Variability of vertical diffusivity at the western gap of the Bussol' Strait

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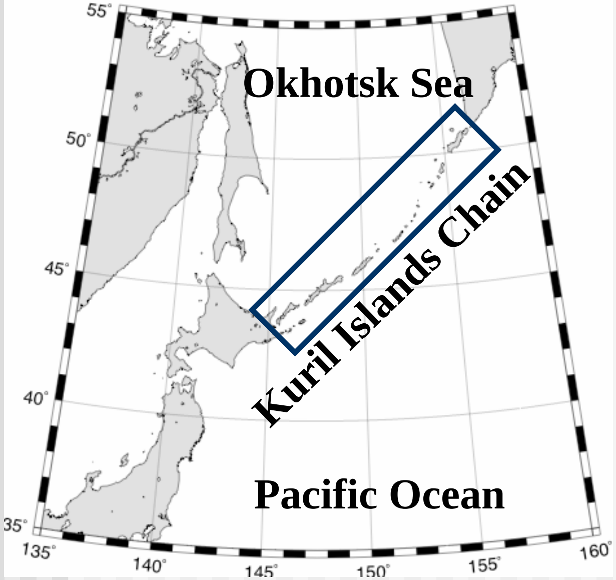
Introduction - Kuril Straits



- **Strong diurnal tide**
  (Kowalik and Polyakov, 1998)
- **Complex topography**

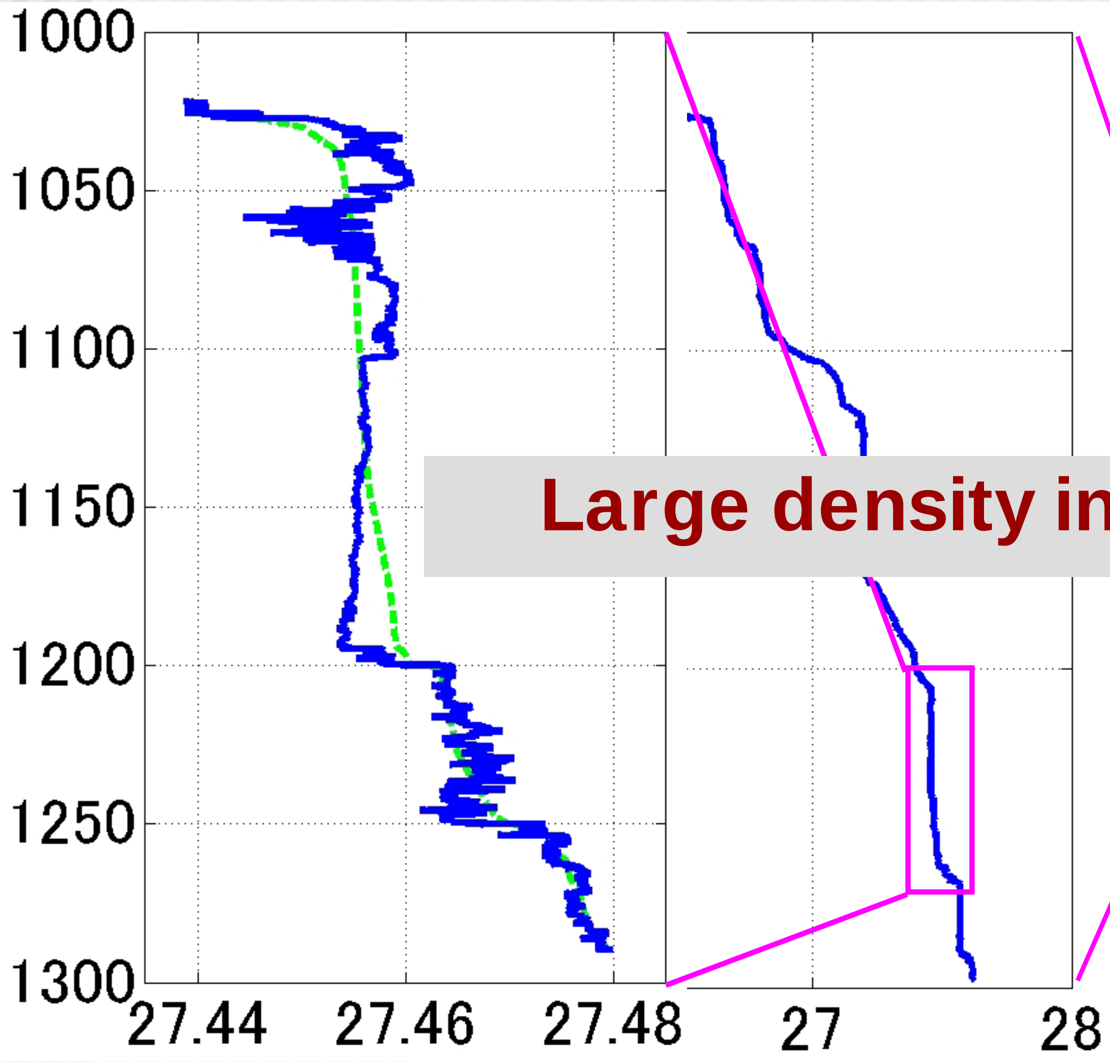
Interaction

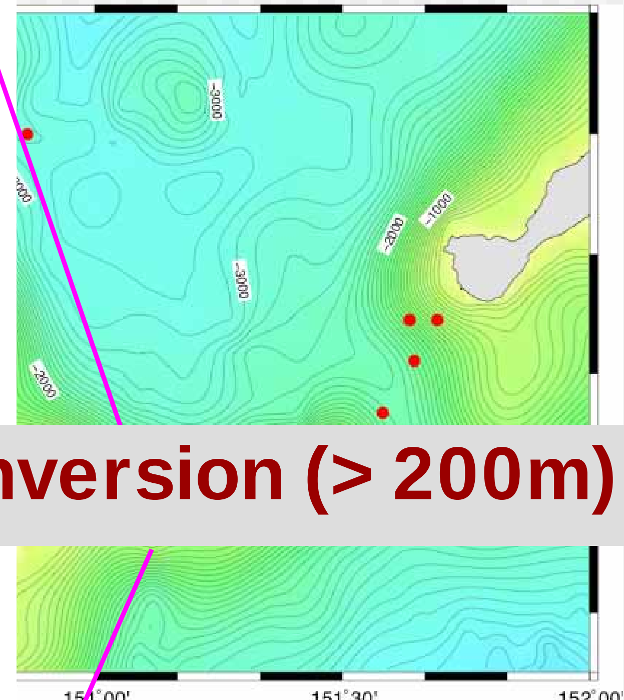
Strong vertical mixing
(Nakamura et al., 2000; Nakamura and Awaji, 2004)

- **The impact of strong vertical mixing in Kuril straits**
  - **The formation of NPIW** **(Nakamura and Awaji, 2004; Yasuda, 2004)**
  - **Southward intrusion of Oyashio** **(Tatebe and Yasuda, 2004)**
  - **Bidecadal variability in northwestern Pacific and Okhotsk sea**
    (Osafune and Yasuda, 2006; Yasuda et al., 2006)

But no direct observation of the dissipation rate ε and the vertical diffusivity K_ρ

Introduction - Bussol' Strait





Large density inversion (> 200m)

(approximately 2200m)

transport 8.2~8.8Sv)

/s)

(Katsumata et al. 2004)

- **Suggestion of strong vertical mixing** (K_ρ ~200cm^2/s)

(Nakamura et al., 2000; Nakamura and Awaji, 2004)

Purpose

- **Estimation of dissipation rate and vertical diffusivity in Bussol' strait by using observation data**

To achieve this,

1. **Direct measurement of turbulence using microstructure profiler**
2. **Indirect estimation from density inversion**

   (Thorpe, 1977; Galbraith and Kelley, 1996)
3. **Compare the indirect estimate with the direct measurements and check the validity to allow the estimate using standard CTD data.**

Indirect estimation of ε from density inversion

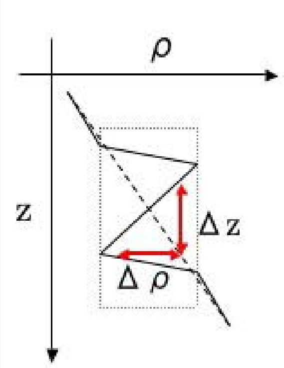
(Thorpe, 1977; Galbraith and Kelly, 1996)

- Ozmidov scale L_o

$$L_o = \left(\frac{\varepsilon}{N^3}\right)^{1/2}$$

- Thorpe scale L_T

$$L_T = \sqrt{\frac{\sum_{i=1}^{n} \Delta z_i^{\,2}}{n}}$$



Empirically, it is shown that L_O can be proportional to L_T. The examples of its proportional coefficient are as follows.

0.8 (Dillon, 1982), 0.95 (Ferron et al. 1998), 1.06 (Stansfield et al. 2001)

$0.25L_O < L_T < 4L_O$ (Wesson and Gregg 1994)

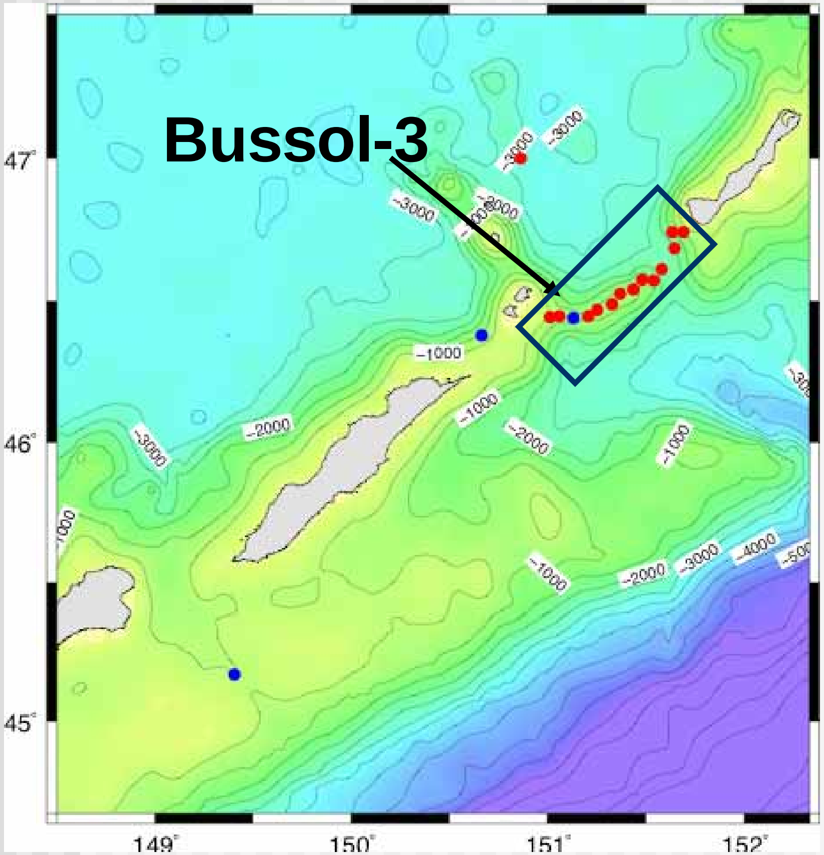
If we assume that $L_O = cL_T$, ε is represented as follow.

$$\varepsilon = c^2 L_T^{\,2} N^3$$

If c is determined, ε can be derived from density profiles.

Observation

- The information of data



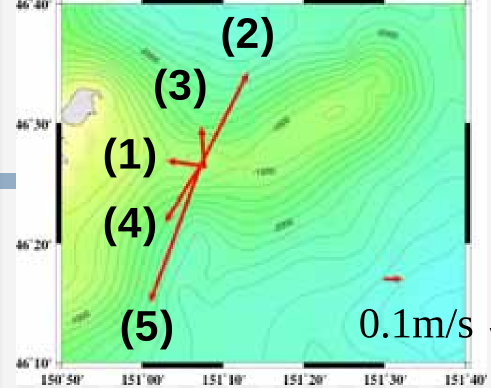
- **Position**
  - 46 26.6’N, 151° 07.4’E
- **Date**
  - 19~20 Aug. 2006
    (1day repeated observation)
  - Spring tide
- **Instrument**
  - CTD + LADCP
    (5 casts in 24hr)
  - Vertical microstructure profiler
    (VMP2000, Rockland Inc.)
    (6 casts in 24hr)

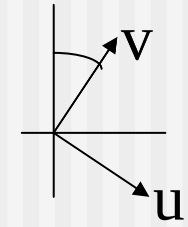
- VMP 2000 and CTD+LADCP are repeated alternately.

VMP2000 (Rockland Scientific International Inc.)

- Features
  - Depth rating 2000m
  - 2 shear probes -> micro scale shear
  - Pressure sensor
  - SBE-3F & SBE-4C -> CTD data (density profile)
  - Tether cable

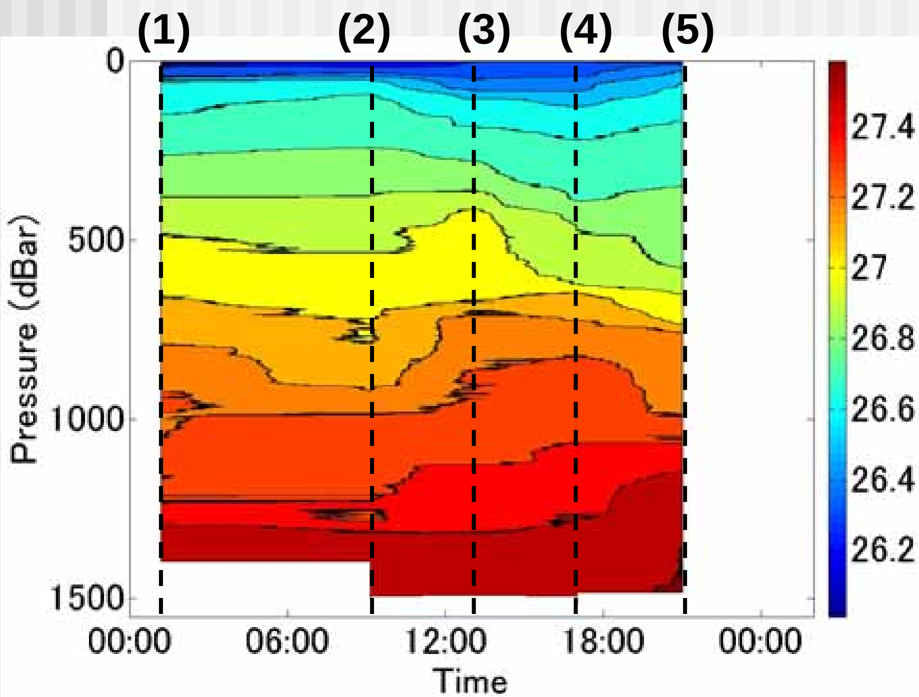
Result 1



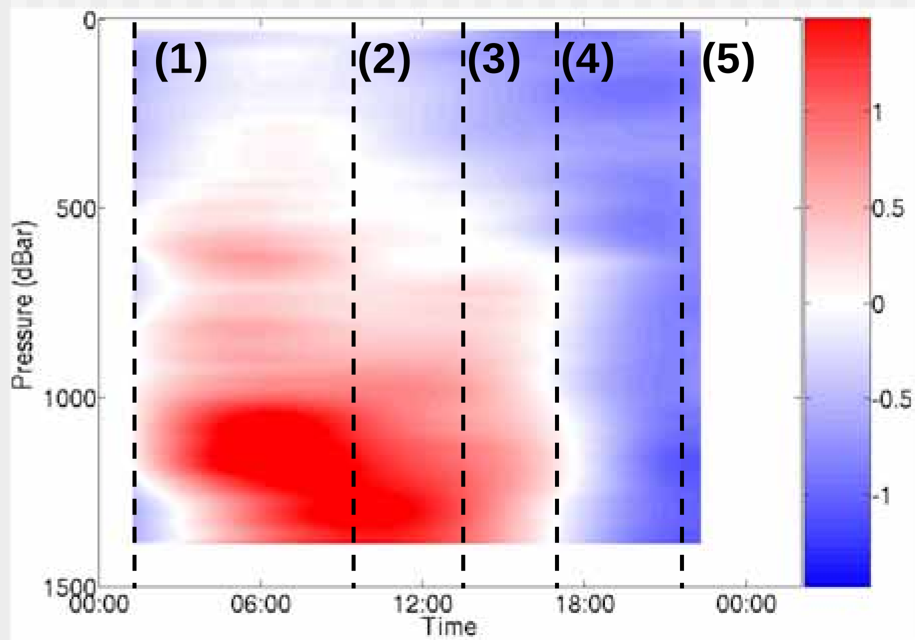


U: the across-strait flow
V: the along-strait flow

Density σ_θ (CTD)



V velocity m/s (LADCP)

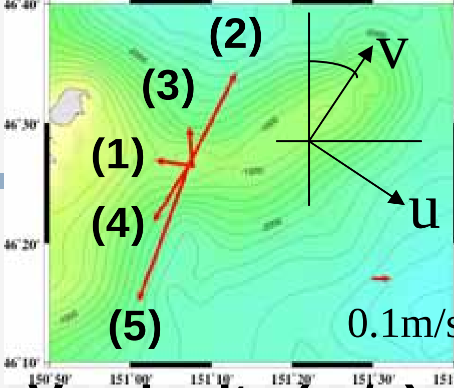


- **Isopycnal depth changes more than 100m**
- **Diurnal change of current is predominant**
- **Amplitude of V is large in a layer deeper than 500m**

(Maximum amplitude of diurnal tide was 1.3m/s at 1100m)

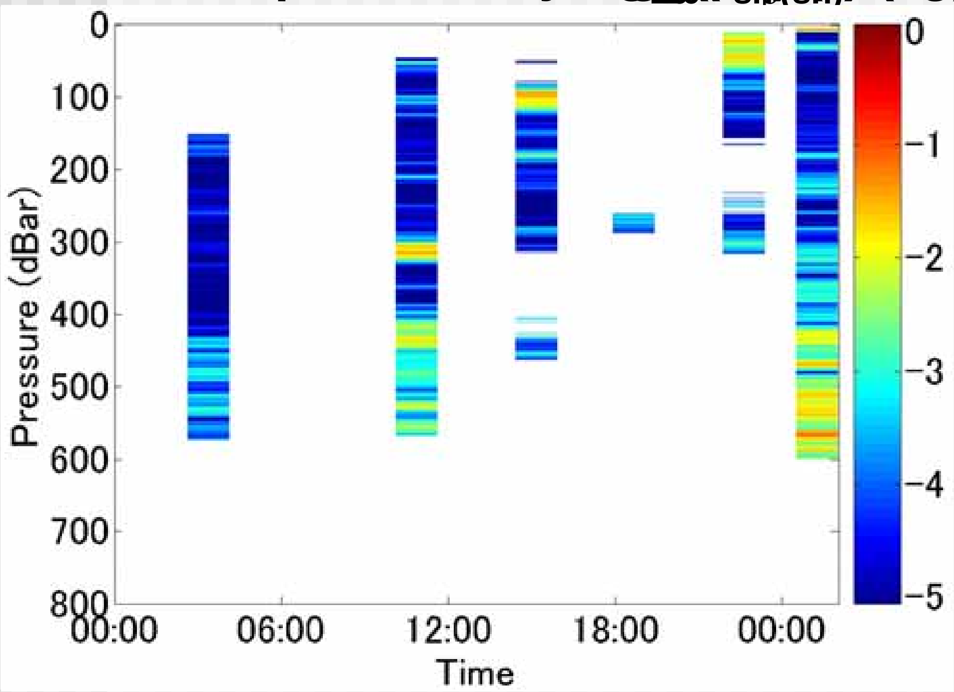
Result 2

- **Directly measured ε_{sh} and $K_{\rho(sh)}$**

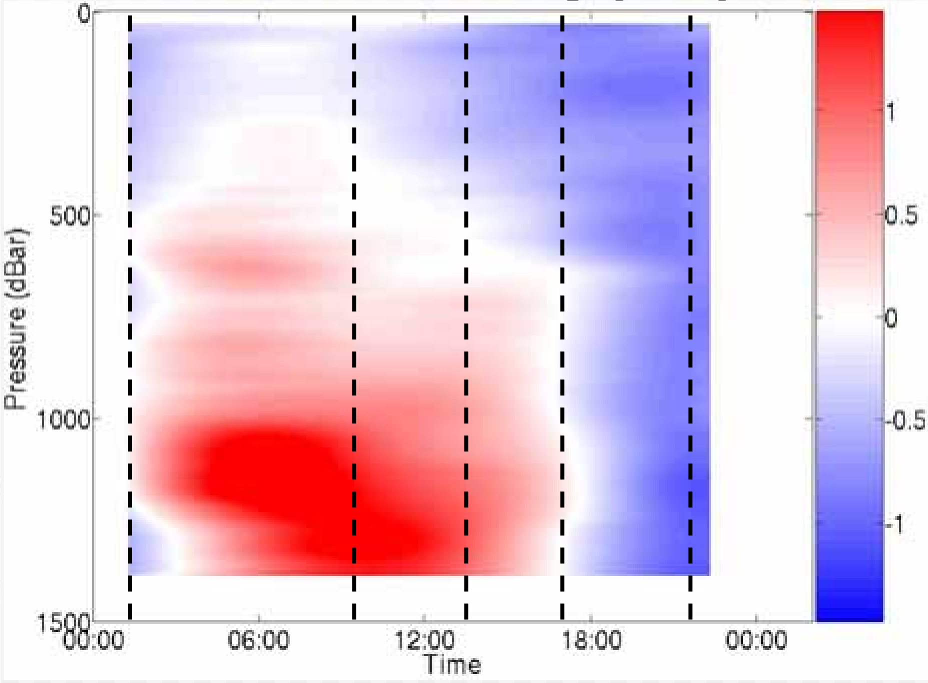


Vertical Diffusivity log$_{10}$($K_{\rho(sh)}$) (m²/s)

Dissipation rate log$_{10}$(ε_{sh}) (W/kg)



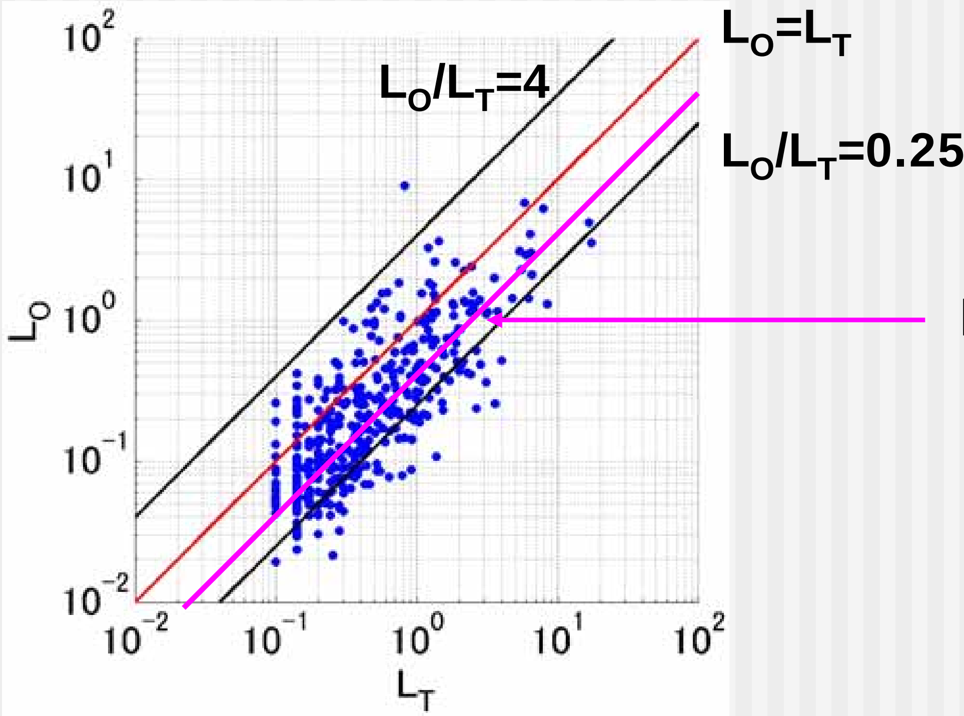
V velocity (m/s)



- $K_{\rho(sh)} > 100$cm²/s in some parts
- Simple average of directly measured $K_{\rho(sh)}$ is **21**cm²/s

➡ **Indirect estimation of K_ρ from density inversion**

Scatter plot between L_T and L_O



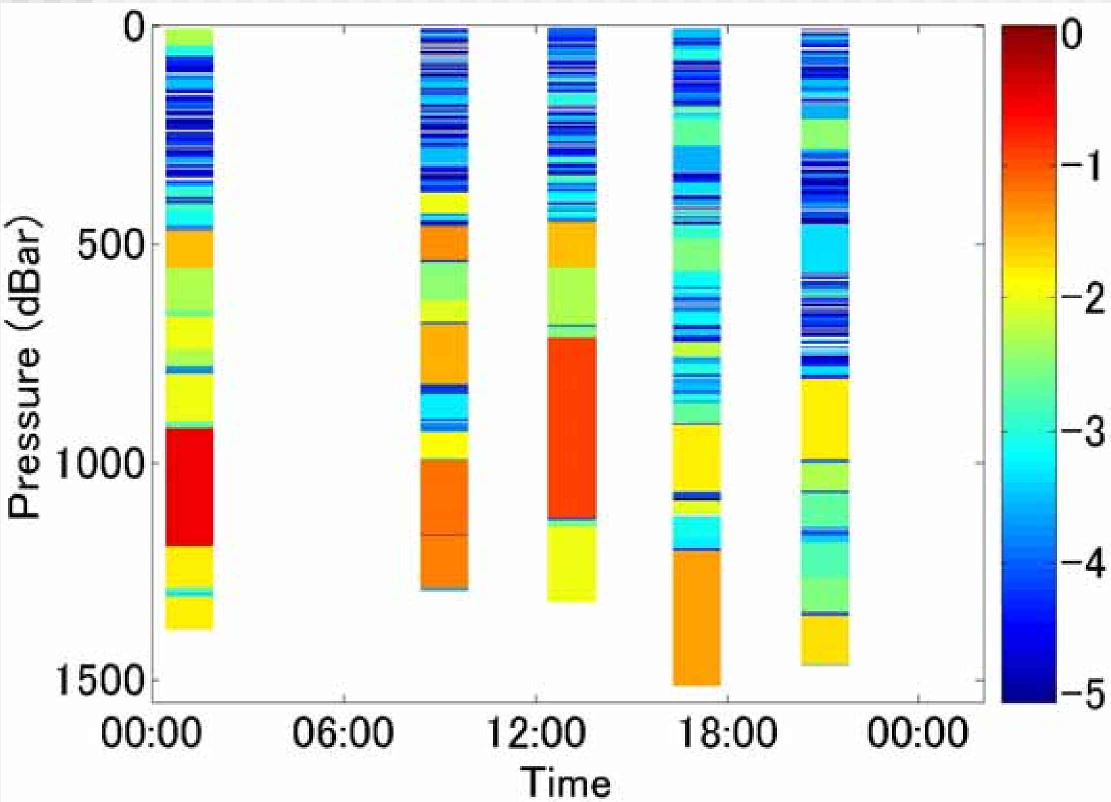
$L_O=0.39L_T$

- L_T is derived from density inversion from CTD profile
- L_O is derived from direct measured dissipation rate

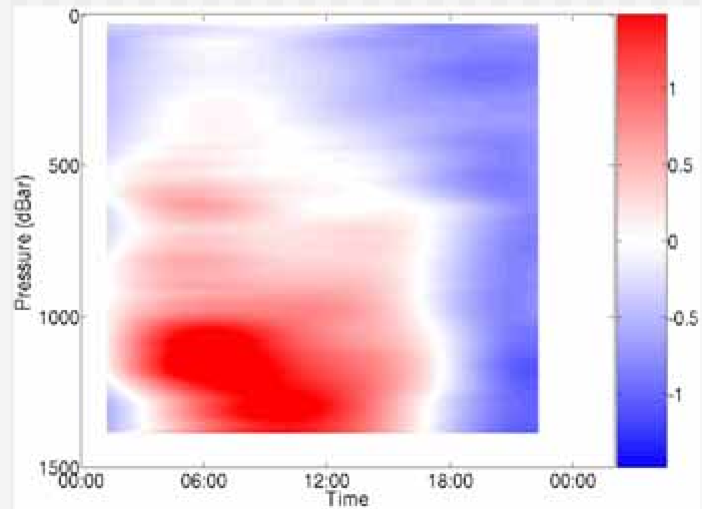
- L_T is proportional to L_O (correlation coefficient is 0.64)
- The proportional coefficient is 0.39 by least square fitting
- $\varepsilon_{GK} = L_0^2 N_3 = 0.39^2 L_T^2 N^3$, $K_{\rho(GK)} = 0.2*0.39^2 L_T^2 N$

Indirect estimation over full depth with CTD profiles

Vertical Diffusivity $\log_{10}(K_{\rho(CTD)})$ (m^2/s)



V velocity (m/s)



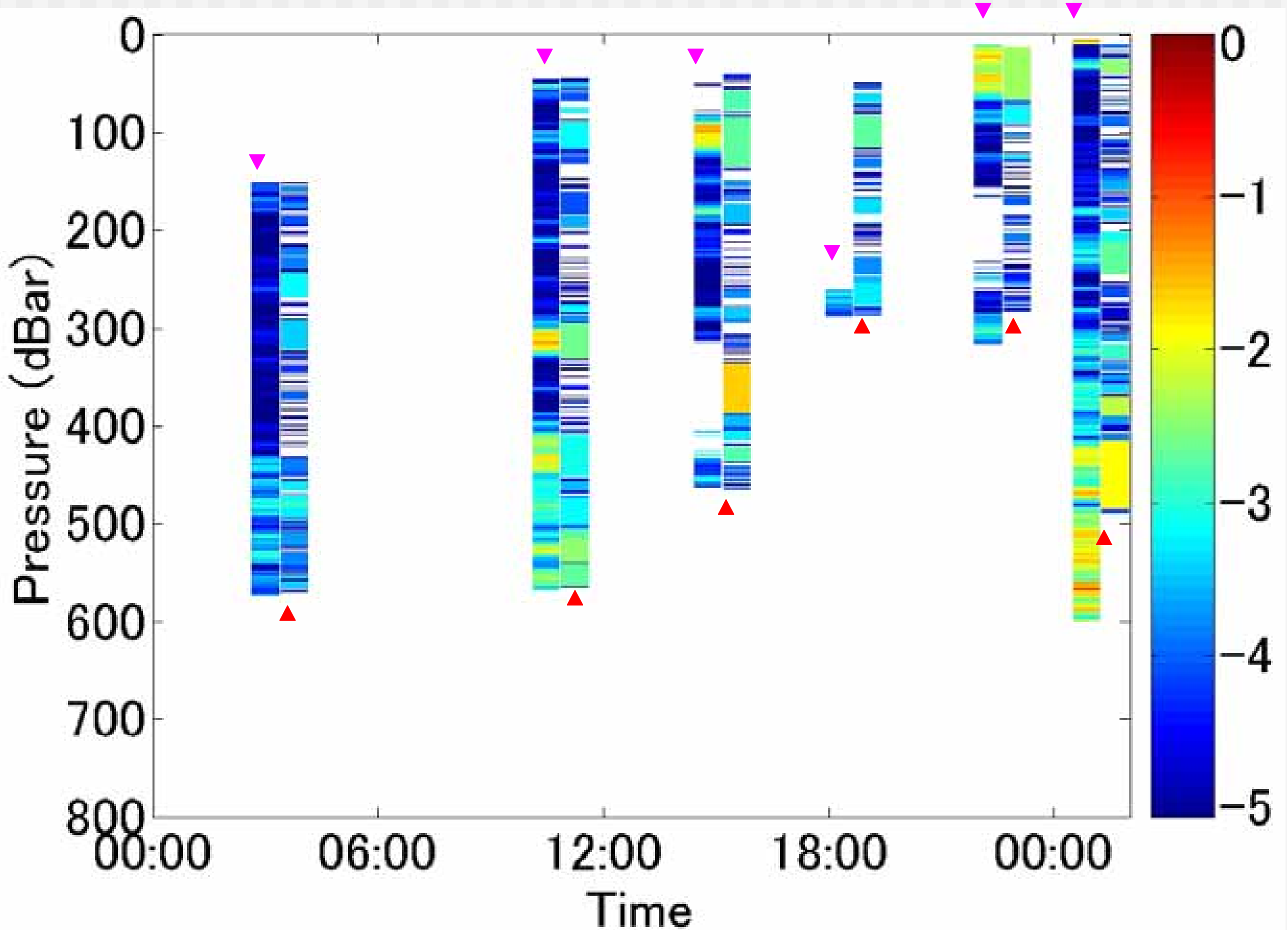
- **Simple average of K_ρ is 288cm^2/s**
- **Large K_ρ were observed in a layer deeper than 500m**

Large diffusivity corresponds to depths with large vertical shear of diurnal tidal flow.

Summary

- **1 day repeated turbulence observation at the western gap of Bussol' strait where the amplitude of diurnal tidal flow reached over 1m/s**
  - **Direct observation down to 600m shows K_ρ reached $O(10^2)cm^2/s$ in some parts and its simple average is 21cm^2/s**
  - **From concurrently measured CTD density profile, Thorpe scale L_T is mostly proportional to Ozmidov scale L_O and $L_O = 0.39L_T$**
  - **Using this linear relation, full depth K_ρ is estimated**
    - **K_ρ was large at depths greater than 500m and reached $O(10^3)cm^2/s$**
    - **1 day full depth average was 288cm^2/s**
- **This diffusivity was as strong as expected from numerical model (Nakamura and Awaji, 2004).**

The comparison between $K_{\rho(sh)}$ and $K_{\rho(GK)}$



▼ $K_{\rho(sh)}$ (directly measured)

▲ $K_{\rho(GK)}$ (indirectly estimated)

- $K_{\rho(GK)}$ mostly corresponds to $K_{\rho(sh)}$
- Simple average in the depth that both data exist,

$K_{\rho(GK)}$ = 14 cm^2/s, $K_{\rho(sh)}$ = 18 cm^2/s