Current and Turbulence Observations of North Pacific Intermediate Water in the Kuroshio-Oyashio Confluence Region

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Introduction

North Pacific Intermediate Water (NPIW)
is characterized by salinity minimum in the mid depth of the subtropical gyre (e.g. Sverdrup et al., 1942; Reid, 1965)

Yasuda et al (1996) :
Subarctic Oyashio water flows into the intermediate depth of the Kuroshio Extension east of Japan

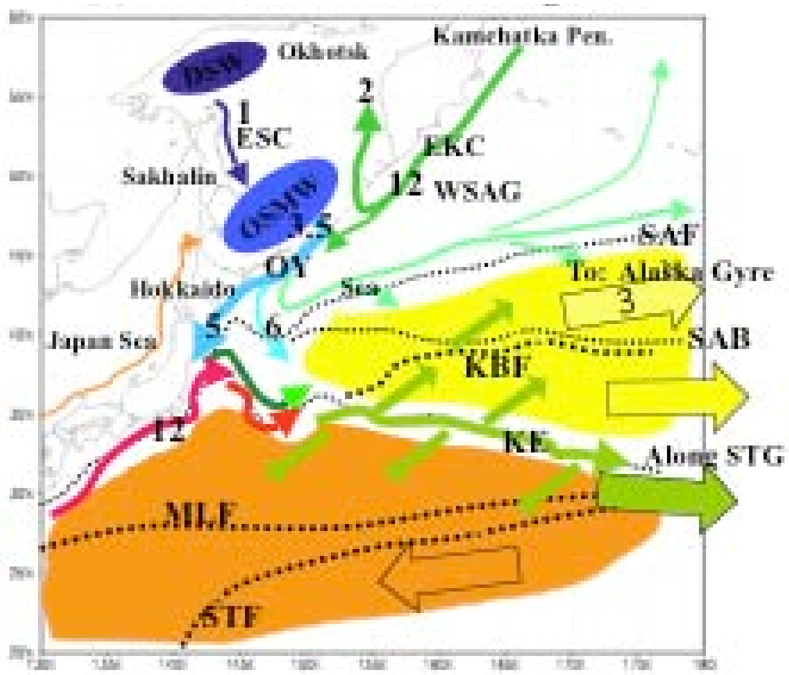


Fig. Schematic illustration of water mass distribution (Yasuda, 2004)

However, formation processes in the confluence of the Oyashio/Kuroshio Extension just after the separation of the Kuroshio have not been investigated in detail.

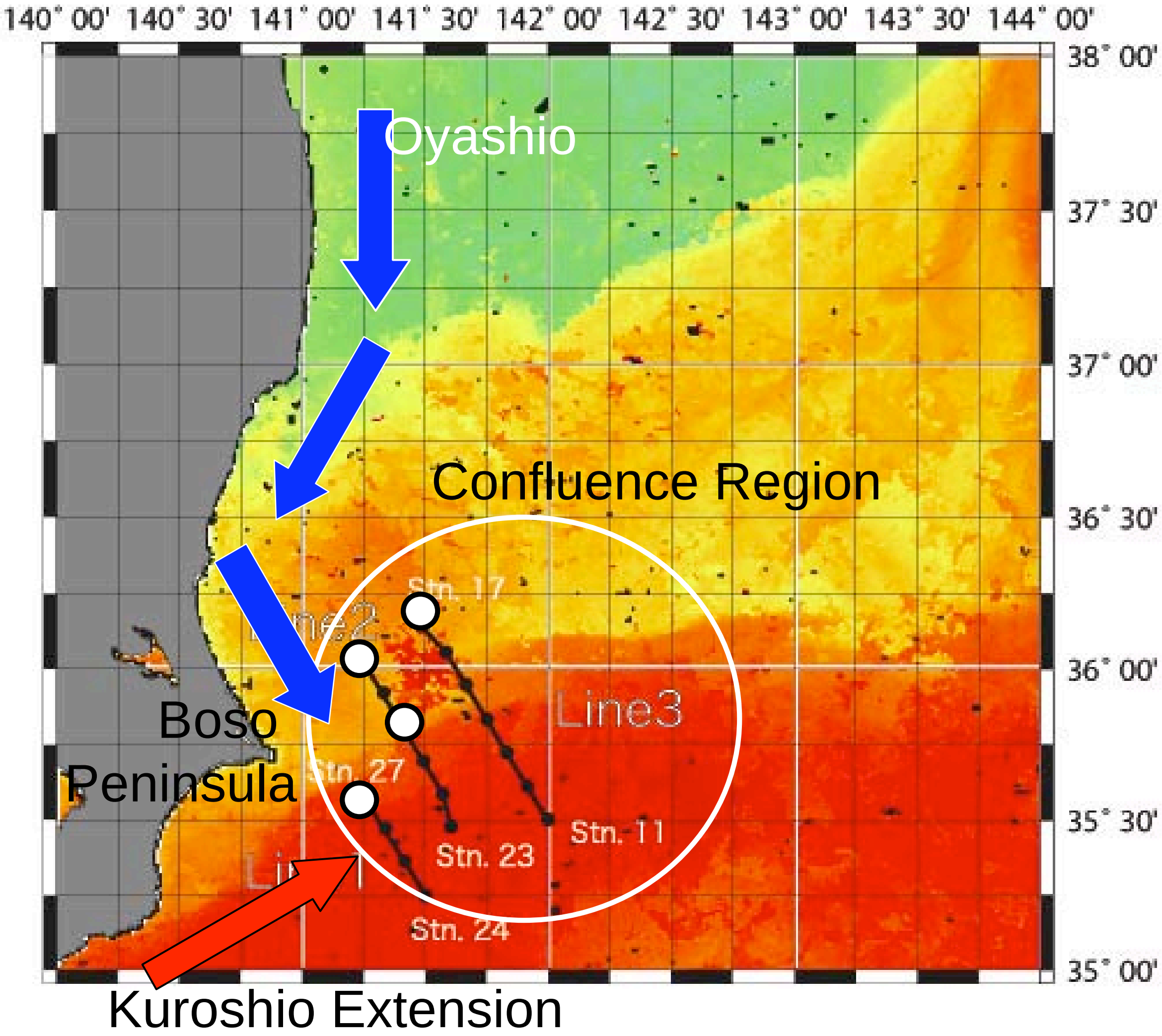
Purpose of the present study

- Question:
  - How do the Oyashio and the Kuroshio merge?
  - How is the salinity minimum developed and modified just after the confluence?
- Objective:

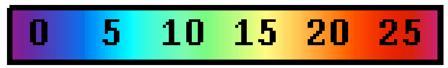
  Clarifying hydrography, current structure, and vertical mixing in the region just after the confluence

We performed observations in the confluence region just east of Japan.

Observation & Data



Observation lines superposed on week Composite SST (NOAA/HRPT SST, May 09-15 2007)



SST(°C)

Tansei-Maru:
May 8-15, 2007

○ turbulence observation

● XCTD

Shipboard ADCP

Method

- Estimate absolute geostrophic velocity from ADCP and baroclinic geostrophic velocity from CTD (Masujima et al., 2003)

- Calculate Oyashio mixing ratio assuming isopycnal mixing of Oyashio & Kuroshio reference waters (Shimizu et al., 2001)

- Calculate Oyashio component volume transport (= Oyashio mixing ratio x total volume transport)

- Directly observed turbulence dissipation rate (ε) from vertical microstructure profiler

- Estimate Vertical diffusivity coefficient ($K\rho$)

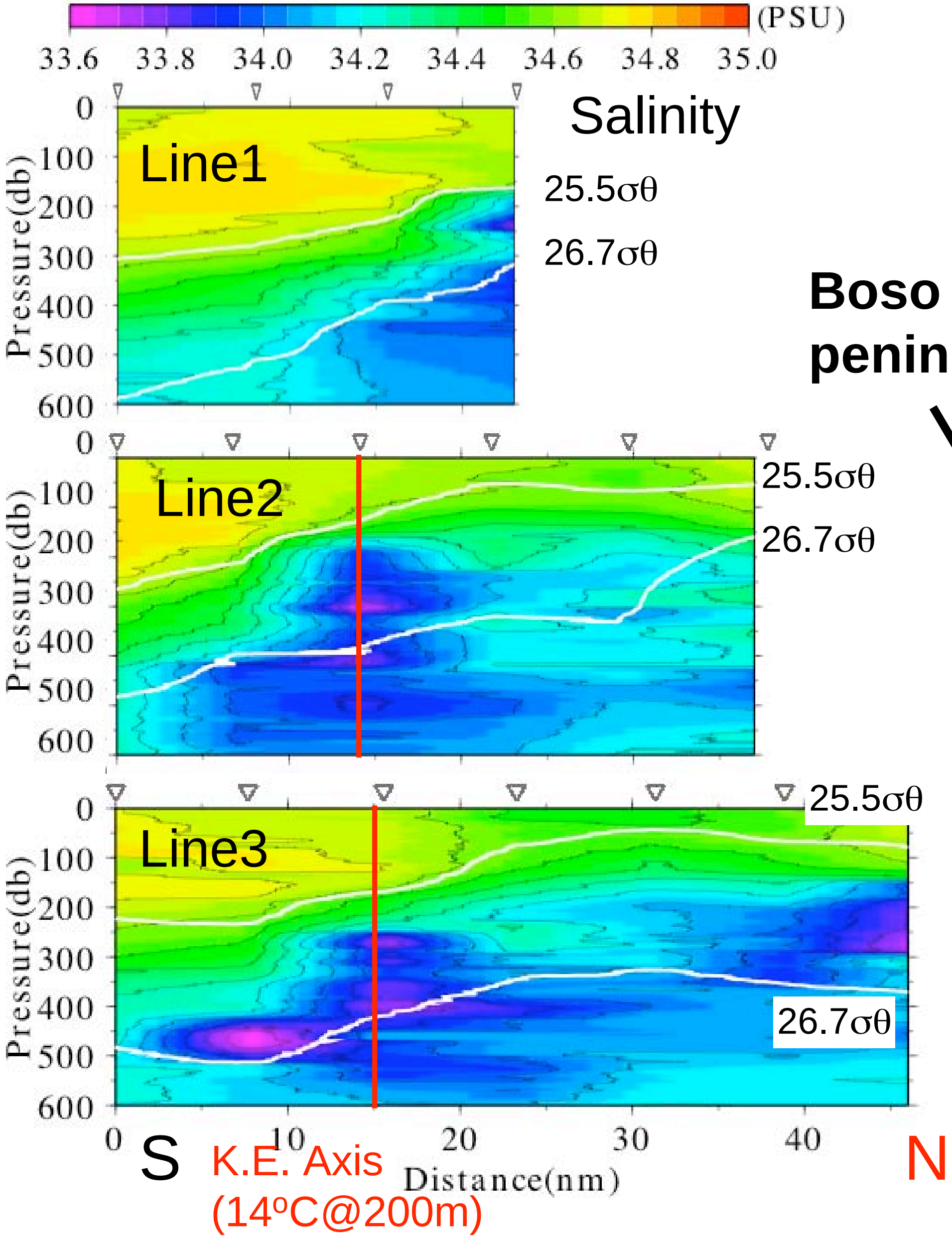
  $K\rho = 0.2\,\varepsilon / N^2$ (Osborn, 1980; N: buoyancy frequency)

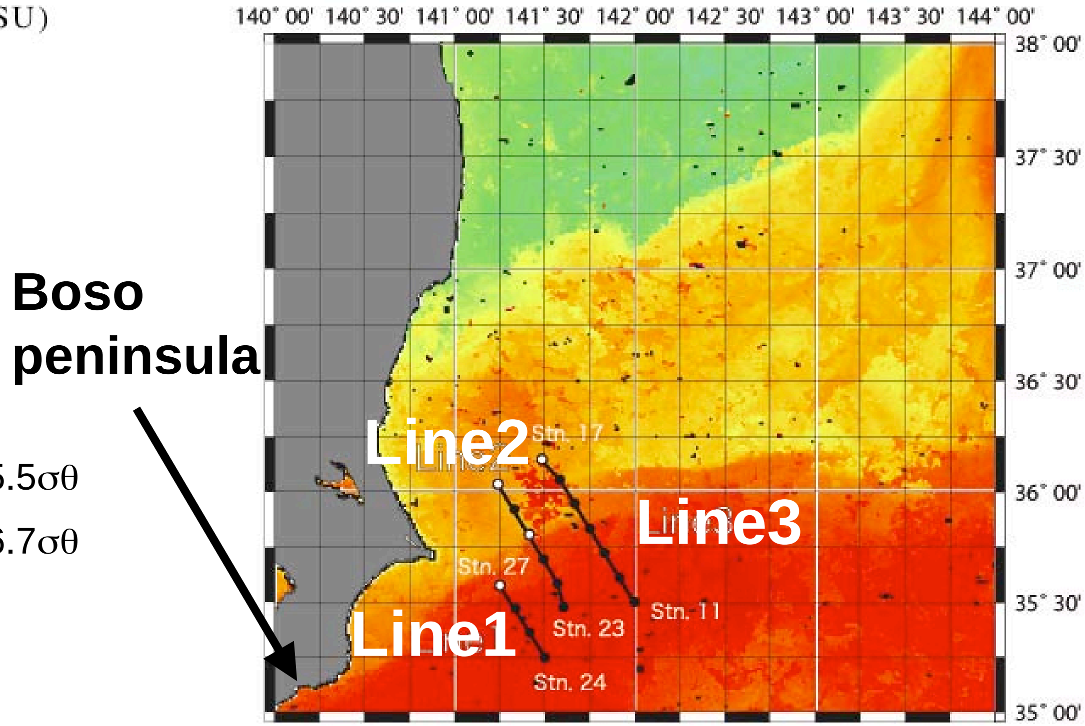
- Indirect estimated ε (parameterization)

  $\varepsilon_{prm} = 7\times10^{-10} \langle N^2/N_0^2 \rangle \langle S_{10}^4/S^4_{GM} \rangle$ (Gregg, 1989)

  using 10m scale velocity shear (S_{10}) from ADCP

Result：Oyashio water intrusion





Along the line2, line3, around 26~27σθ, low salinity Oyashio water (S<34PSU) is found south of the Kuroshio Extension axis(14ºC @200m)

Oyashio intrusion into the intermediate layer

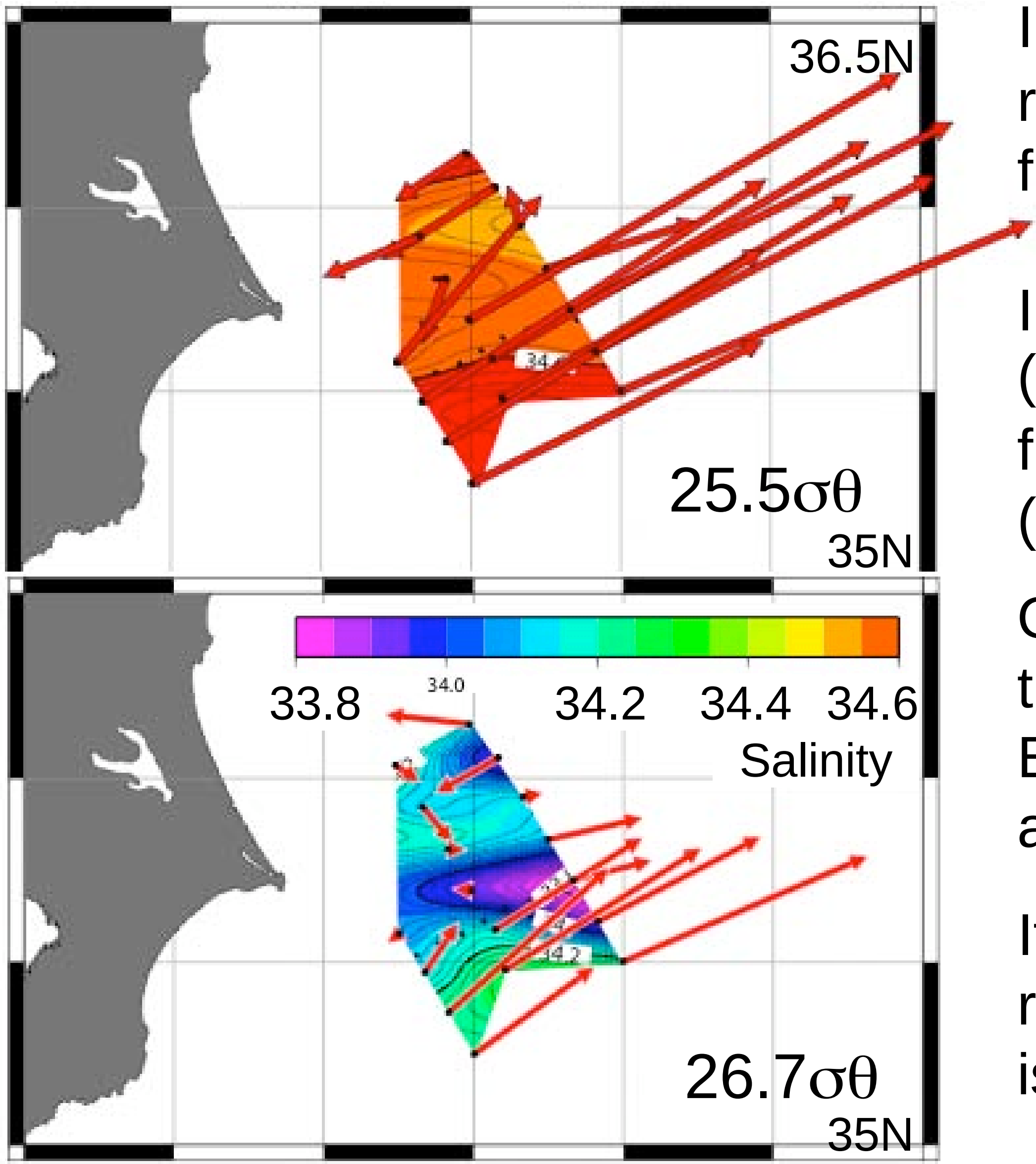


Fig. Horizontal distribution of current & salinity at each isopycnal surface

In the upper layer (25.5σθ), relatively high salinity water flows northeastward.

In the intermediate layer (26.7σθ), low salinity water flows eastward.
(the direction is different)

Oyashio water intrudes into the mid depth of the Kuroshio Extension across the K.E. axis.

It suggests that…
remarkable salinity minimum is formed.

Oyashio component volume transport into the intermediate layer of K.E.

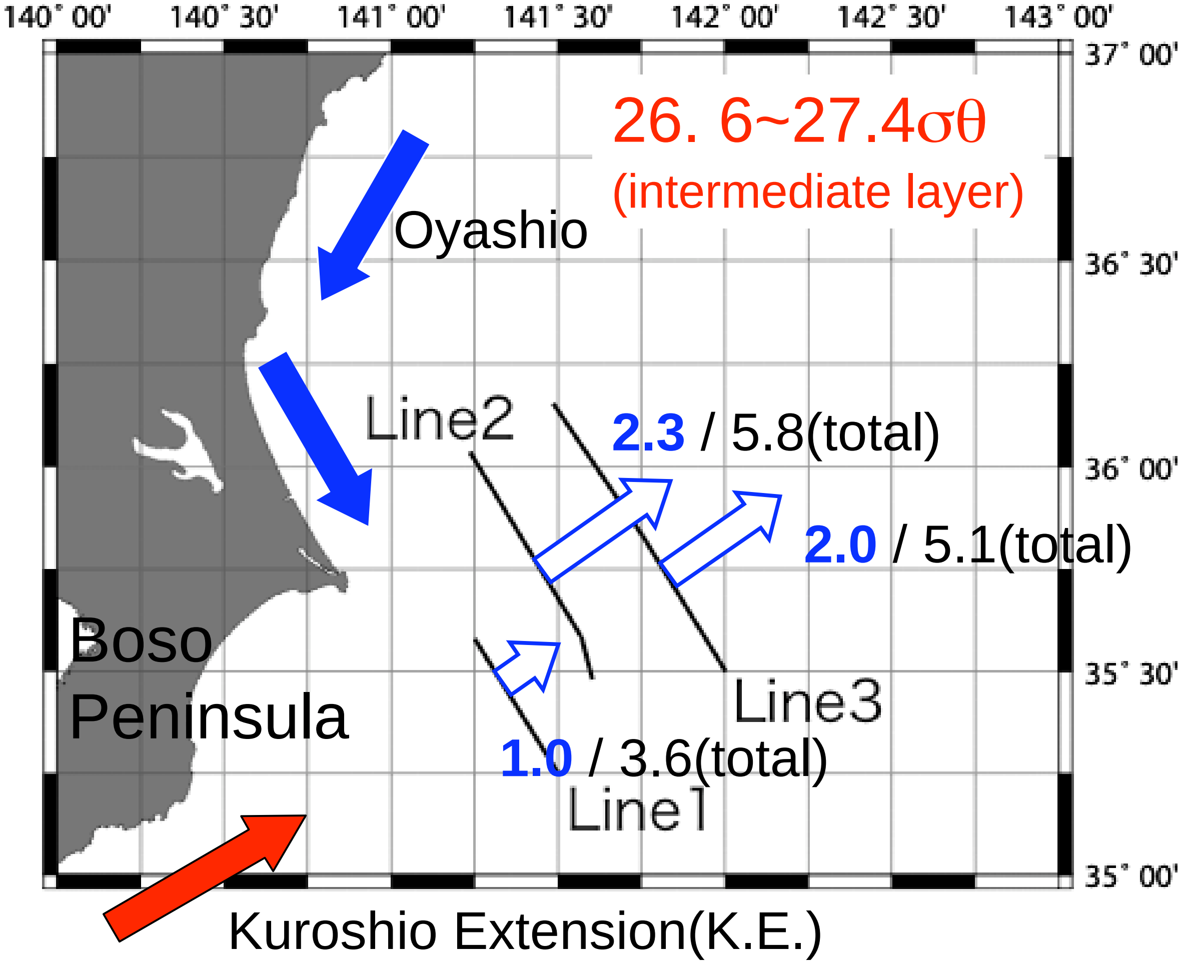


Fig. Oyashio component volume transport across each section

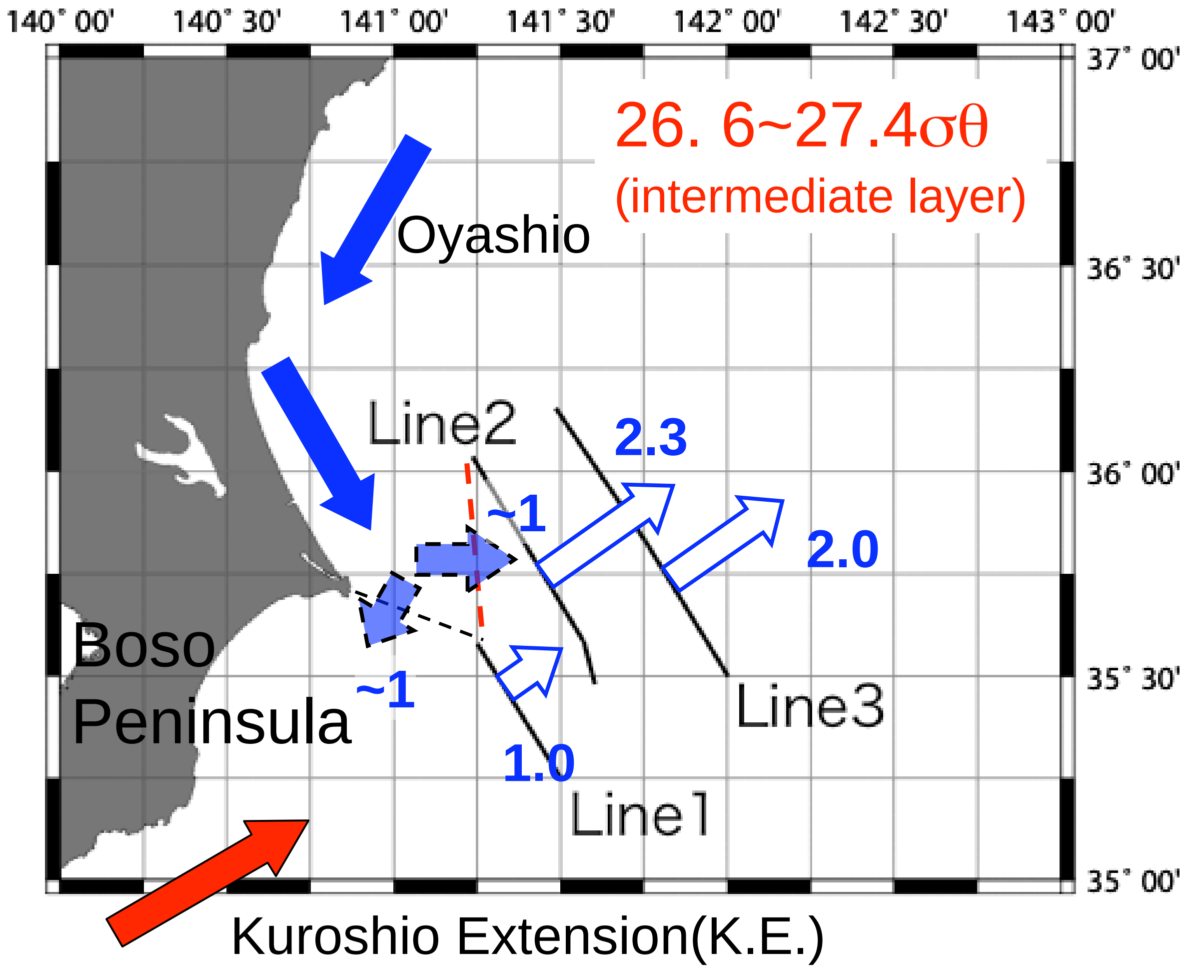
Volume transport (26.6~27.4σθ)

	OY	KR	Total	OY%
Line1	1.0	2.6	3.6	27.8
Line2	2.3	3.4	5.8	40.5
Line3	2.0	3.2	5.1	39.2

1Sv ($10^6 ms^{-1}$) Oyashio water flows eastward across line1 (2Sv; line2, 3)

This result shows that…

Oyashio component volume transport into the intermediate layer of K.E.



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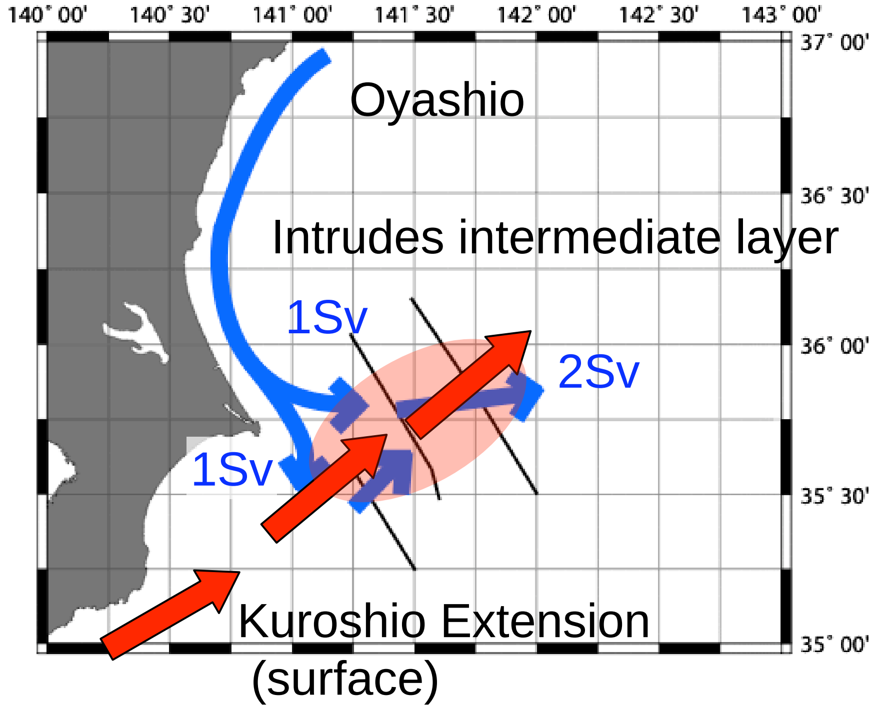
This result shows that… Oyashio water does not flow inshore but offshore in the confluence region.

Across the red line (between line1,2) 1Sv Oyashio water joins the K.E.

Structure of Oyashio intrusion

Based on the results, we infer that…

- Southward Oyashio intrudes into the intermediate layer of K.E. off the Boso Peninsula
- About 1Sv Oyashio Water flows into the K.E. west of line1
- Across the line between Line1&2, about 1Sv Oyashio water joins
- Salinity mininum associated with the Oyashio intrusion becomes prominent.



In the confluence region where the Oyashio intrudes, vertical salinity gradient and shear of velocity are so large.

Where and how much does vertical mixing occur?

Direct observation of vertical diffusivity Kρ

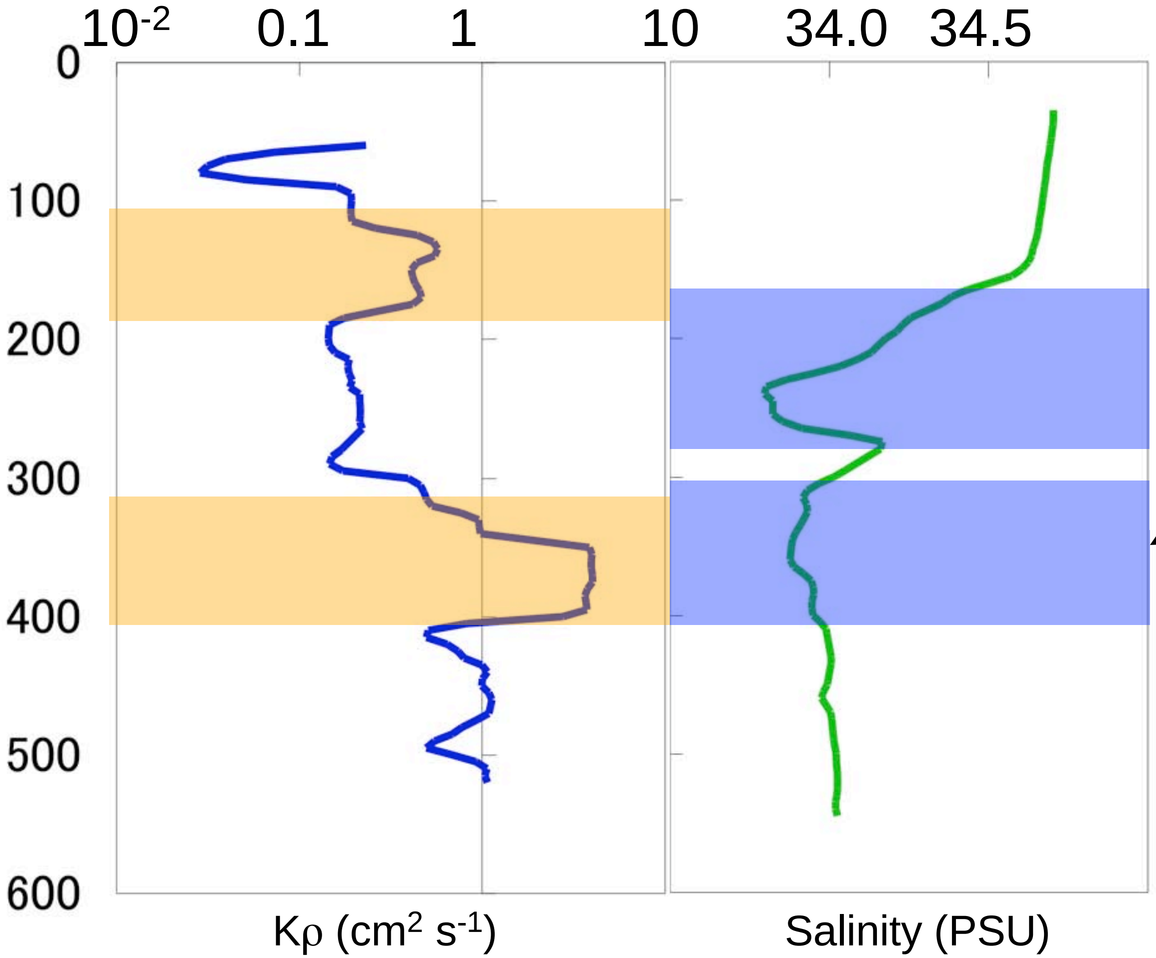
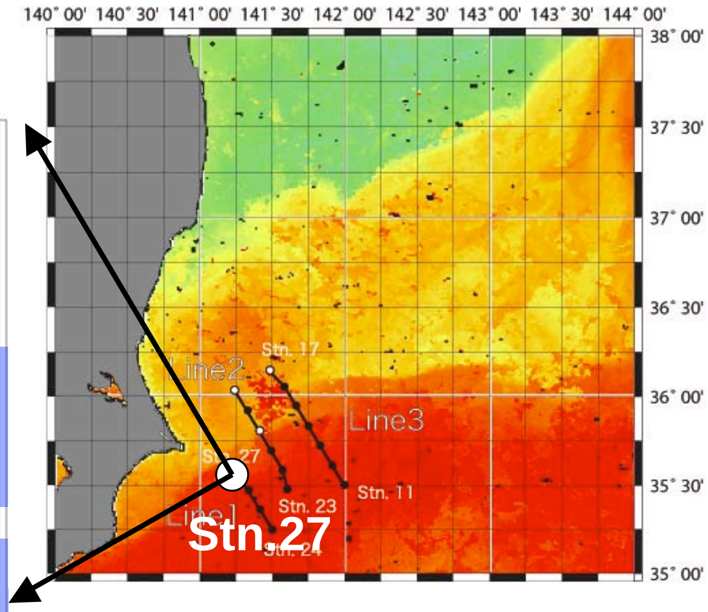


Fig. Vertical profile of observed diffusivity coefficient, and Salinity at Stn.27 located on the K.E. SST front.



Low salinity water is found at 200-300m, 300-400m.

Kρ is relatively large at 100~200m, 300~400m.

Implying that…

Relatively large vertical mixing occurs around salinity minimum.

Comparison of dissipation rate, ε between direct and indirect methods

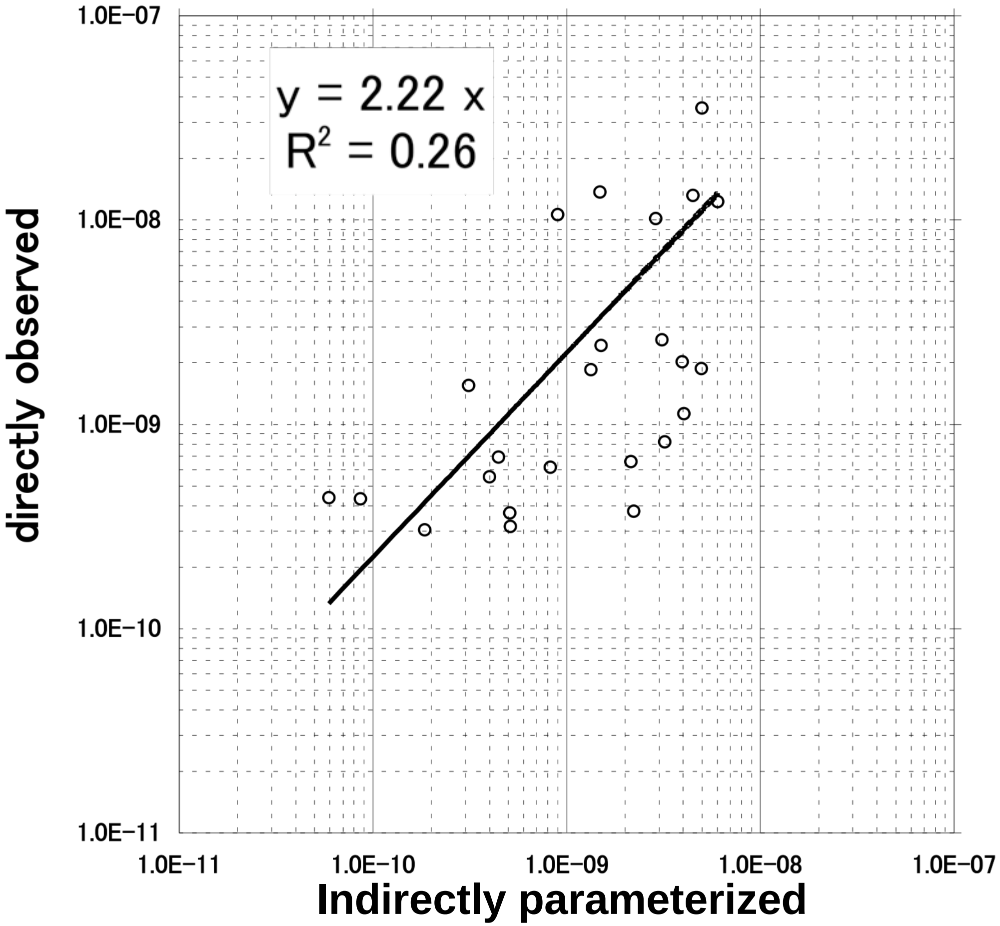


Fig. Scatter plot of dissipation rate between direct observation and Gregg's parameterization

At each station, 100m-averaged dissipation rate is calculated.

Indirectly parameterized dissipation rate (ε_{prm}) is roughly proportional to the directly observed one (ε_{obs})

$$\varepsilon_{obs} = 2.22\varepsilon_{prm}$$

(r ~ 0.5: statistically significant)

Using this relation, distribution of vertical diffusivity Kρ is mapped for each section.

Distribution of vertical diffusivity Kρ

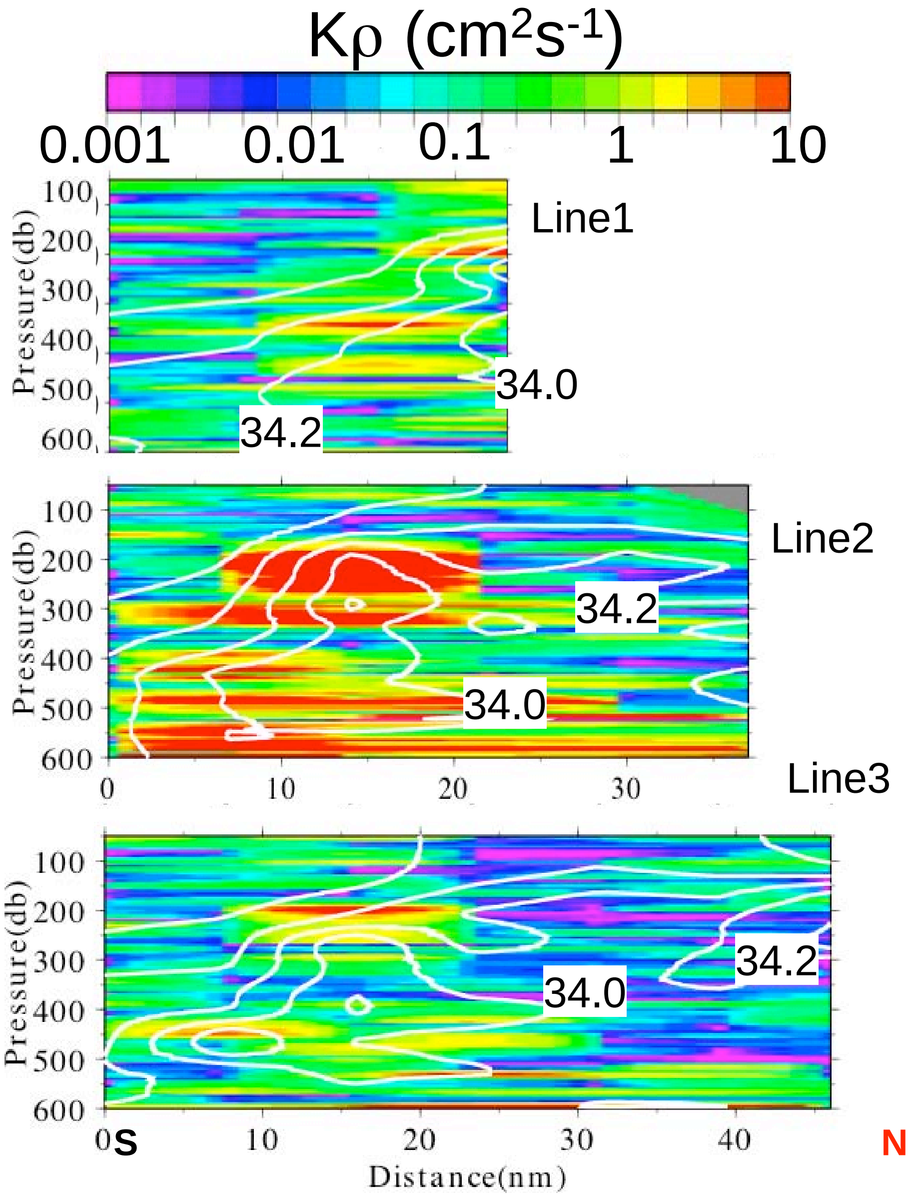


Fig. cross-sections of vertical diffusivity estimated from indirect method
White contours indicate salinity(CI=0.2PSU)

Large vertical diffusivity ($\sim 10 cm^2 s^{-1}$) distributes around the upper part of low salinity water intrusion.

Diffusivity is particularly large along line 2, corresponding to large velocity shear.

Intruded Oyashio water may be transformed by this strong vertical diffusion.

Summary

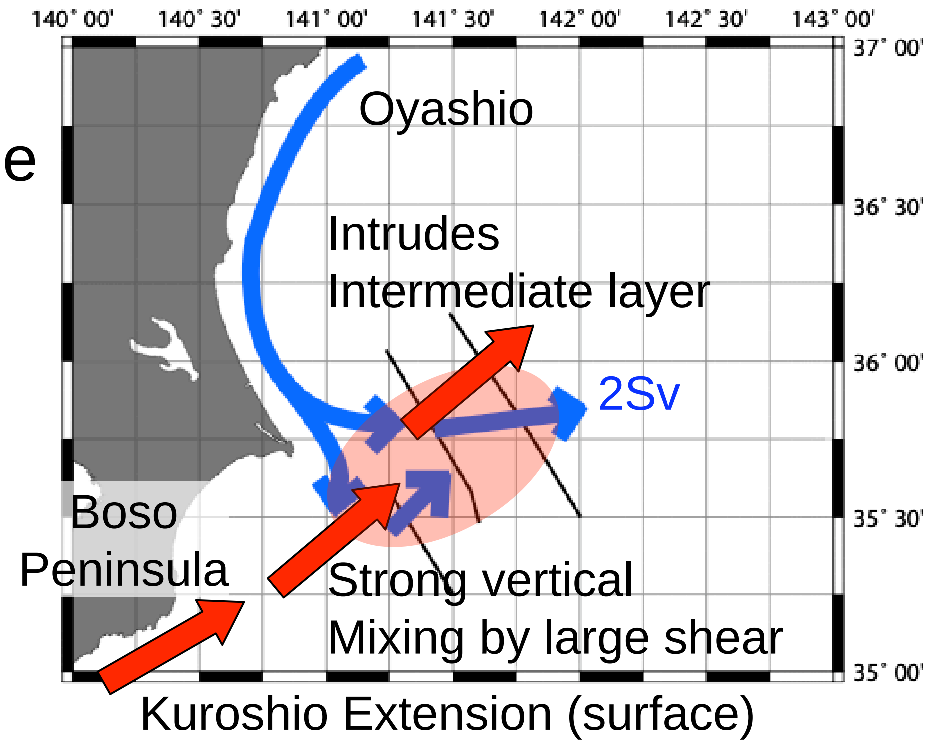


Fig. structure of Oyashio intrusion

- Oyashio water intrudes into the intermediate layer of the Kuroshio Extension just after the confluence east of Boso peninsula.
- Intruded Oyashio water transport is 2 Sv in the intermediate layer(26.4~27.4$\sigma\theta$)
- Strong vertical diffusion occurs around the uppermost of the salinity minimum just after the confluence.
- This implies erosion of the uppermost of the salinity minimum
  and this could contribute to the NPIW formation.

Section of velocity from ADCP(V)