Observations of internal tide dissipation and mixing during Mouton2008

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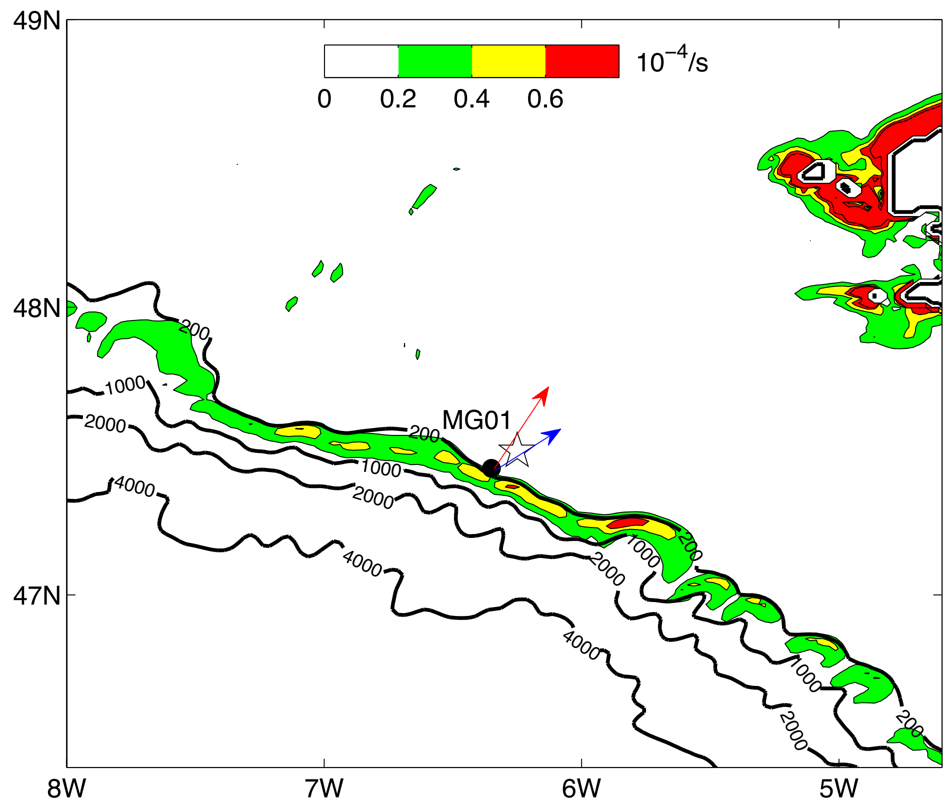
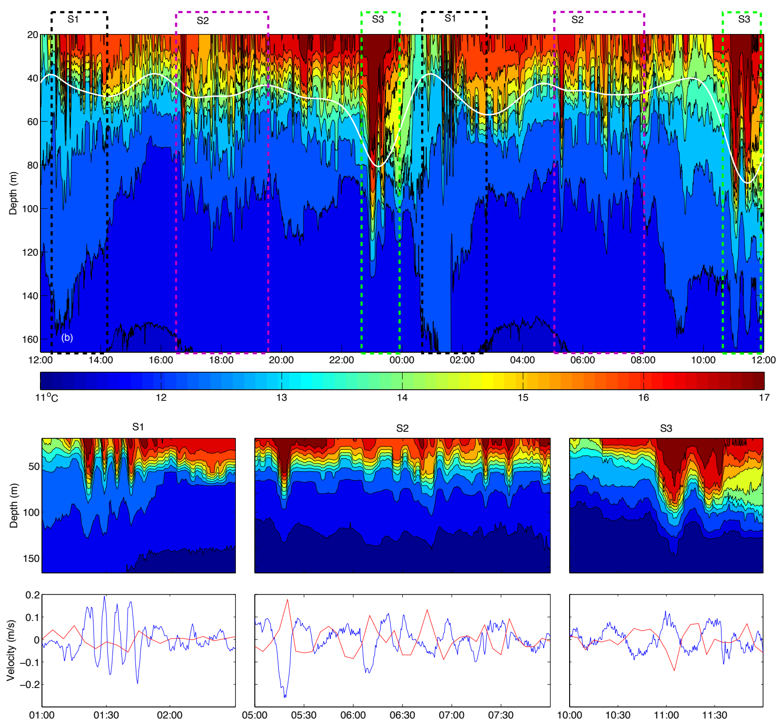
The first subject: generation and propagation of internal tides and solitary waves in the Bay of Biscay

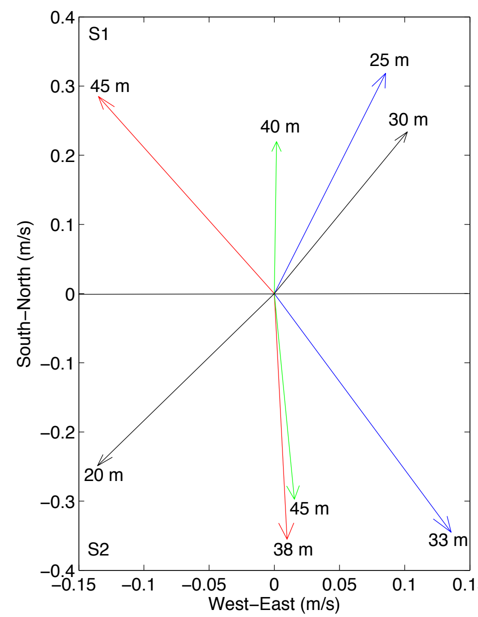
- Last year, we used a set of mooring temperature and current data collected in Mouton 2008 experiment and a three dimension HYCOM model to investigate generation and evolution of internal tides and solitary waves in the Bay of Biscay.



Generation and propagation of internal tides and solitary waves in the Bay of Biscay

Solitary waves





shoreward

seaward

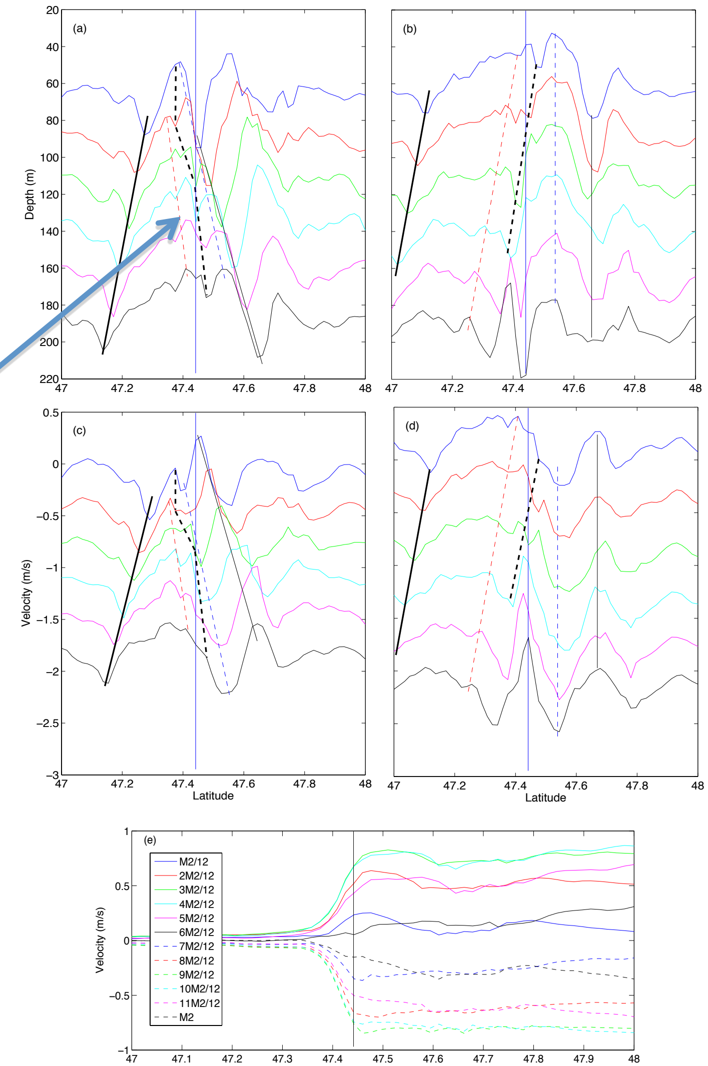
In the Bay of Biscay, solitary waves are often generated by internal tide. So, the Hycom model is used to investigate generation and propagation of internal tide to explore the possible mechanism of opposite propagation.

Generation and propagation of internal tides and solitary waves in the Bay of Biscay

By the Hycom model, it is found that advection by strong barotropic current plays an important role in changing propagation of internal tides and solitary waves.

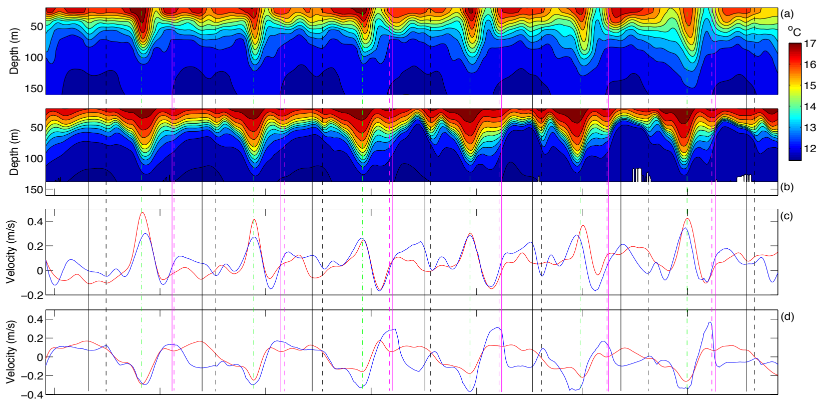
Because of strong barotropic current at the flood tide, the seaward going internal tide, which generates possibly the seaward travelling solitary waves, is advected to shelf. At ebb tide, they are back to deep sea and propagate offshore.

So, it is possible for the seaward and shoreward going solitary waves to be simultaneously observed at mooring site onshore of internal tide generation site.



Generation and propagation of internal tides and solitary waves in the Bay of Biscay

Strong nonlinear internal tides

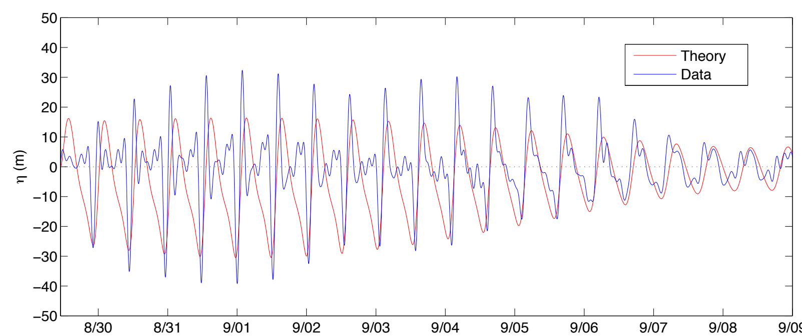


Pichon and Maze [1990]

$$\eta(y,t) = (ah/H)e^{-(a/H)(C_0 t' + \int_0^{t'} U(\tau)d\tau)} \times \int_0^{t'} U(\tau) e^{(a/H)(C_0 \tau + \int_0^{\tau} U(\tau')d\tau')}$$

Generation mechanism

Two-layer analytic model



Advection by barotropic current

Conclusions

- Large nonlinear internal tide and solitary waves are observed during Mouton 2008. A realistic hydrostatic HYCOM model can reproduce nonlinear internal tide well.
- Occurrence of solitary waves is regular, but more than one packet is seen in a tidal period.
- Advection induced by barotropic current not only play an important role in generation of internal tide, but in the change of their propagation direction.

The second subject: Internal tide dissipation and mixing

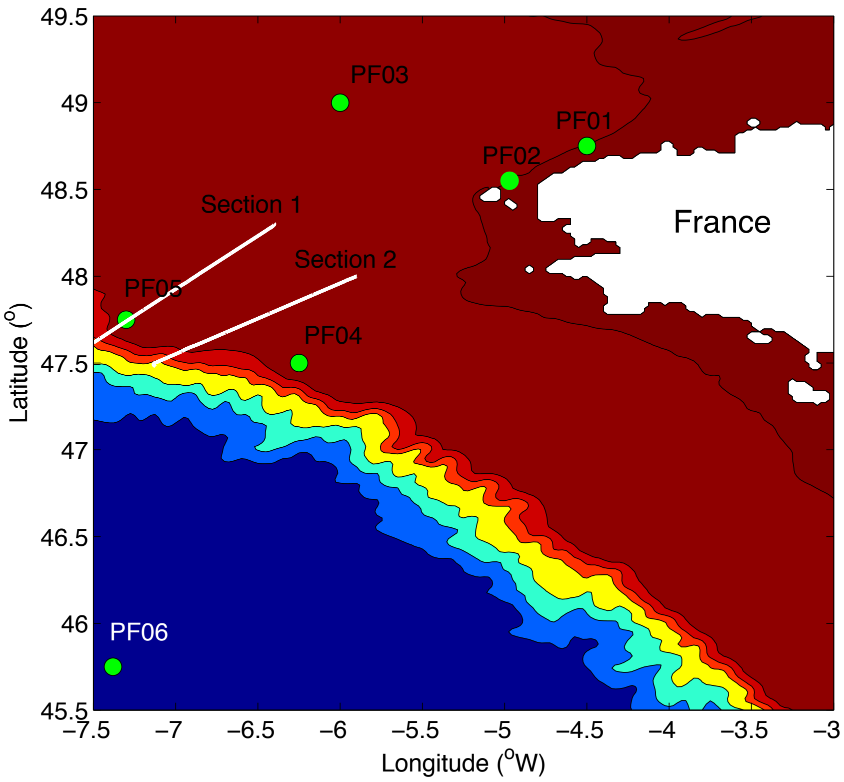
Aim

- Confirming the relationship between internal tide and turbulent mixing
- Parameterization of internal tide mixing in the Bay of Biscay.
- Application of parameterization

Internal tide dissipation and mixing

Data

- For this subject, CTD/seasoar and LADCP/VMADCP at six fix-points and in two cruise transections collected from Mouton experiment are used.
- VMP and Scamp microstructure data near PF06.



Methods

Indirect estimation of dissipation rate ε

- Based on two parameterization formula (Gregg-Henyey and Mackinnon-Gregg scaling) , as well as CTD and ADCP data, turbulent kinetic energy dissipation rate ε is estimated.

$$\epsilon_{GH} = 1.8 \times 10^{-6}\left[f \cosh^{-1}\left(\frac{N_0}{f}\right)\right]\left(\frac{S_{10}^4}{S_{GM}^4}\right)\left(\frac{N^2}{N_0^2}\right)$$

$$S_{GM}^4 = 1.66 \times 10^{-10}\left(\frac{N^2}{N_0^2}\right)^2.$$

Gregg-Henney

$$\epsilon_{MG} = \epsilon_0\left(\frac{N}{N_0}\right)\left(\frac{S_{lf}}{S_0}\right) \quad (\mathrm{W\ kg^{-1}})$$

Mackinnon-Gregg

Invalid for solitary waves

Direct measurement of ε

- Microstructure observation: VMP and Scamp

- Turbulent mixing rate

Shih et al (2005)

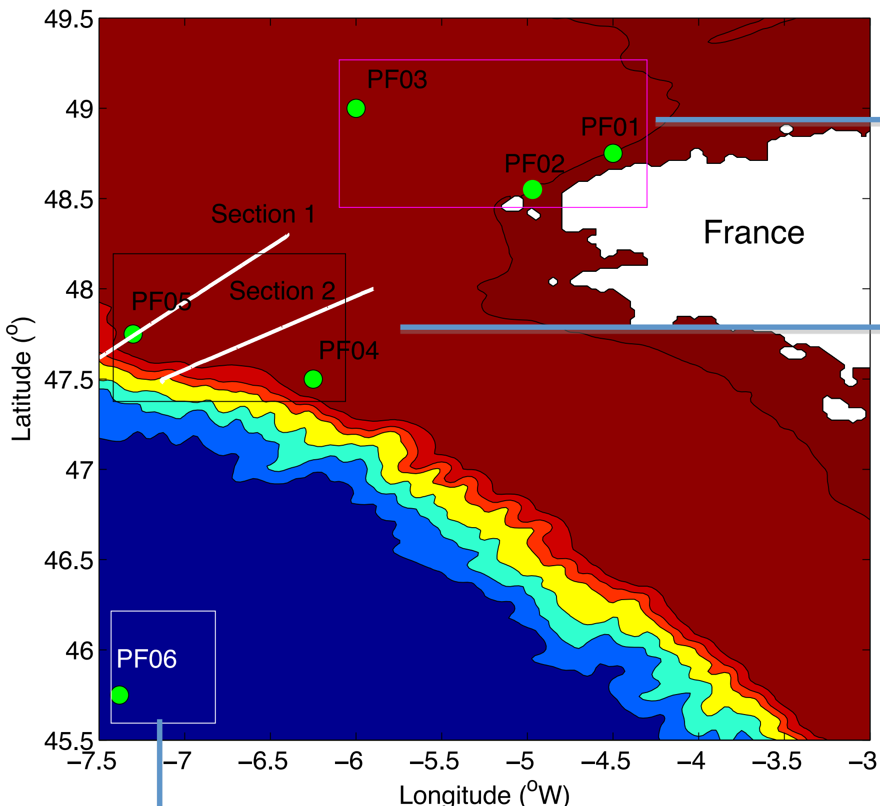
$$\kappa_\rho = \varepsilon / \nu N^2 (7 < \varepsilon / \nu N^2 < 100)$$

$$\kappa_\rho = 2\nu(\varepsilon / \nu N^2)^{1/2} (\varepsilon / \nu N^2 > 100)$$

Comparing the estimation to the direct measurement, we can confirm whether two formula are suitable in the Bay of Biscay.

Parameterizations available to the Bay of Biscay

Overview of Internal tide and turbulent dissipation rate

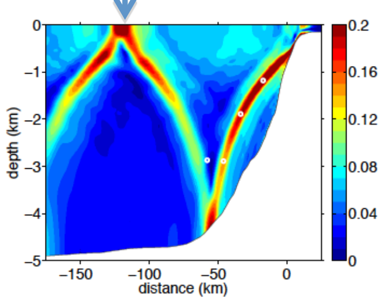


Weak dissipation?

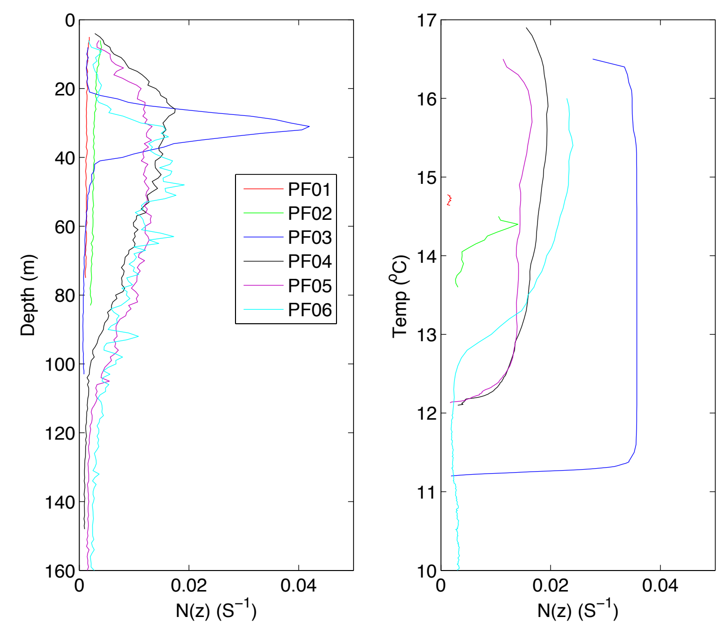
Shelf region away from internal tide generation location

Strong dissipation?

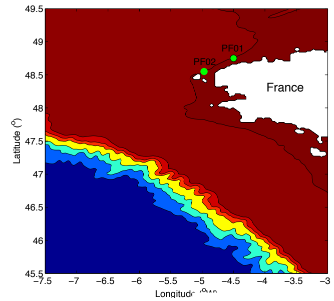
Near Shelf edge, where internal tide is generated



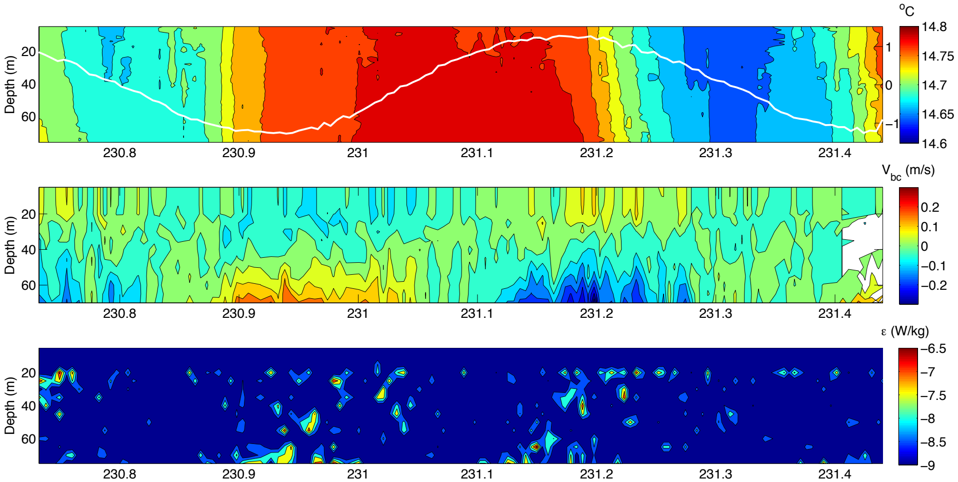
PF06 is located in a region of surface reflection of internal tide beam. Strong dissipation?



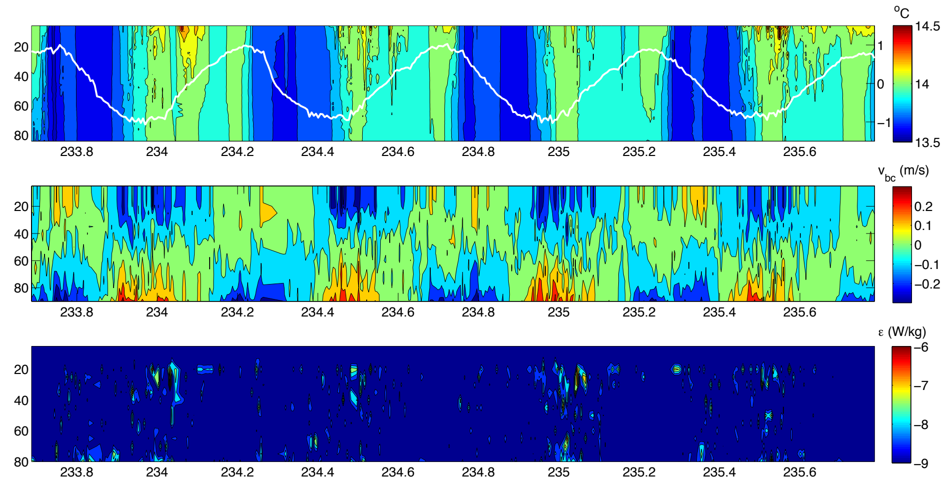
Shelf away from the generation area



PF01

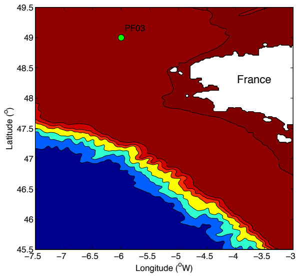


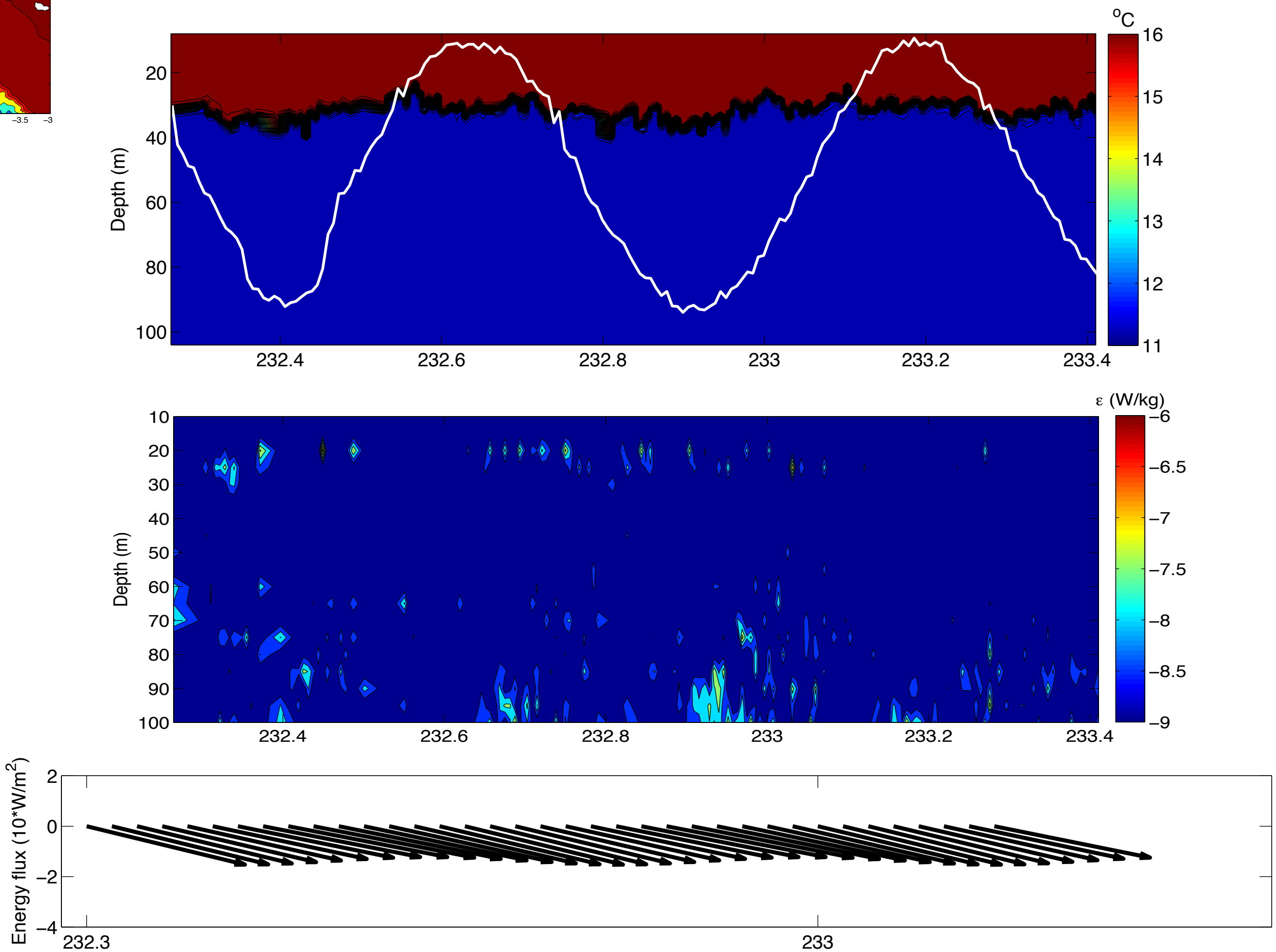
PF02



Weak stratification and internal tide is weak. Instead, temperature fluctuations are evidently associated with advection by strong barotropic current.

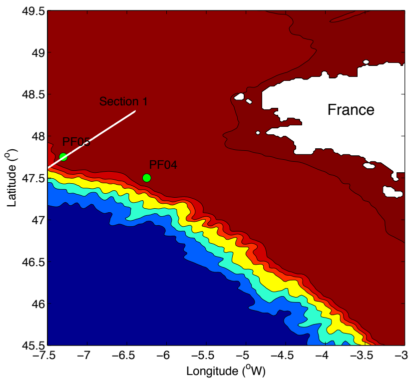
PF03



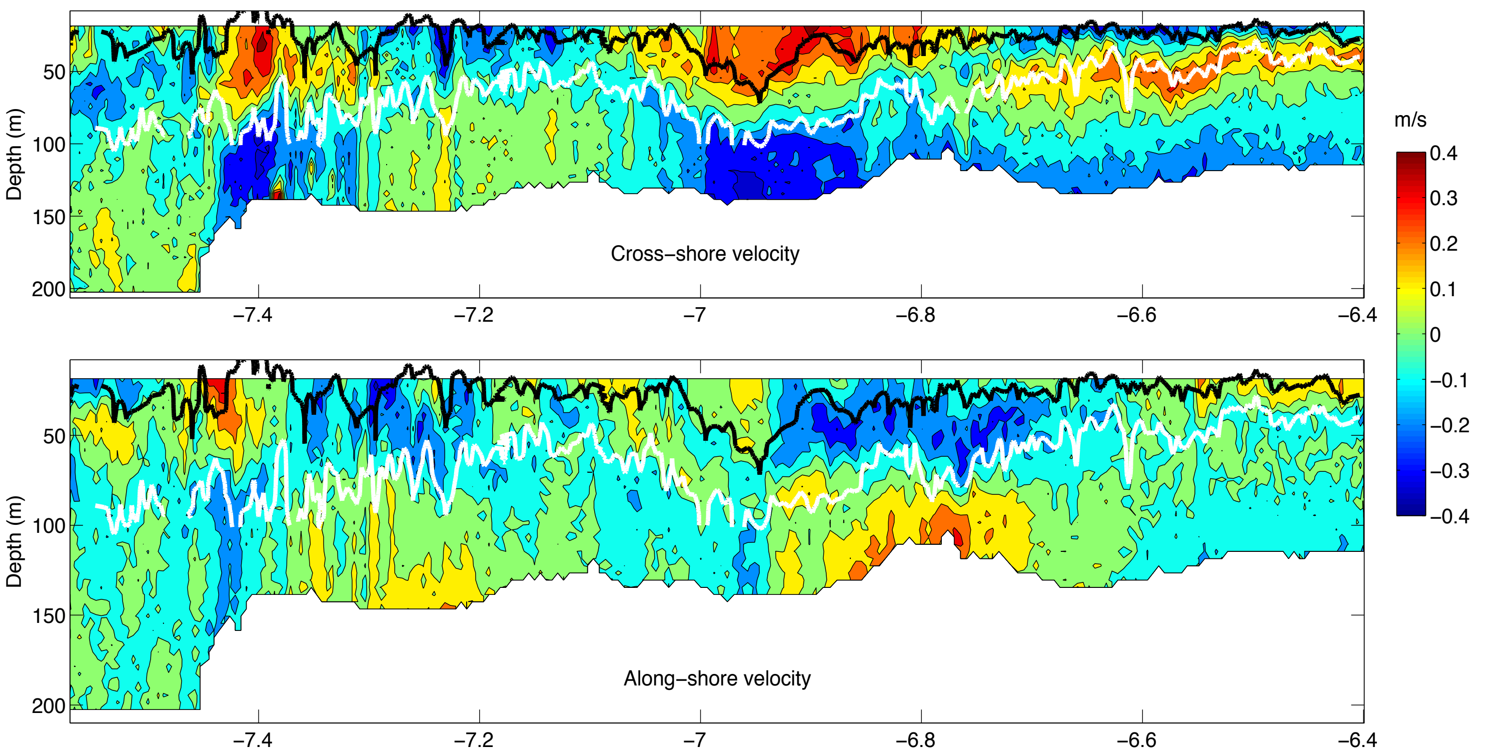


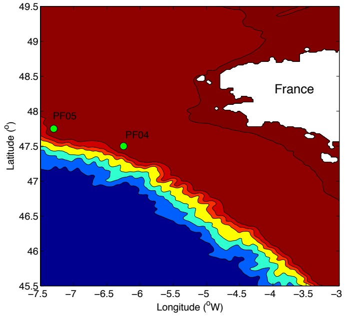
Strong thermocline: two-layer model; weak dissipation. The internal tide propagates south-west. The energy flux is only 20 W/m2.

Characters of internal tides near the shelf edge



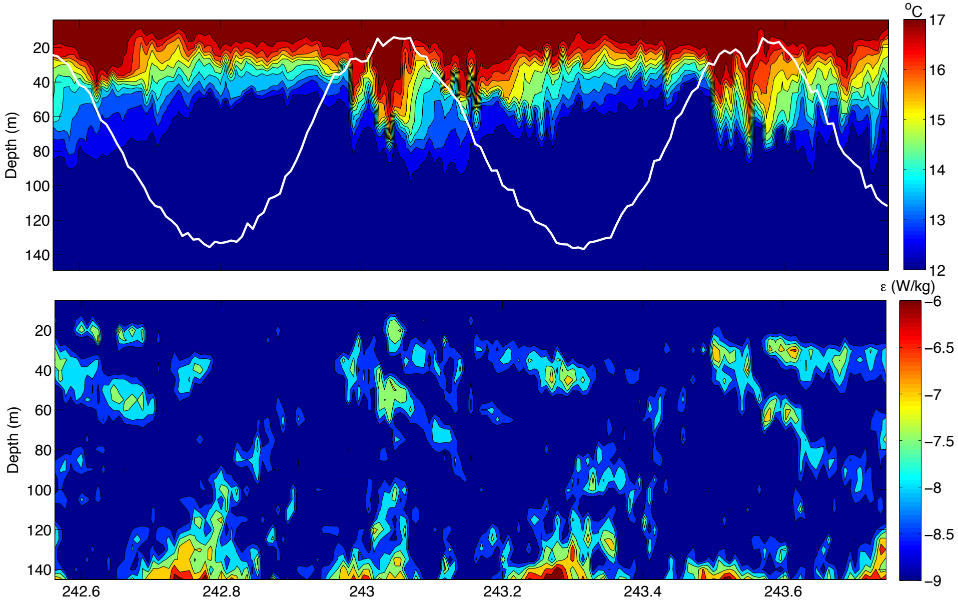
Large internal tide and solitary wave. Internal tides propagate onshore not only as a form of mode structure, but as a beam. High-mode structure is clearly visible.

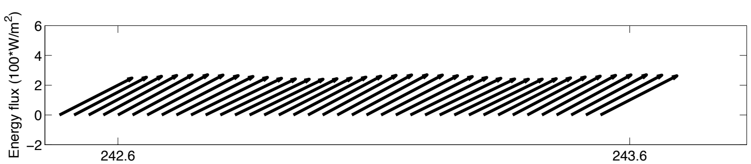




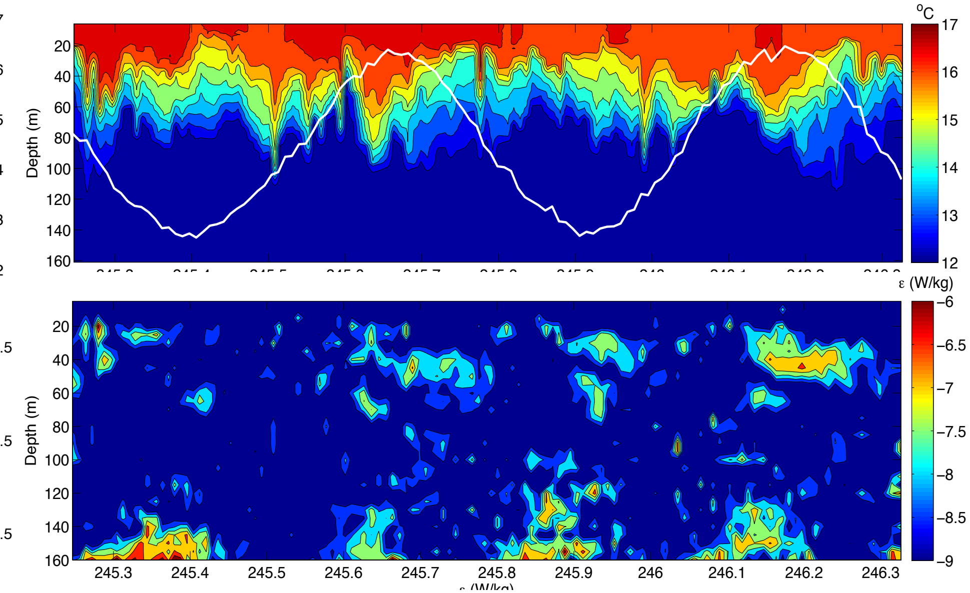
PF04 and PF05

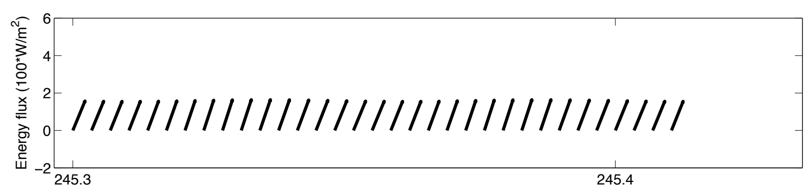
PF04





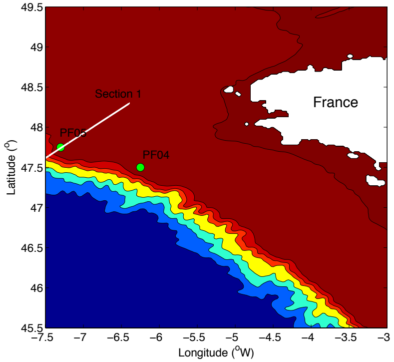
PF05

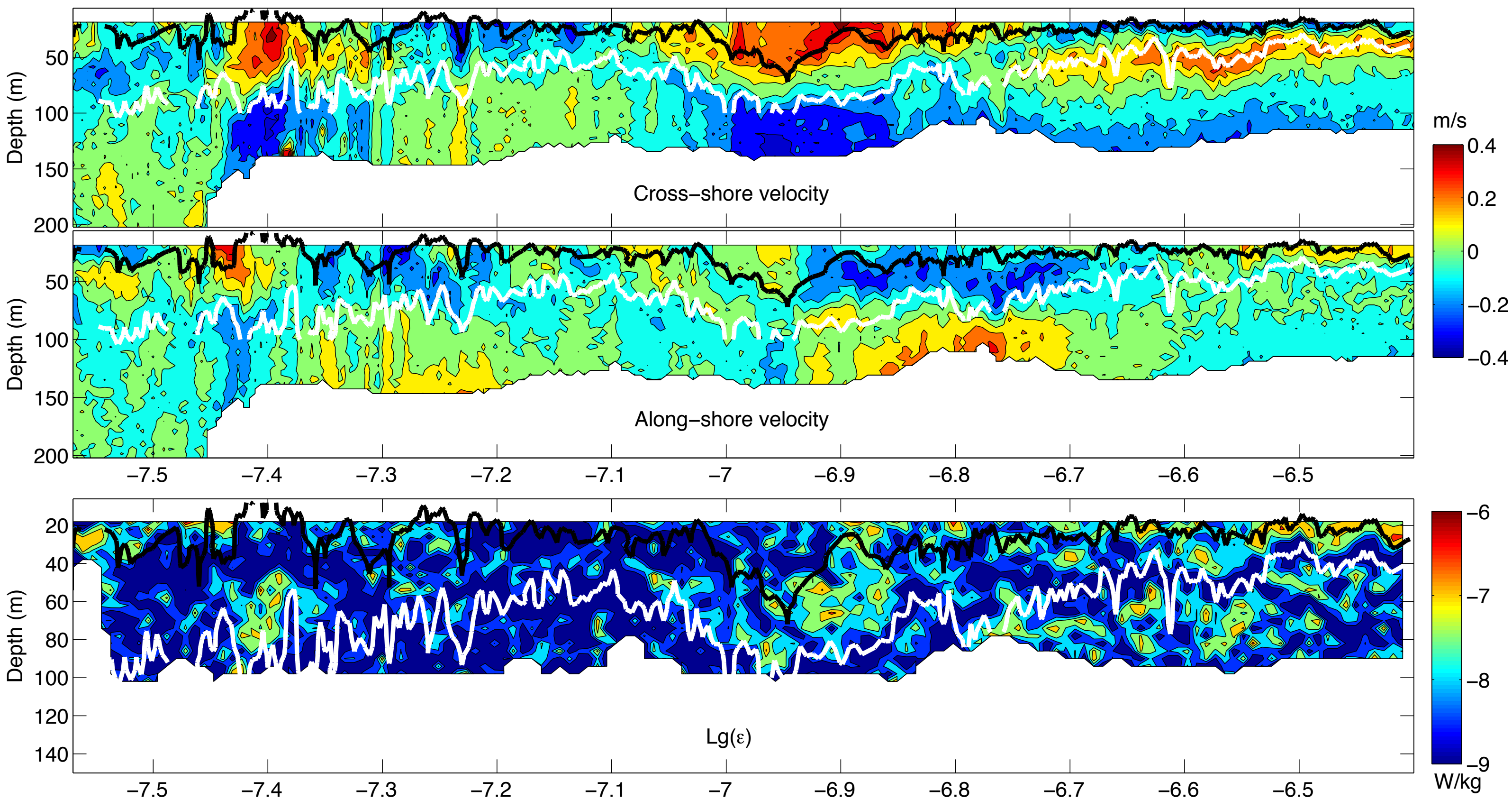




- Large internal tide; Northeastward energy flux, ~200 W/m2
- The enhanced dissipation in the thermocline have a semi-diurnal modulation. In the bottom, ε has a quarter-diurnal period.

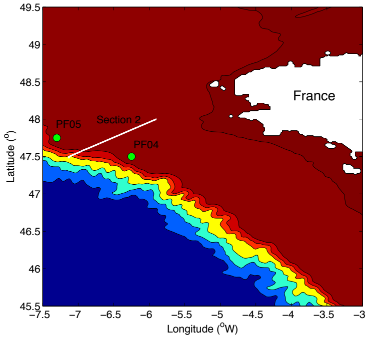
Section 1

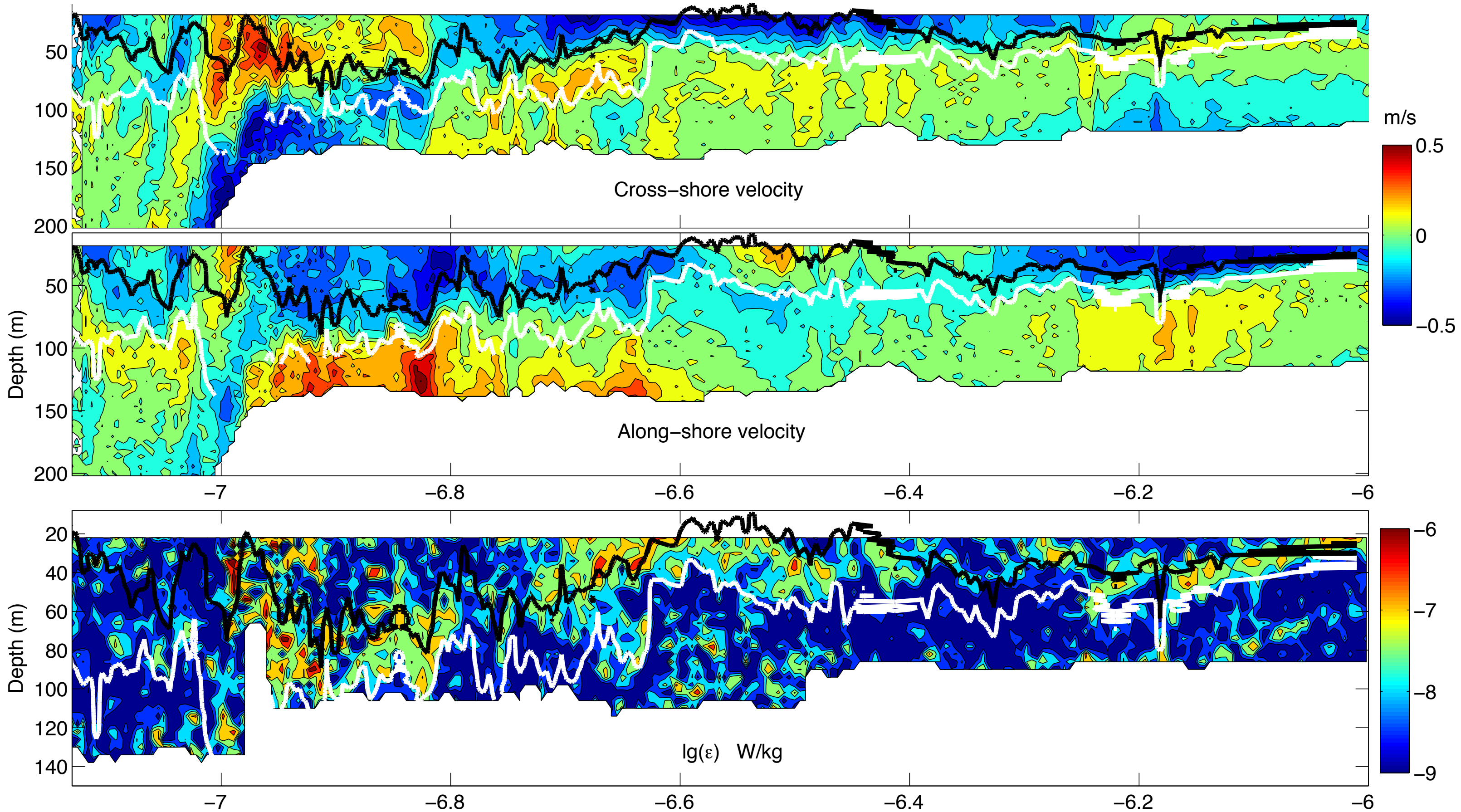




Large dissipation rate often corresponds to high-mode structure and narrow beam.

Section 2

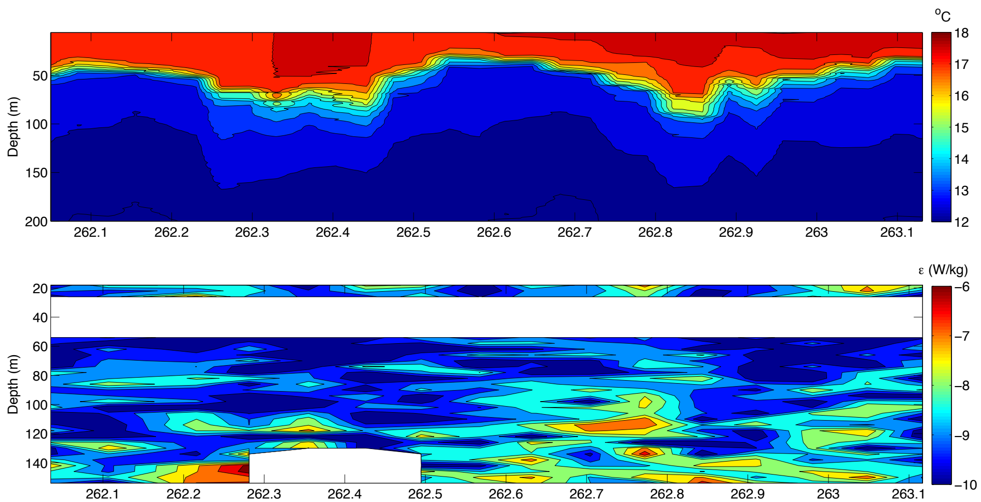




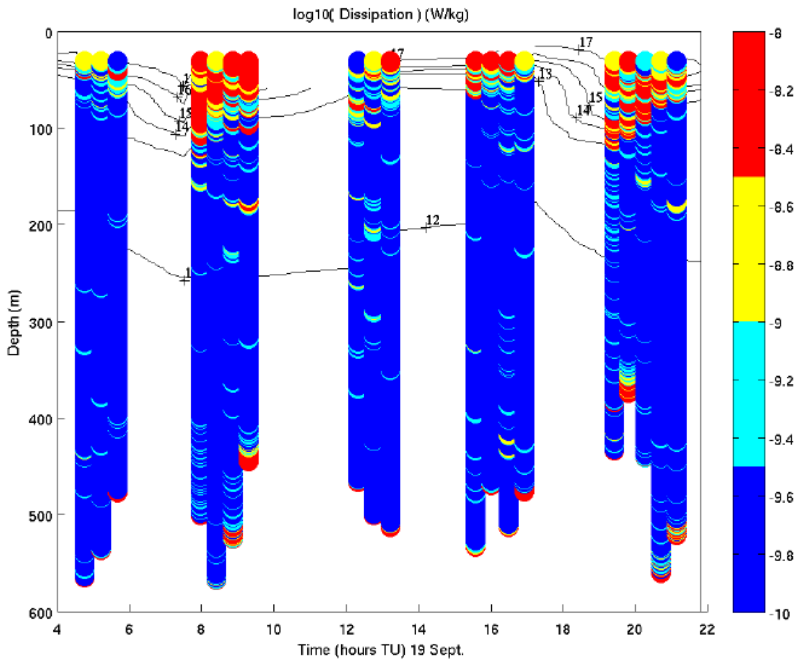
Large dissipation rate often corresponds to high-mode structure or internal tidal beam.

Deep sea: PF06

CTD/VMADCP

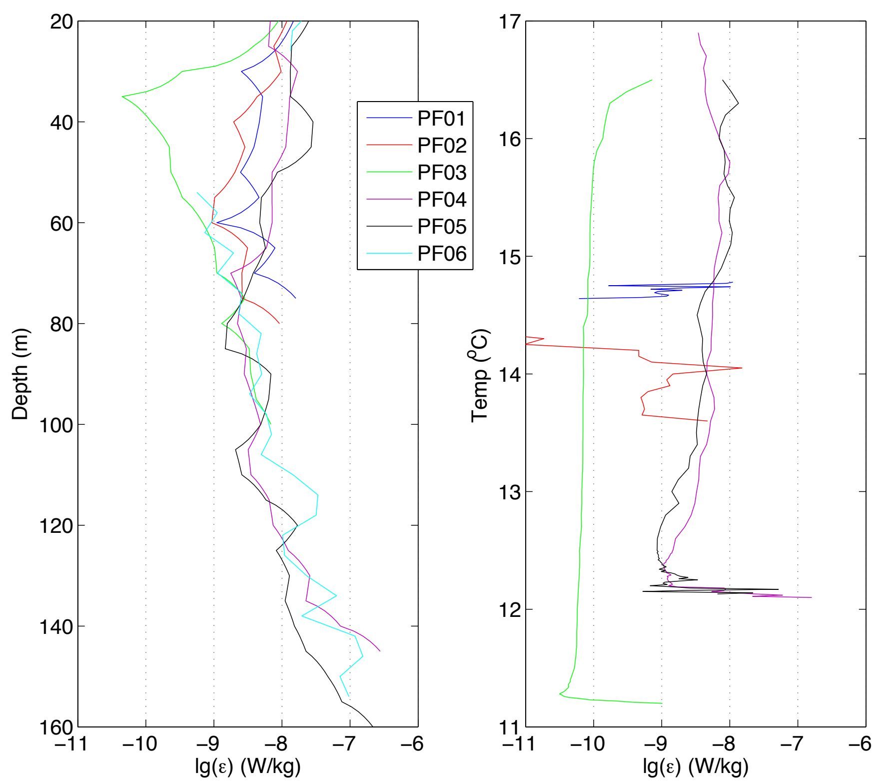


VMP



Time-average

- The strongest dissipation appears in the shelf edge and PF06, as expected.
- For a strong two-layer structure, namely PF02, dissipation rate is low except in the bottom.
- Near the coast (PF01 and PF02), where there is a weak stratification, dissipation rate does not show a large variation in depth.



Parameters

Station	PF01	PF02	PF03	PF04	PF05	PF06
Energy flux of internal tide (W/m2)			20	210	190	
Dissipation rate (W/kg)	6e-9	2e-9	4e-9	2e-8	2e-8	3e-8

Preliminary conclusions

- During the observation, strong dissipation is evidently associated with internal tides.
- In the shelf edge near internal tide generation location, as well as the reflection region of internal tide beam in the deep sea, the strongest dissipation is found. The estimated dissipation is O(1) larger than that in the region away from internal tide generation location.
- Near the coast, where stratification is weak, the enhanced dissipation may be due to the bottom friction induced by barotropic or baroclinic currents.
- Large dissipation rate away from boundary is mainly associated with high-mode or a narrow beam-like internal tides.

Perspectives

- Computation of turbulent mixing rate
- Confirming relationship between strong mixing and internal tides/solitary waves.
- Test of fine-scale parameterization: indirect estimate and direct measurement of dissipation rate.

Merci !