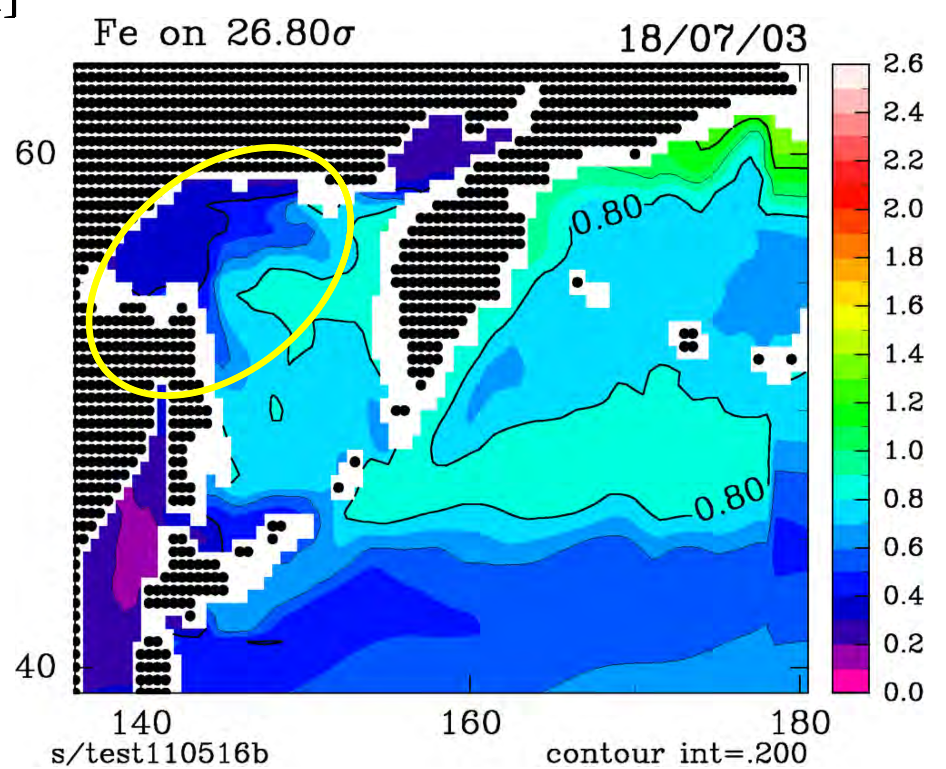
sediments

$1\mu mol/m^2/d$

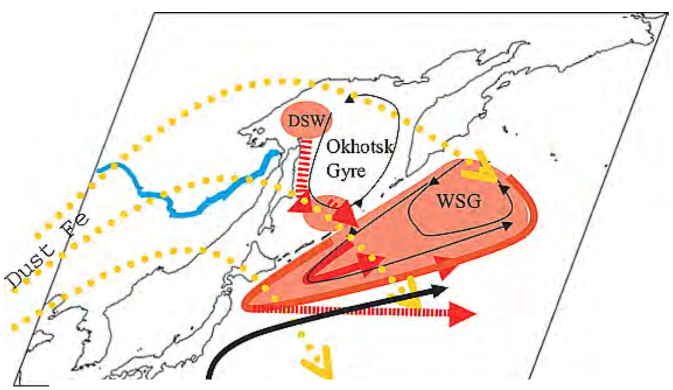
(shelf shallower than 300 m)

Fe distribution in the model



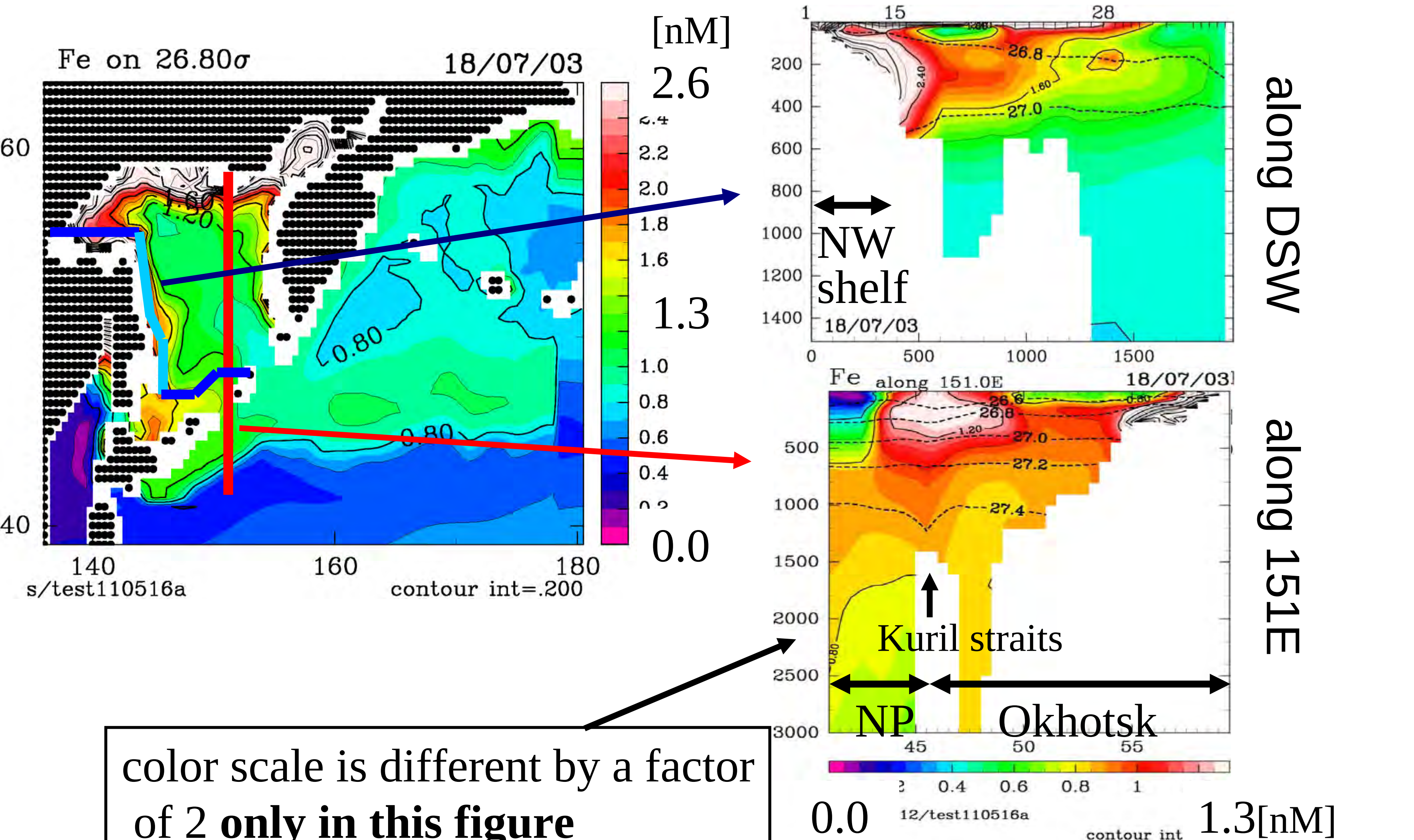


experiment without
sedimentary Fe



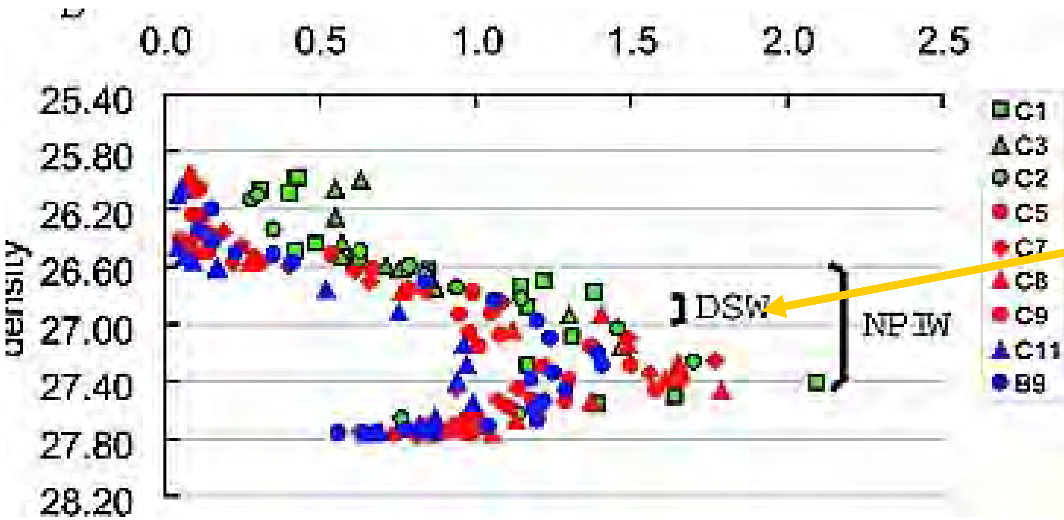
Nishioka et al. (2007)

Fe distribution in the model



color scale is different by a factor of 2 **only in this figure**

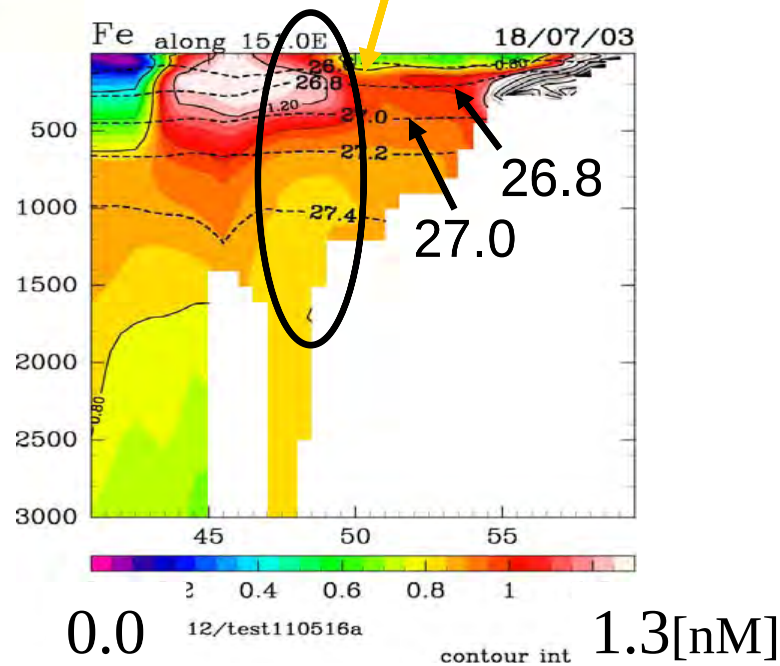
Fe distribution in the model



Max. concentration around 27 σ_θ

greens: observed in Okhotsk

Nishioka et al. (2007, JGR)



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.