Ocean mixing layer variation as indicated by the measurement of the dissipation rate in the Kuroshio Extension region

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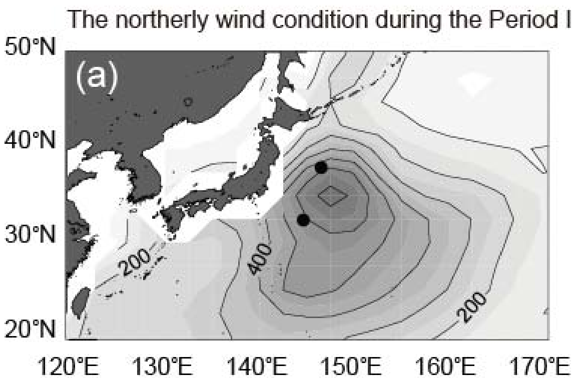
Motivation



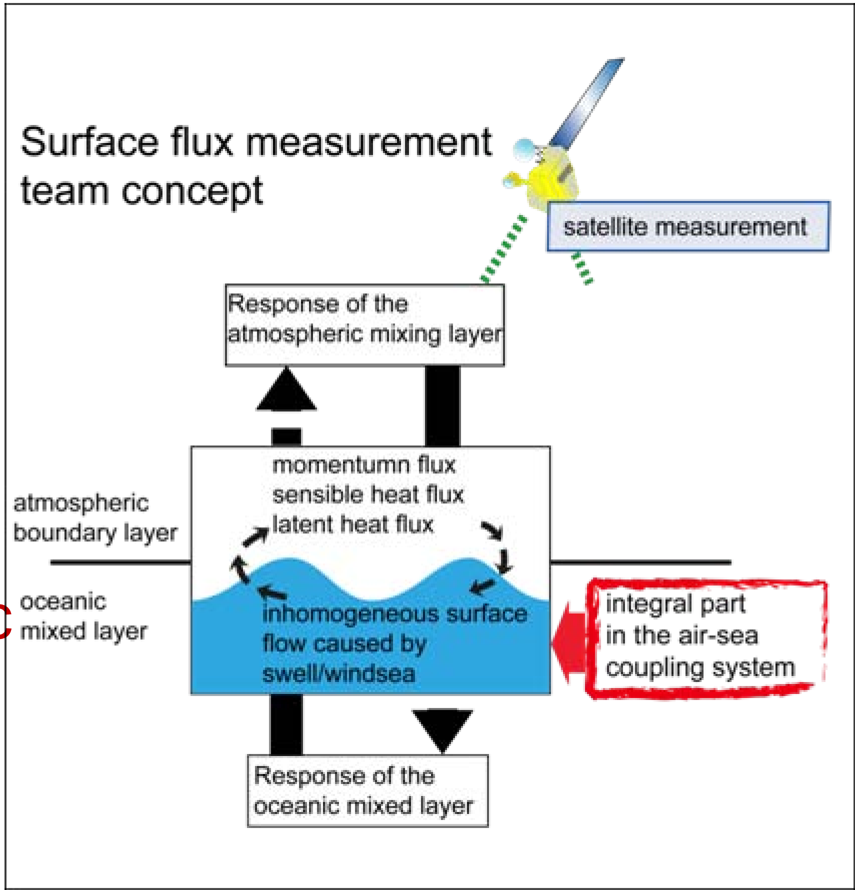
Konda et al.(2010)

The remarkable heat release from the ocean to the atmosphere in the Kuroshio Extension region (e.g.Deser et al.1999;Qiu et al.2004, Konda et al. 2010)

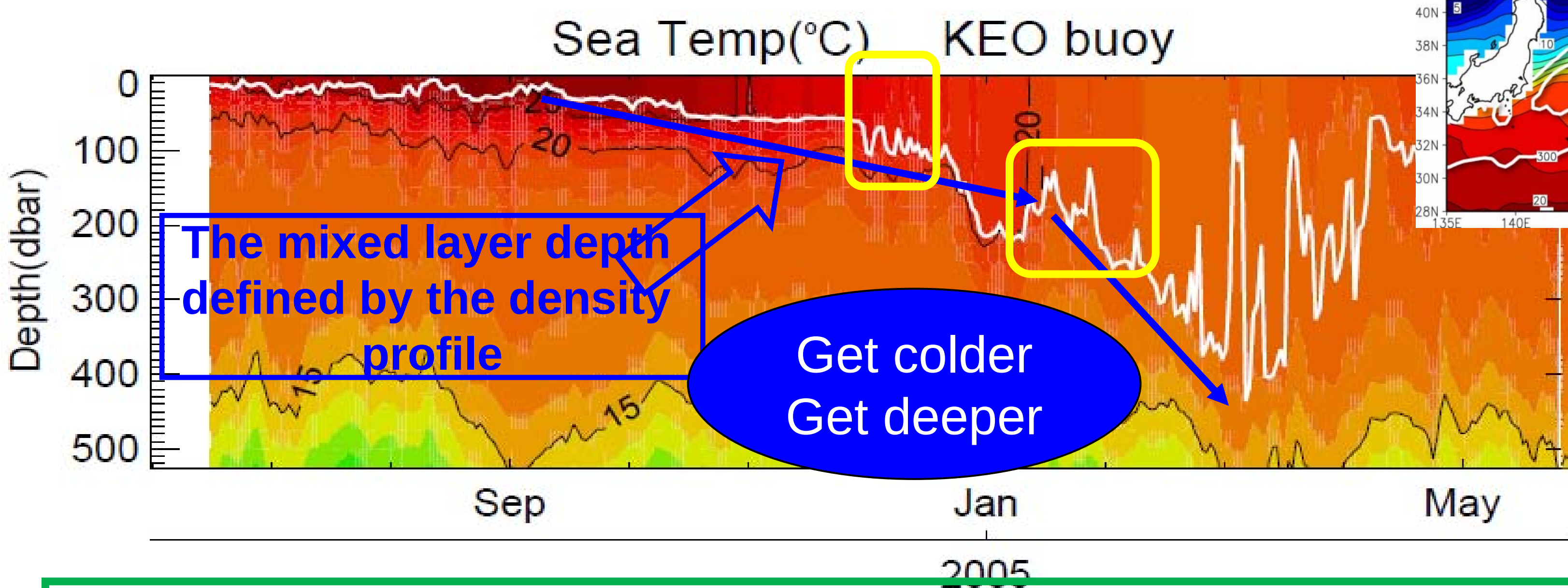
→ A possible impact on the mid latitude climate (Liu and Wu 2004;Frankignoul and Sennechael 2007、Minobe et.al.(2009))

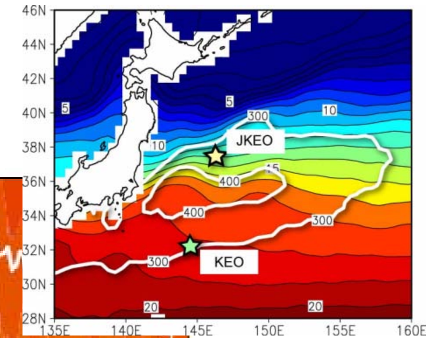
The mechanism of the air-sea feedback system is still unknown well.

The relationship among atmospheric boundary layer processes, **energy exchange at the sea surface**, **and ocean mixed layer processes**.



Seasonal change of the ocean mixed layer





The definition by the density profile (Mixed layer):

Seasonal time scale – the mixed layer depth --- the surface cooling

the maxim… depth

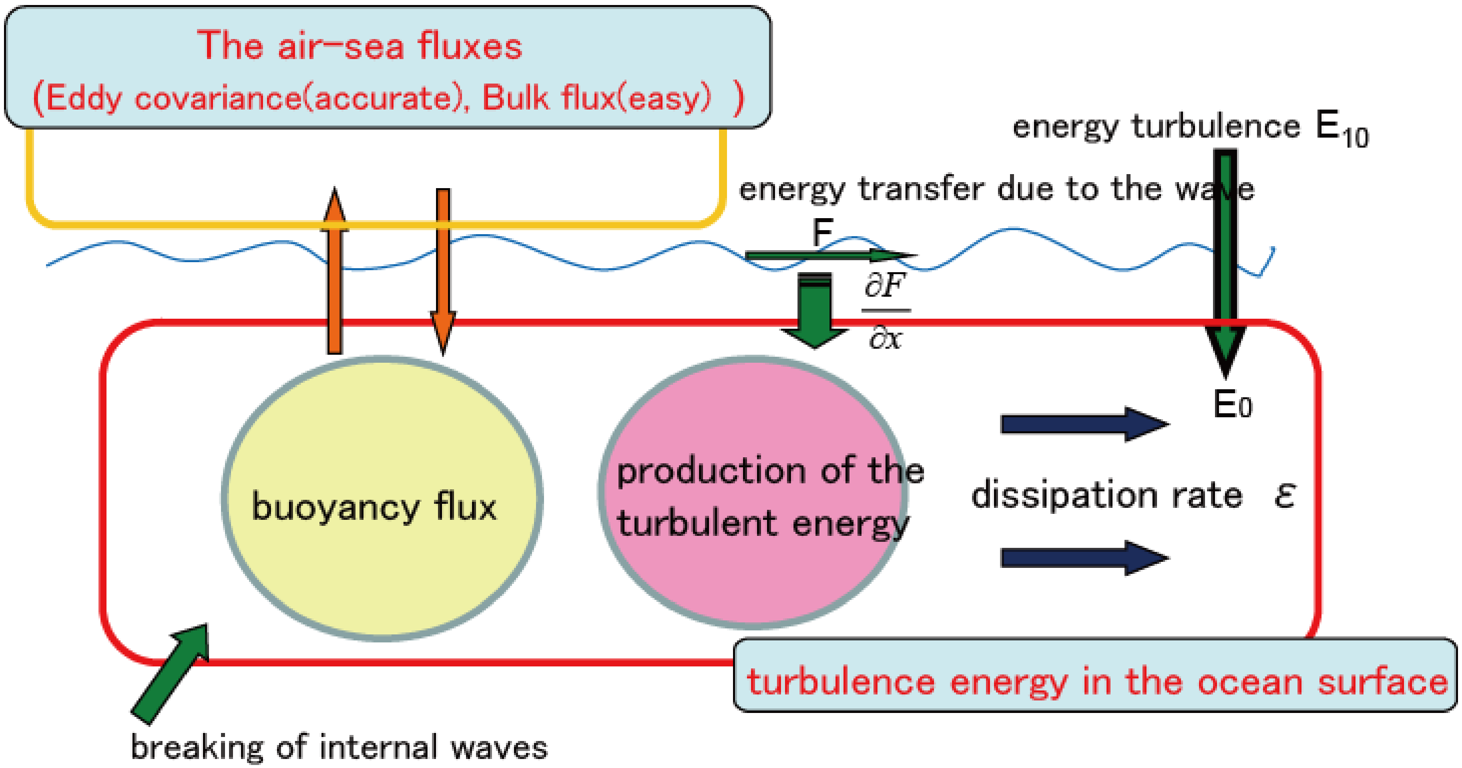
Preconditioning in the preceding summer (Kako and Kubota 2009)
Potential vorticity (Qiu and Chen 2005)

Synoptic scale～unknown (Iwasaka et al. 2006)

It is still unknown how the water is mixing in the mixed layer.

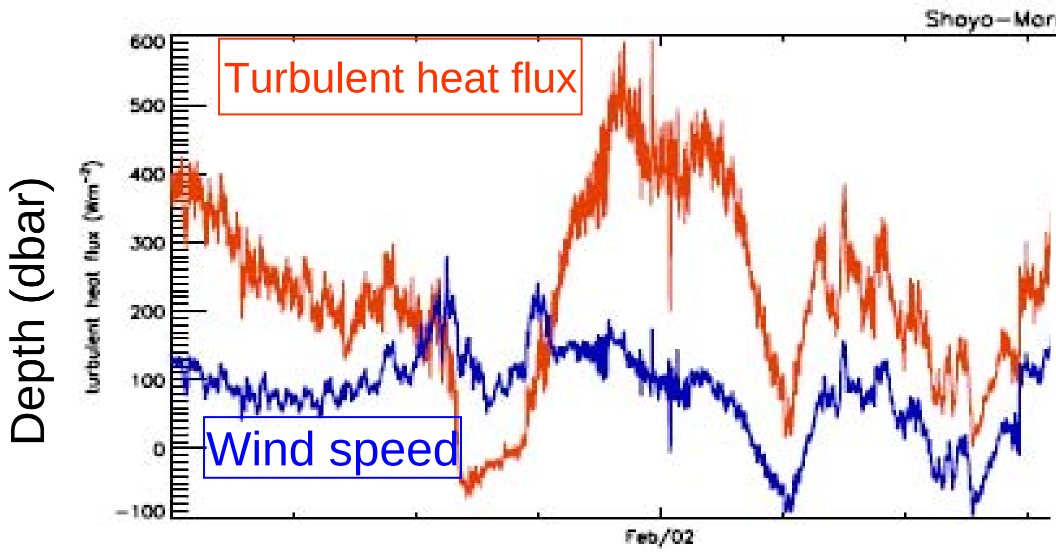
Turbulent energy in the ocean mixed layer

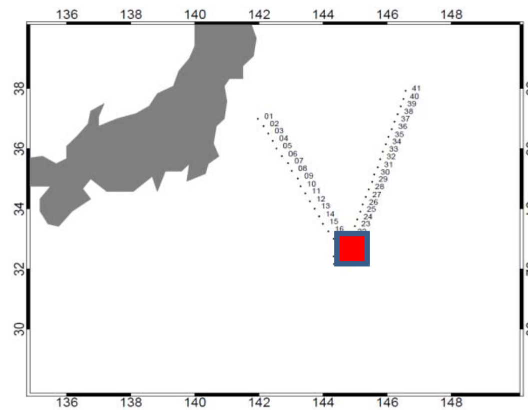
Turbulent Kinetic Energy equation $\frac{\partial \overline{E_t}}{\partial t} = -\overline{u'w'}\frac{dU}{dz} - \frac{g}{\rho}\left\langle \overline{w'\rho'} \right\rangle - \varepsilon$



The influence of the TKE budget on the formation/variation of the Mixed Layer

Redistribution of the surface generated heat and kinetic energy in the ML (Jan. 2009: R/V Shoyo-maru)





SY0901: near-stationary repeated measurement of the dissipation rate around KEO buoy January 29 to February 11, 2009

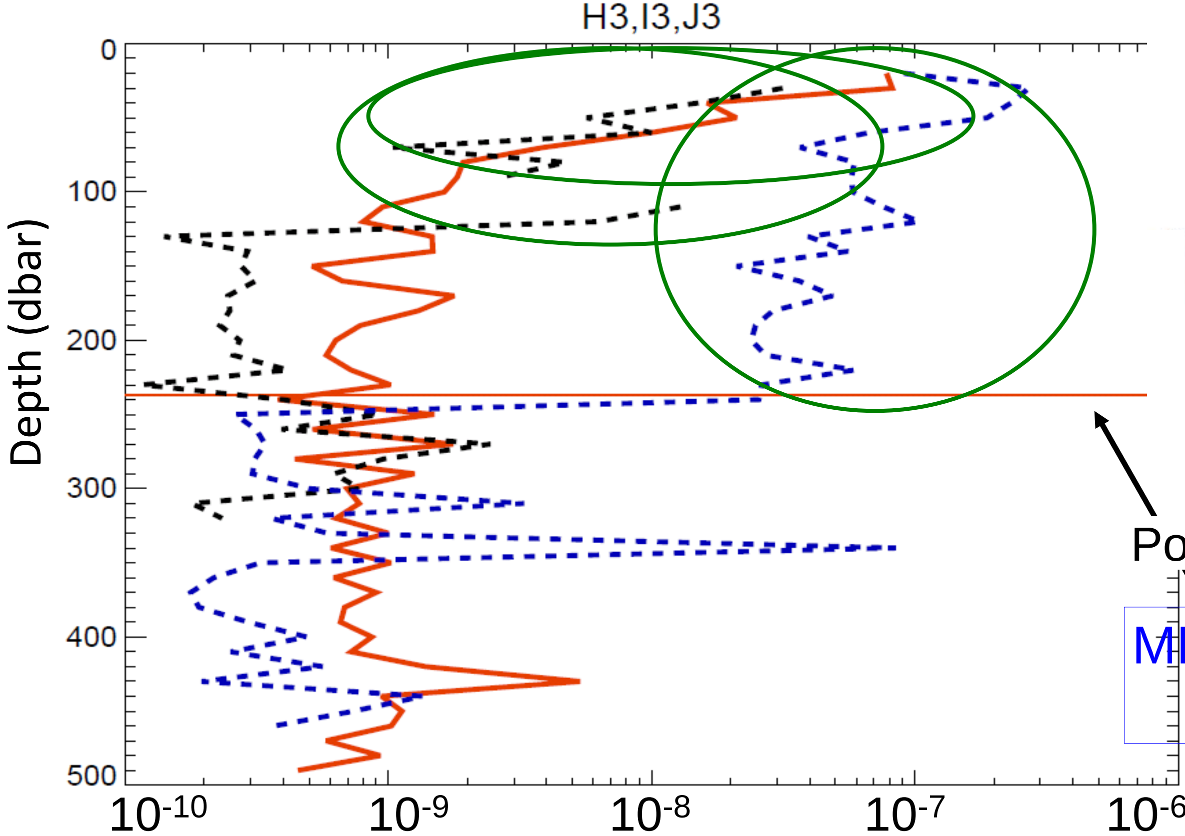
-Before the wind (A)
- Mature state (B)
- After the wind (C)

smaller than the usual definition of the mixed layer depth ($0.125 kg/m^3$) by 1 or 2 orders.

Small-scale disturbances above the pycnocline during the strong wind

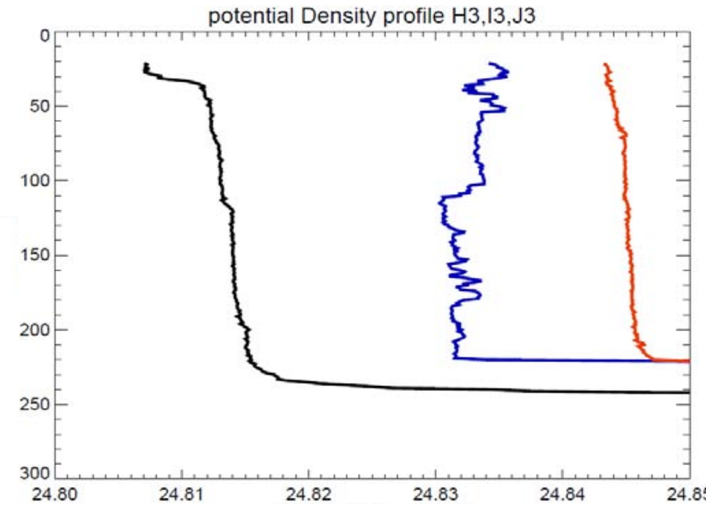
-> Mixed Layer ? Mixing Layer ?

Dissipation rate profile



-Before the wind (A)
- Mature state (B)
- After the wind (C)

Potential density (close-up)

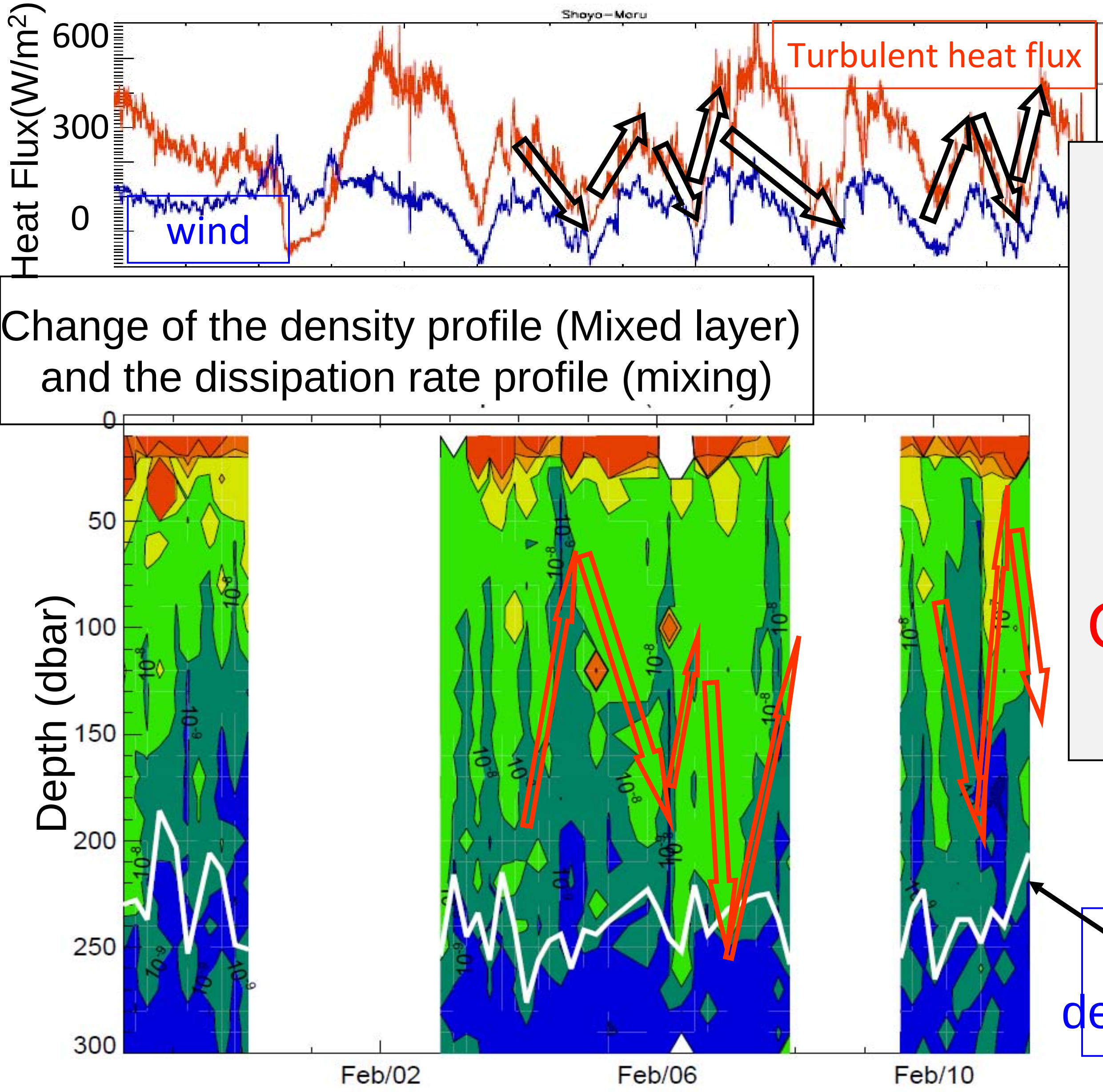


Potential Density (σ − 1000 kg/m^3)

MLD defined by the difference of the potential density

Active mixing does not reach the bottom of the Mixed Layer when the surface disturbance is weak.

The dissipation rate (mixing) in the mixed layer (profile)

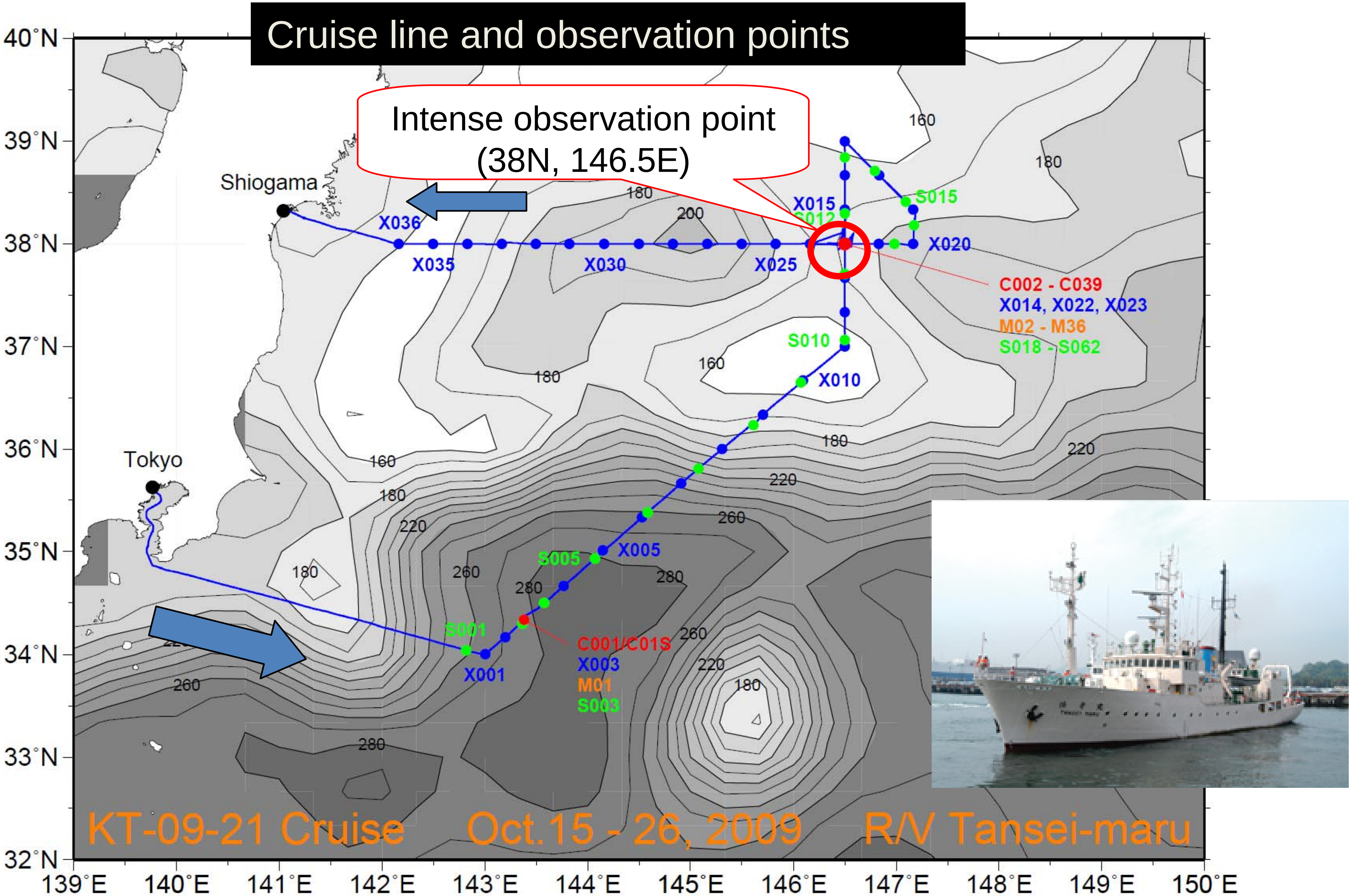


good correspondence between the surface (heat and momentum fluxes) and the oceanic turbulences (dissipation rate)

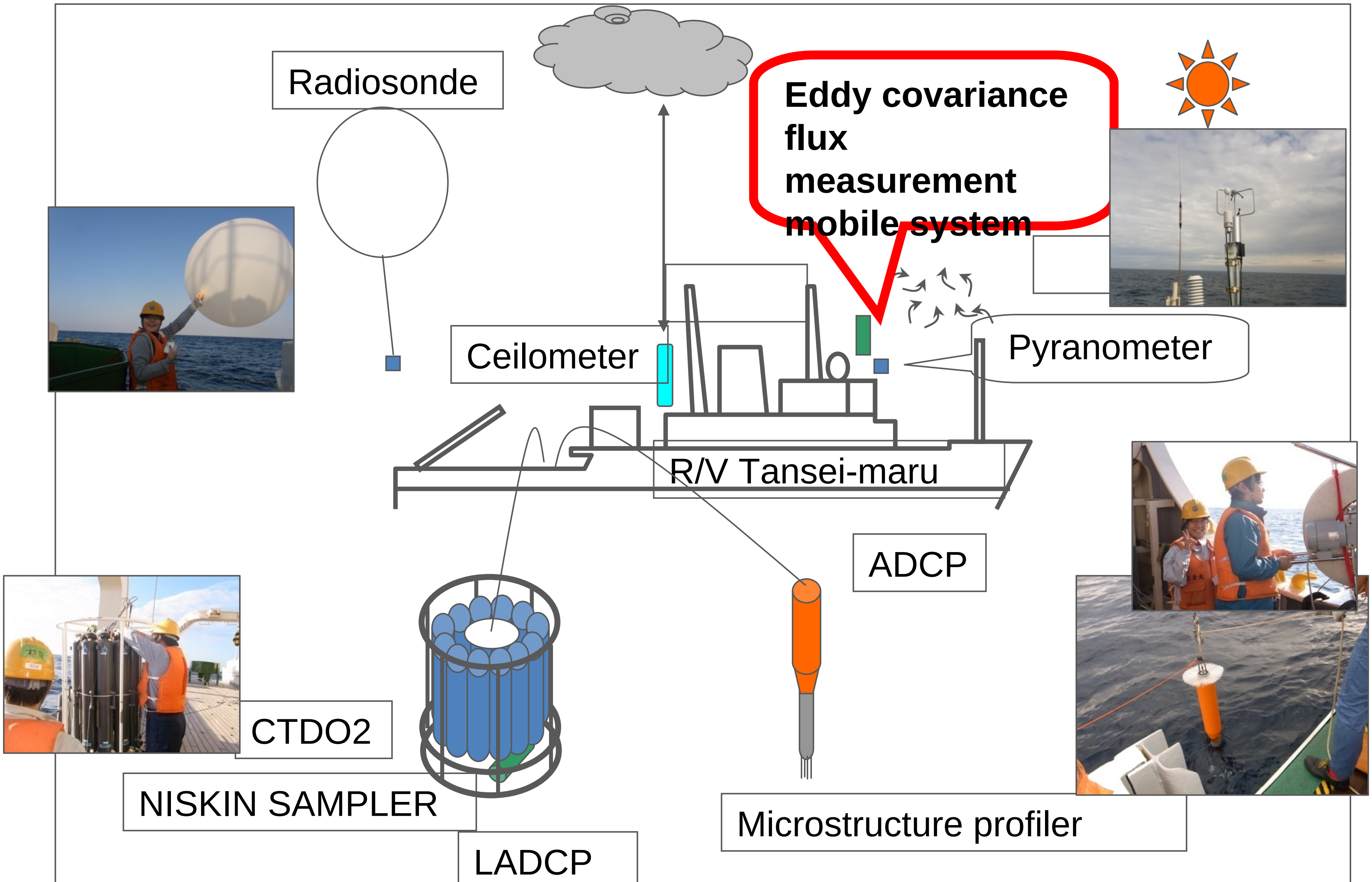
Ocean Mixing Layer

The Mixed layer depth defined by the potential density

KT0921 air-sea interaction measurement by R/V Tansei maru



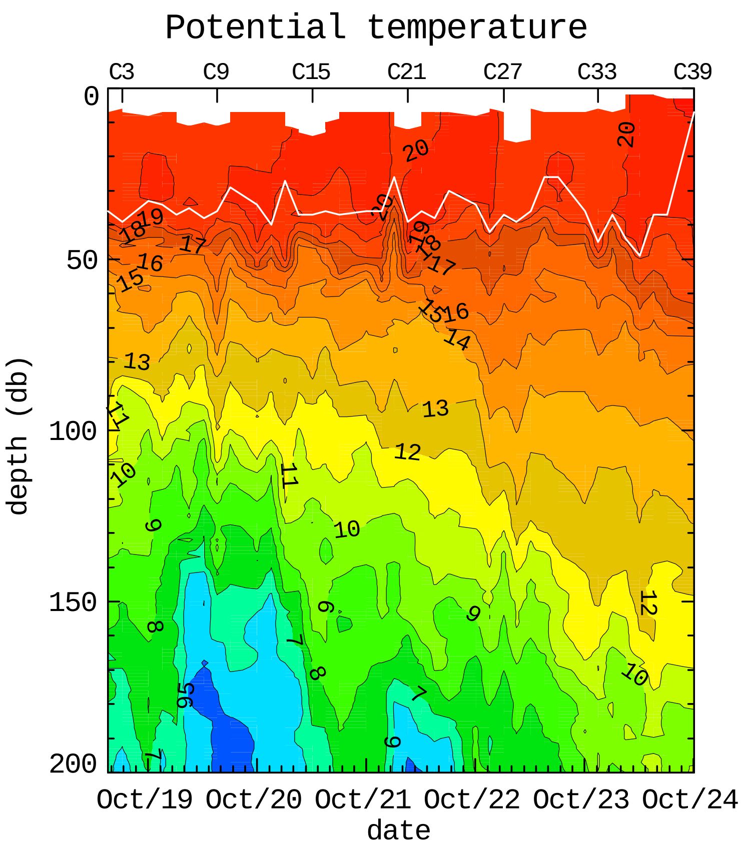
Observation at 38N, 146.5E
October 18-23



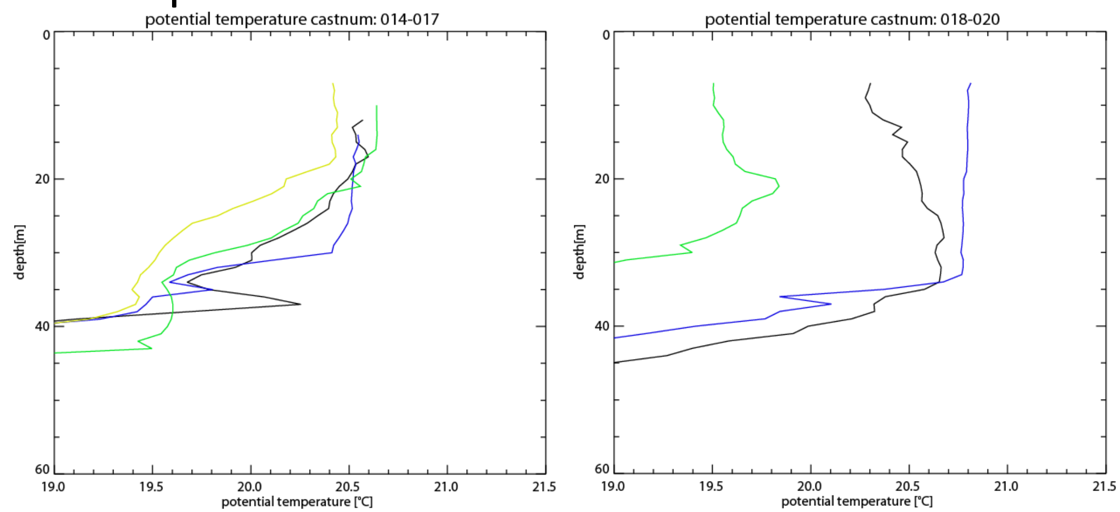
KT0921 – R/V Tansei-maru cruise

Mixed layer temperature is 19~20C
Density uniform layer is about 50m,
whereas the salinity and the temperature slightly changes in the early stage.

Density uniform layer is well mixed and the weak stratification of
the salinity and the temperature disappeare after the midnight of Oct. 20.

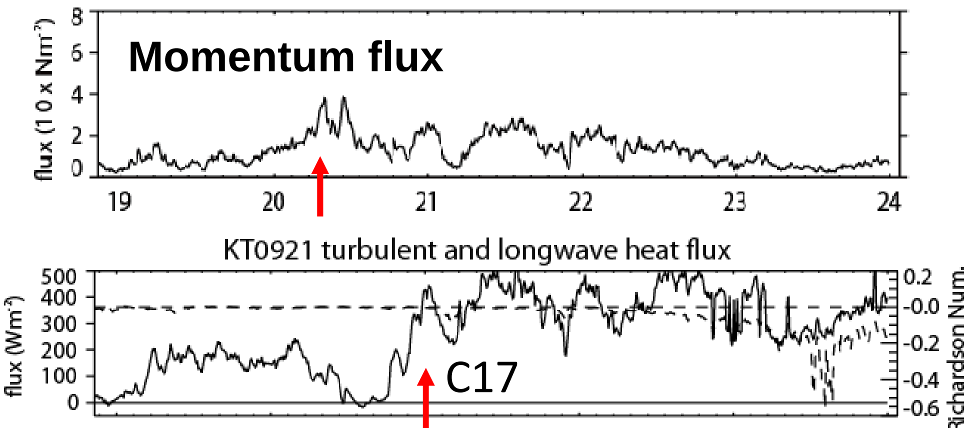


Examples of the potential temperature profiles before and after Oct. 20.

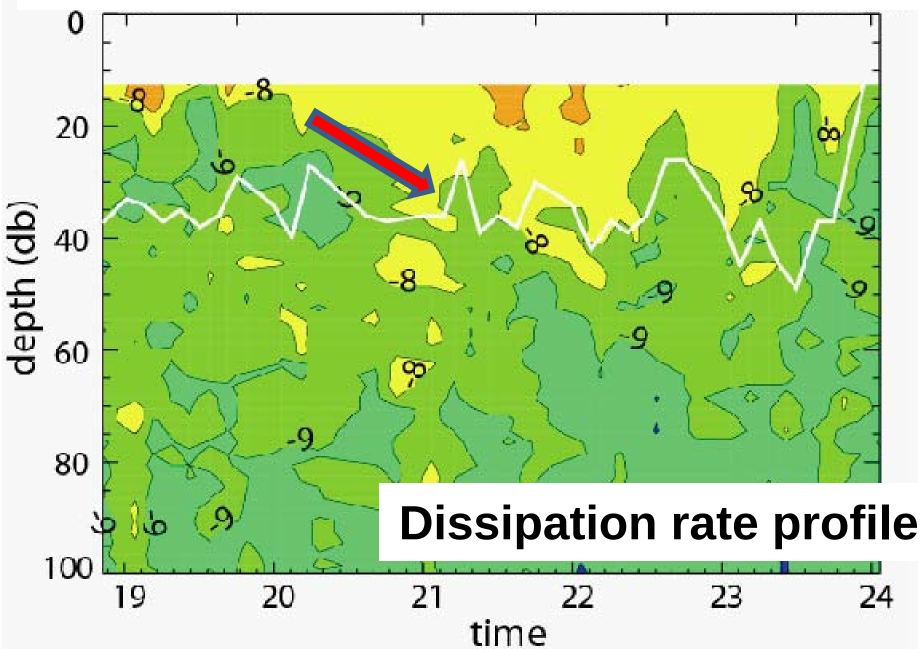


Change of the dissipation rate by the surface disturbance

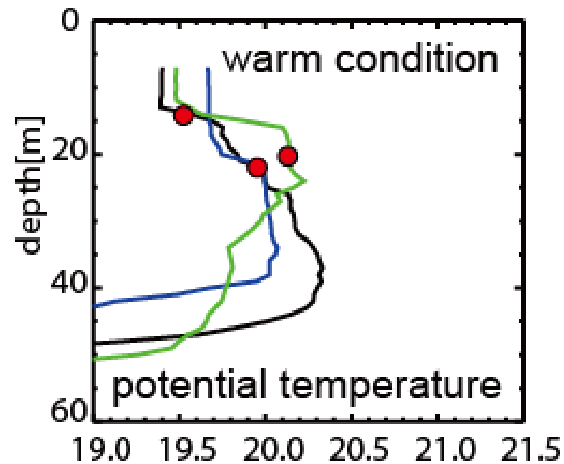
The temperature and the salinity profiles changed after the midnight of Oct. 20.
The surface heat flux increased from 200 Wm^{-2} to 500 Wm^{-2} .

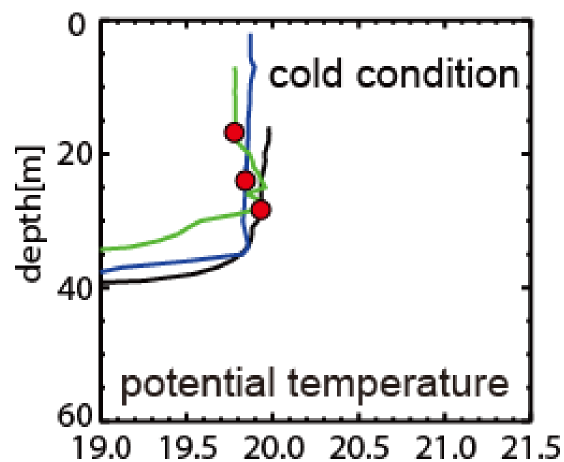


Heat flux (turbulent flux and the longwave radiation)



Dissipation rate profile





● Depth of the mixing layer
$\varepsilon = 10^{-8}$ W kg^{-1}

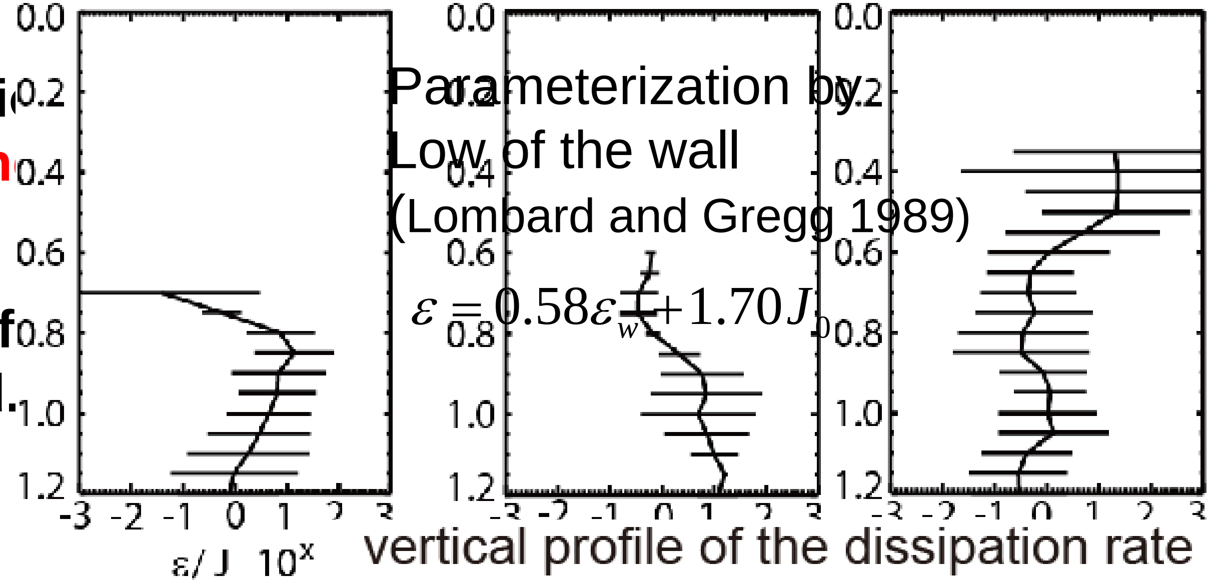
Shallow Mixing layer (stratification by salinity)

Ratio between the dissipati buoyancy energy (Jb) chan

$$\varepsilon = 0.52 J_b$$

Parameterization by Low of mixing layer seems to hold.

$$\varepsilon = 0.125 \varepsilon_w$$



vertical profile of the dissipation rate normalized by the low of wall

Difference of the relationship

Deep Mixing layer (well mixed to the pycnocline)

Ratio between the dissipation rate ε and Jb is almost constant.

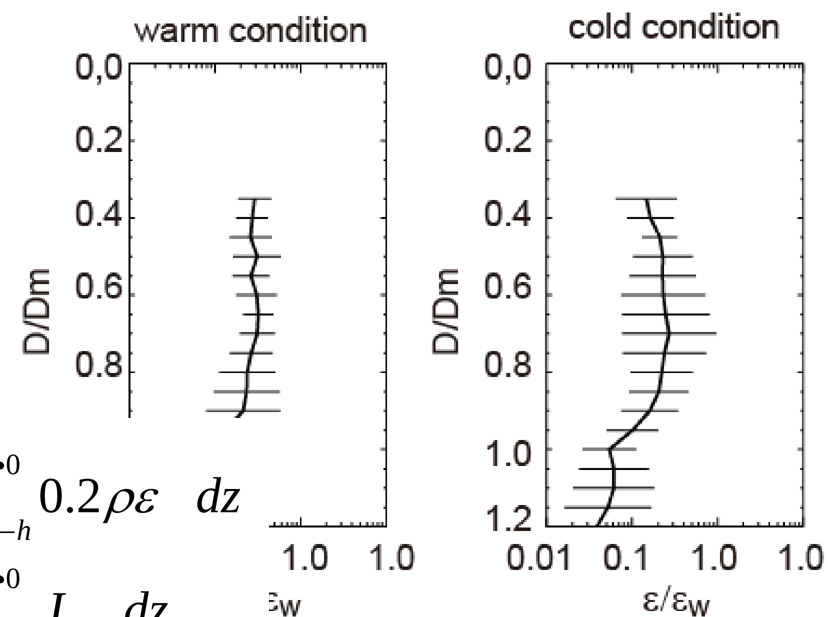
$$\varepsilon = 0.68 J_b$$

Parameterizat the mixing lay

$$\varepsilon = 0.193 \varepsilon_w$$

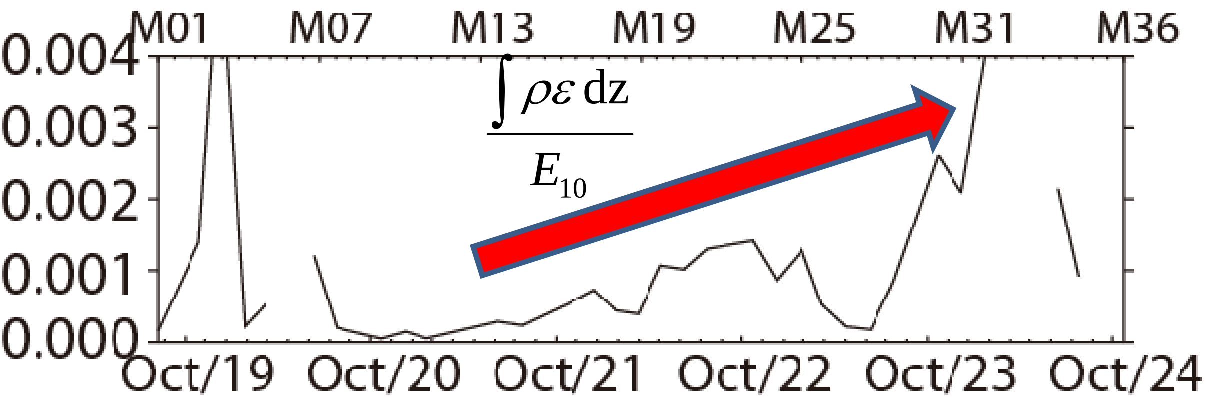
Constant ratio between ε and the buoyancy energy (Osborn,1980)

$$J_I = \int_{-h}^{0} 0.2 \rho \varepsilon \, dz = \int_{-h}^{0} J_b \, dz$$



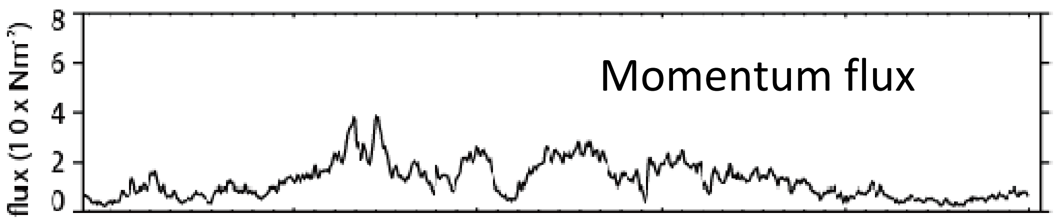
e depth of the mixing layer

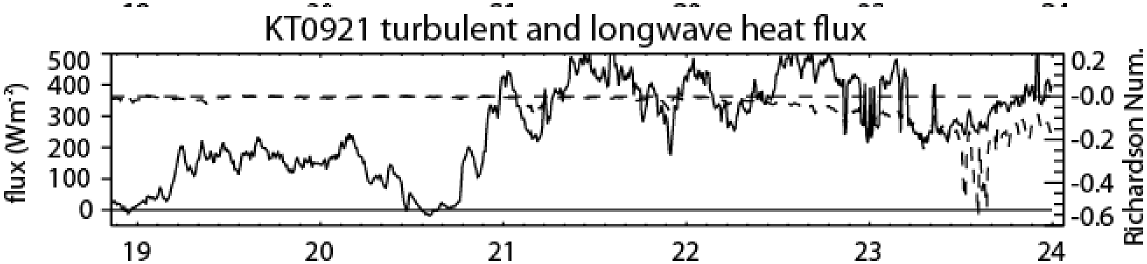
How much does the TKE is taken into the ocean?



$\int \rho\varepsilon\, \mathrm{dz}$ Integrated dissipation energy in the Mixing Layer

$E_{10} = \tau U_{10}$ Energy of the wind





Ratio of the TKE input is small in the early stage, whereas it become large after the wind and the density flux (surface cooling) become strong.

summary

- We investigated the turbulent energy balance in the mixed and the mixing layer, with the reliable surface turbulent heat flux.
- The large discrepancy between the mixing and the mixed layer was observed when the surface turbulent energy and the buoyancy flux enter the ocean surface layer.
- The vertical profile of the dissipation rate showed the similarity of the law of wall regardless of the surface condition.
- It is suggested that the turbulent energy balance in the layer with the near uniform density vertically changes due to the temperature and the salinity stratification. Therefore, the effect of the buoyancy flux should not be ignored in the ocean mixing layer.