Turbulent mixing and its relationship with internal tides in the Indonesian Throughflow as inferred from the INDOMIX cruise

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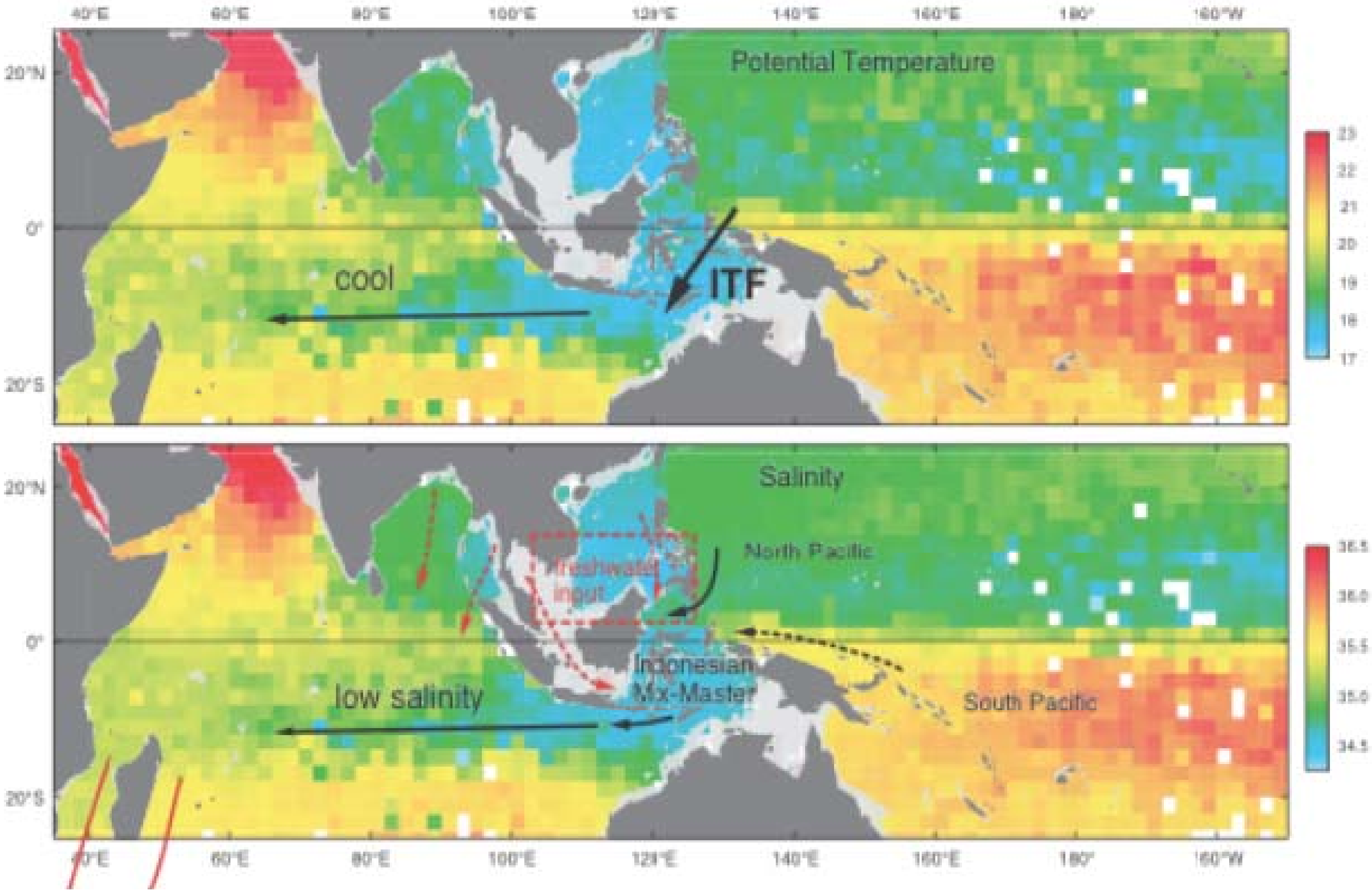
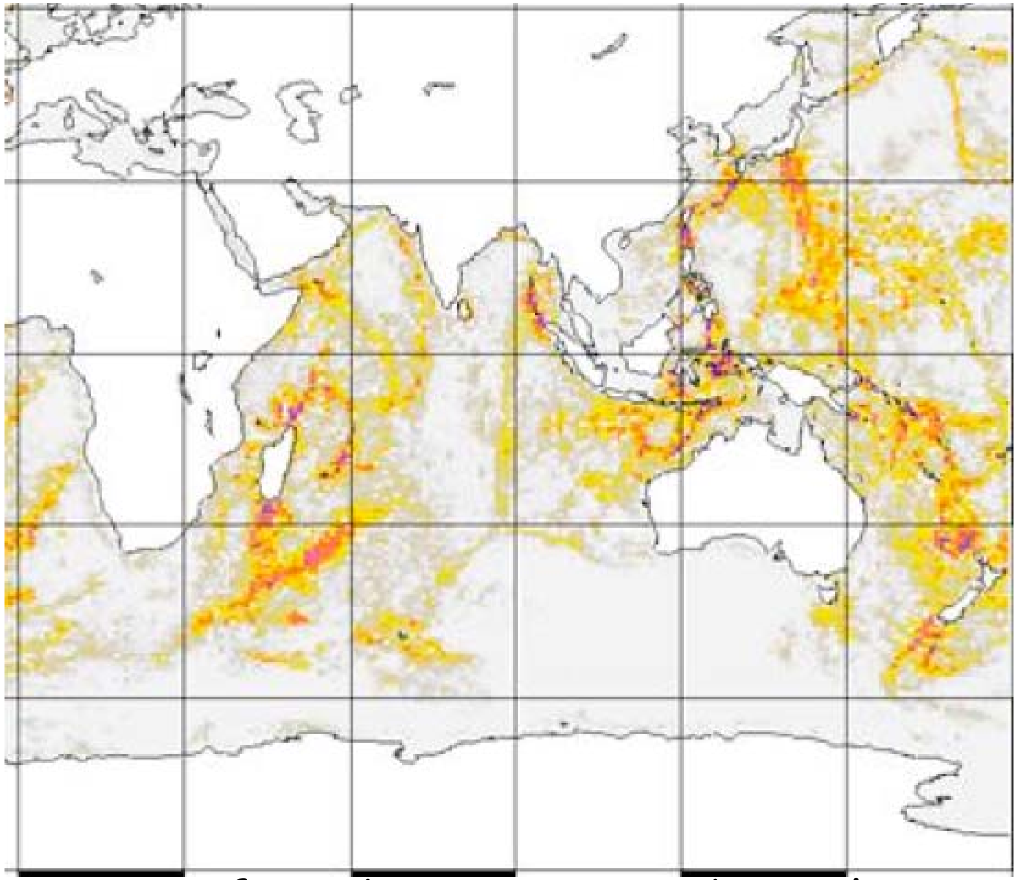
A region of intense watermass transformati...



Potential temperature and salinity along isopycnal σ=25.5 in the main thermocline (from Koch-Larrouy, 2007)

A region of strong internal tide generation

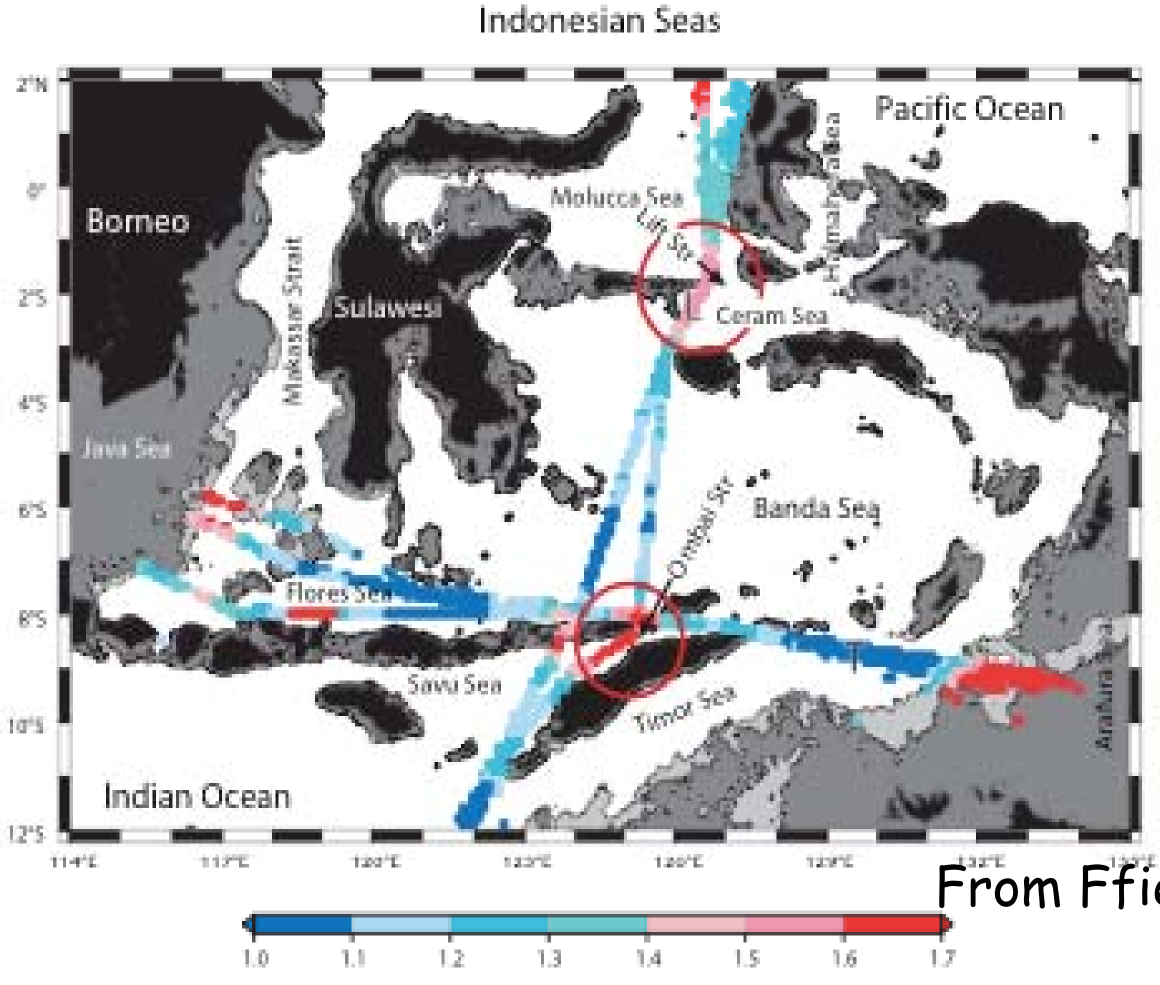


Power conversion from barotropic to baroclinic tides for M2
(Le Provost & Lyard, 2002)

⇒turbulent mixing induced by internal tides:
one main process responsible for watermass transformation?

Internal tidal mixing from in situ data

Indirect estimates from 21 years XBT sections



From Ffield et al (2005)

Finestructure, displayed in color, is an indicator of turbulent mixing

=> Locations of enhanced finestructure: straits & shelf-slope boundary

* Indonesian seas are a region of intense internal tides whic
induce turbulent mixing when they break

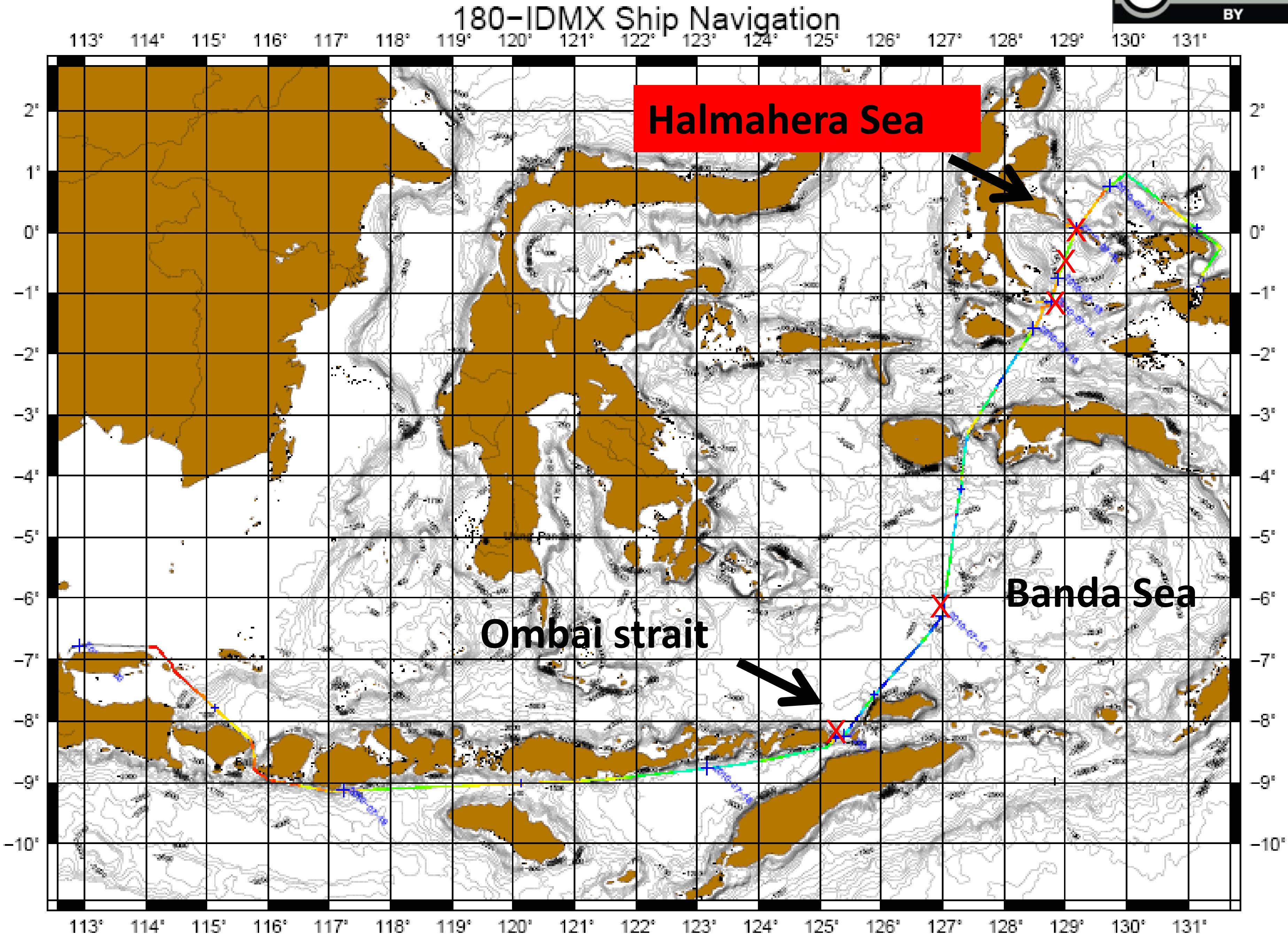
* Enhanced impact of internal tides since they break locally, Indonesian seas being almost enclosed

- However few measurements that enable to characterize internal tides and turbulent mixing

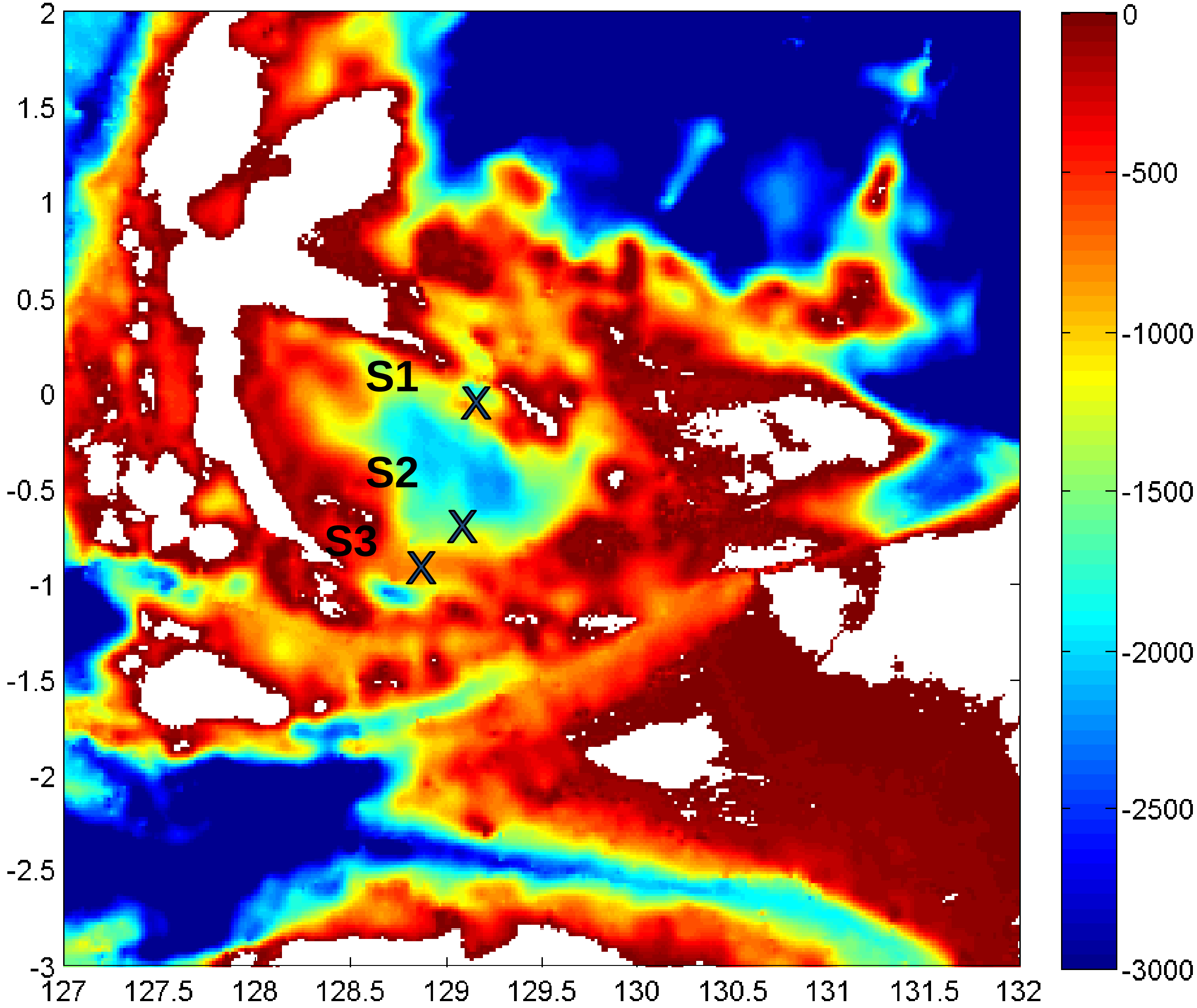
=> main objective of INDOMIX cruise (July 2010) on board Marion Dufresne

characterize internal tides and turbulence along one energetic section through Halmahera sea and Ombai strait

INDOMIX cruise

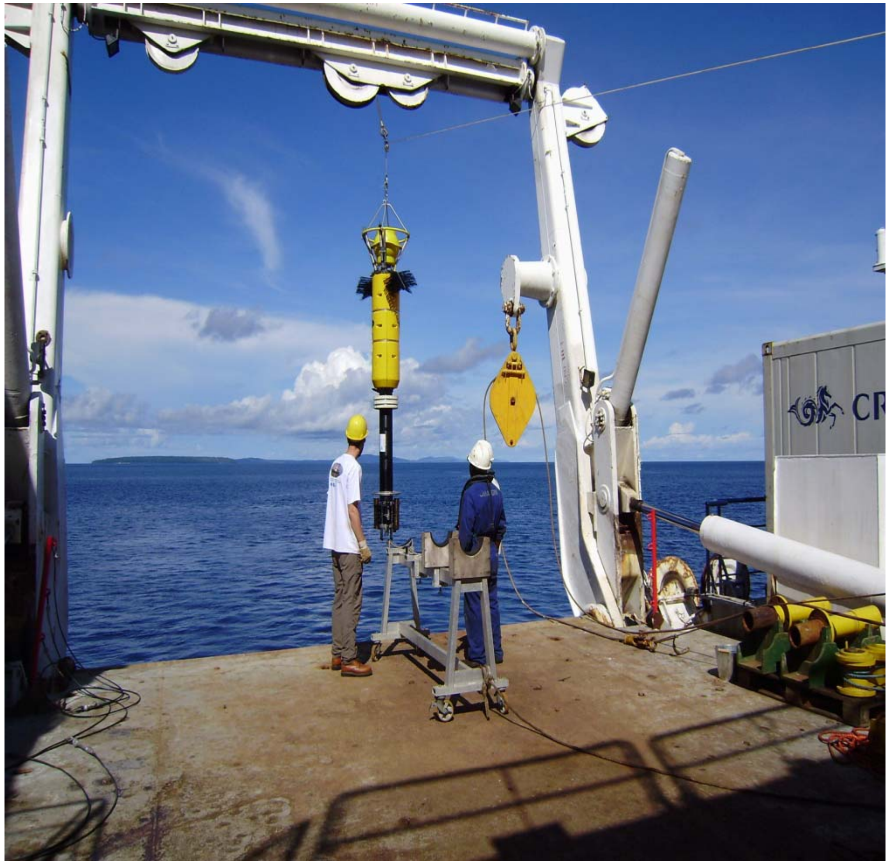


Focus on Halmahera Sea: 3 fixed point stations with microstructure measurements



Joint microstructure measurements and CTD/LADCP profiles during 2 M2 cycles

VMP6000- Velocity microstructure profiler



•Microstructure sensors:

temperature, vertical shear, conductivity

•Seabird sensors + pressure sensors

•Fall velocity U_{fall} ~0.5m/s

•Sensor time response:

-Shear and conductivity : 3 ms

-Temperature: 10 ms

=> Vertical resolution $\Delta x = U_{fall}\,\Delta t \approx$mm-cm

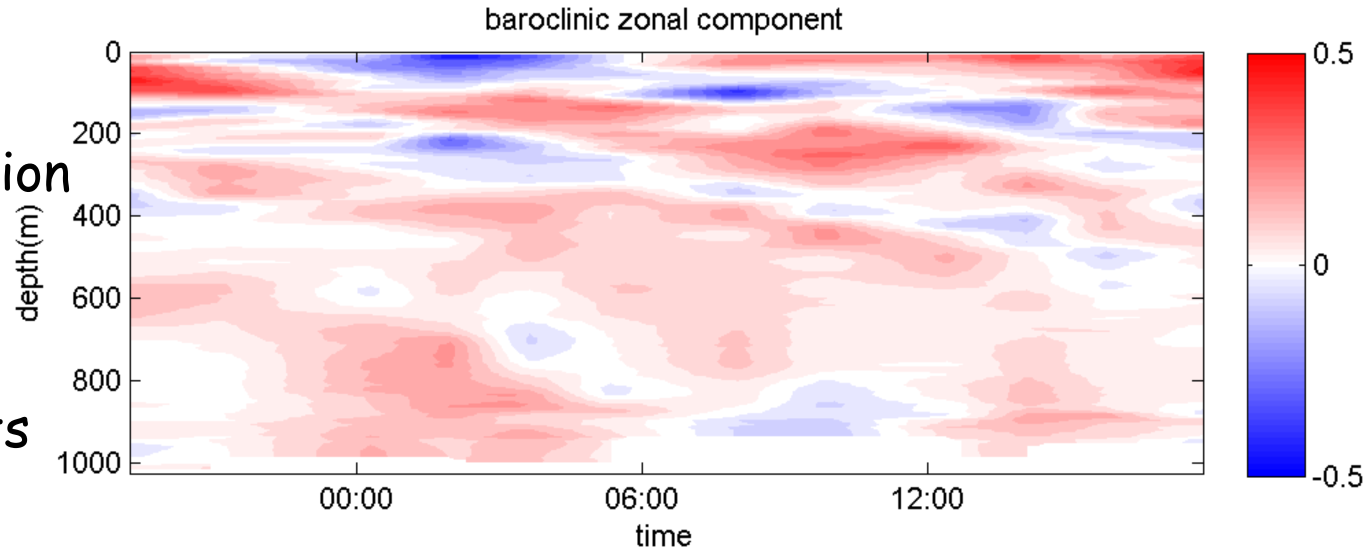
Kinetic energy dissipation inferred
from vertical wavenumber shear spectra

Figure 5: Sensor head of the MSS profiler. The microstructure sensors are standing in front of the other sensors. This arrangement guarantees undisturbed measurements of the micro-scale stratification and velocity fluctuations.

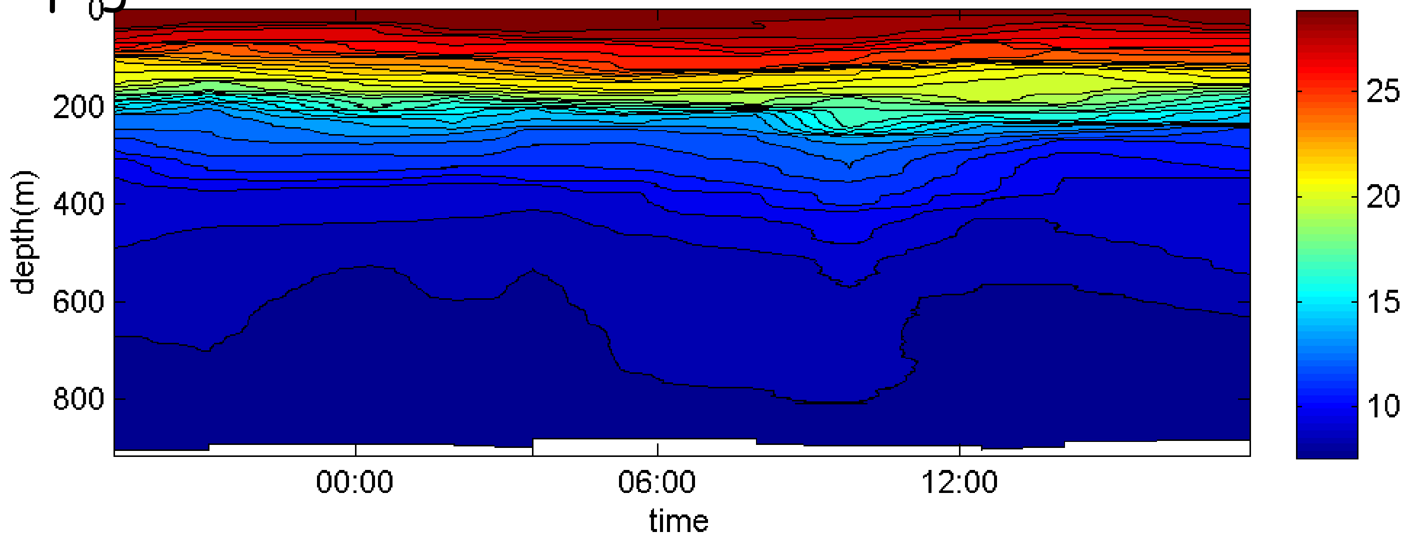
Station3: Overview of the dynamics

- Dominant
semi-diurnal oscillation

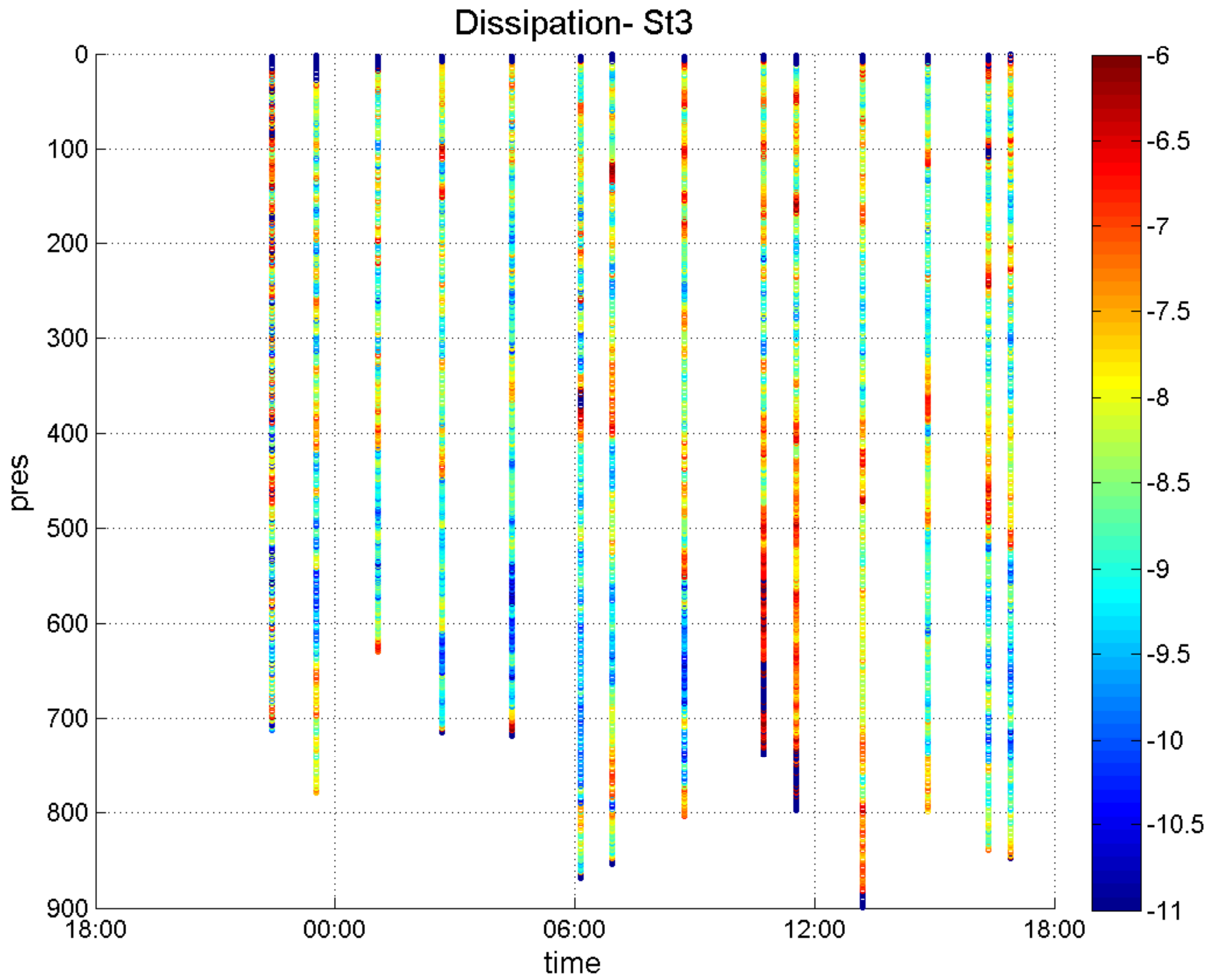
- Large amplitude:
~0.5m/s
~100m displacements
at depth



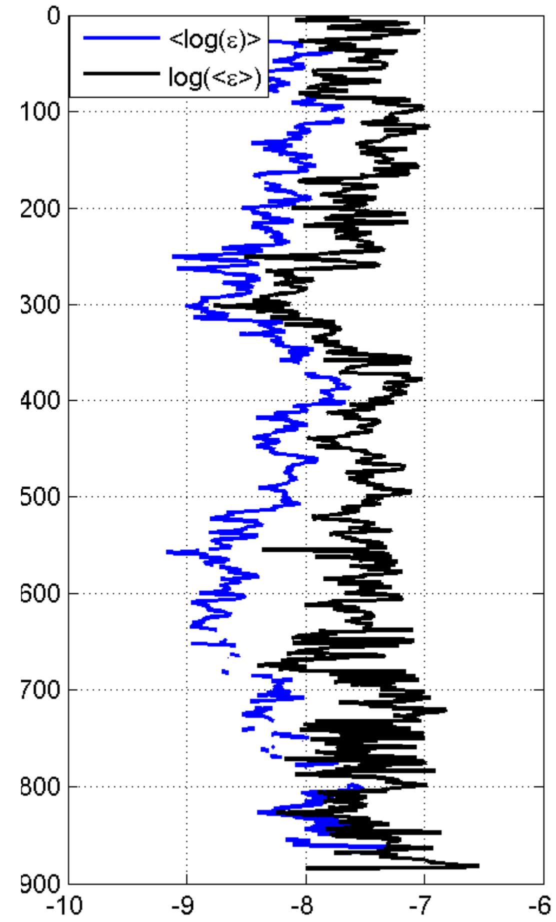
- Downard phase propagation



Kinetic energy dissipation at Station 3



Mean pro

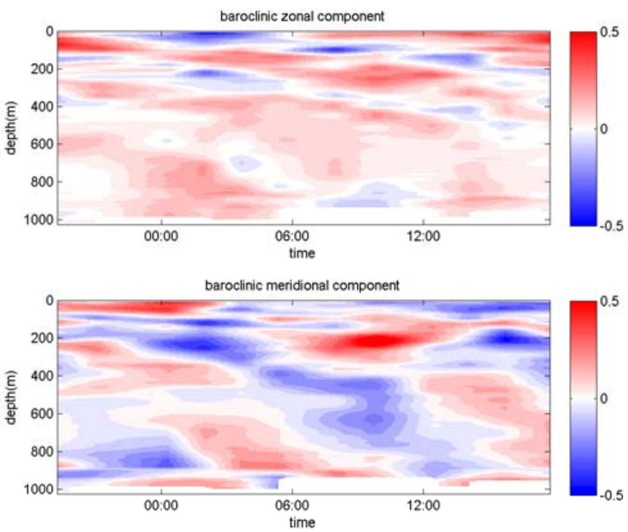


➢ Spots of strong dissipation in the interior, enhanced dissipation in the bottom boundary layer;

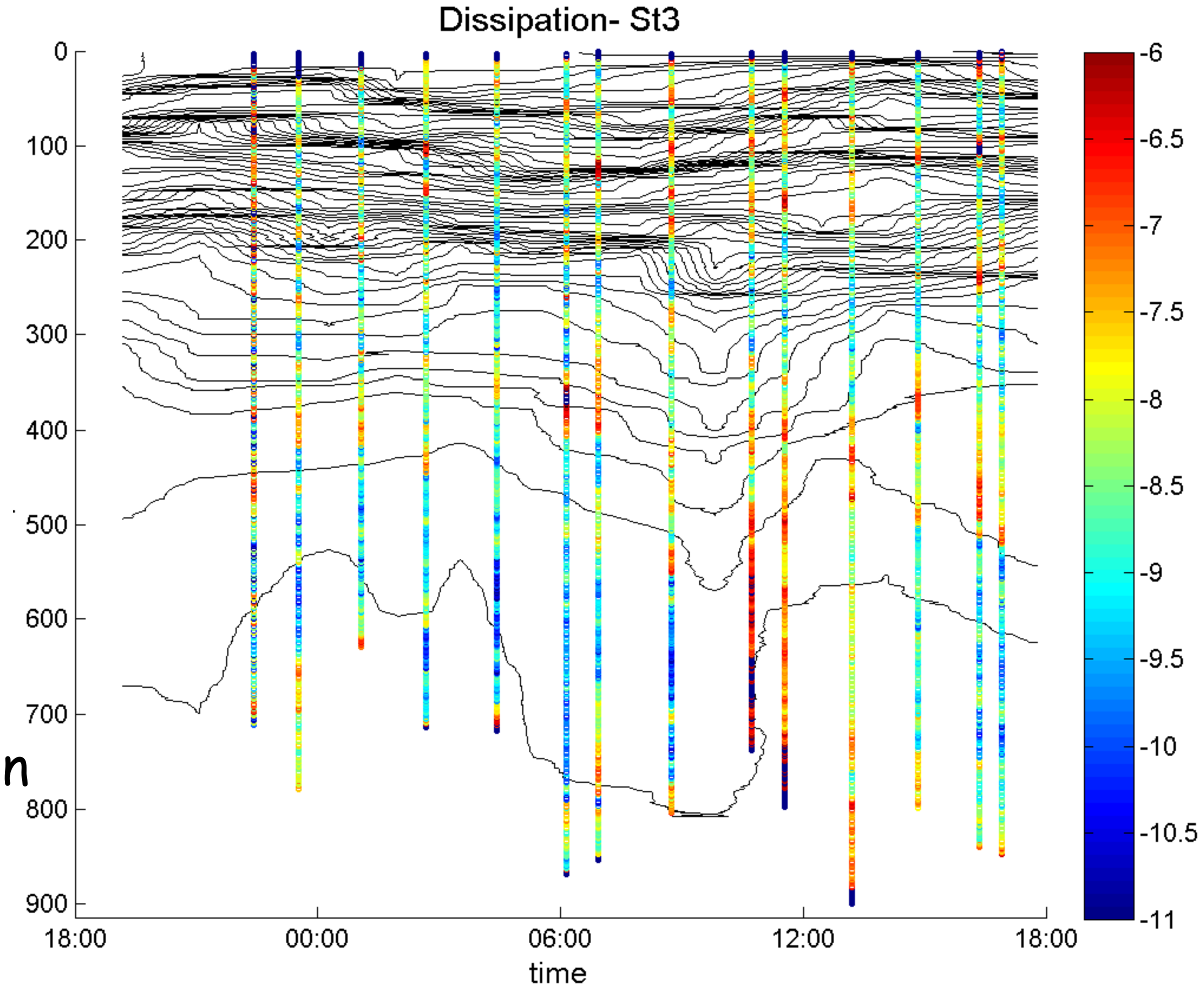
➢ Averaged values within [1.5 10^-9;2.8 10^-7]W/kg

Correlation between strong dissipation & internal t (Station 3)

Baroclinic current with evidence of semi-diurnal internal tides



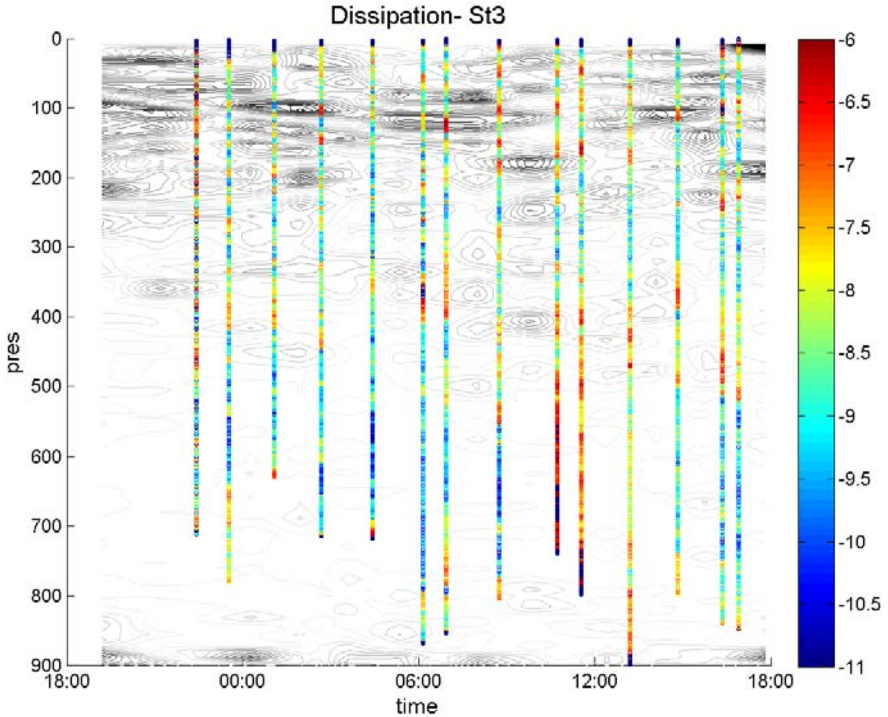
Dissipation with isotherms superimposed



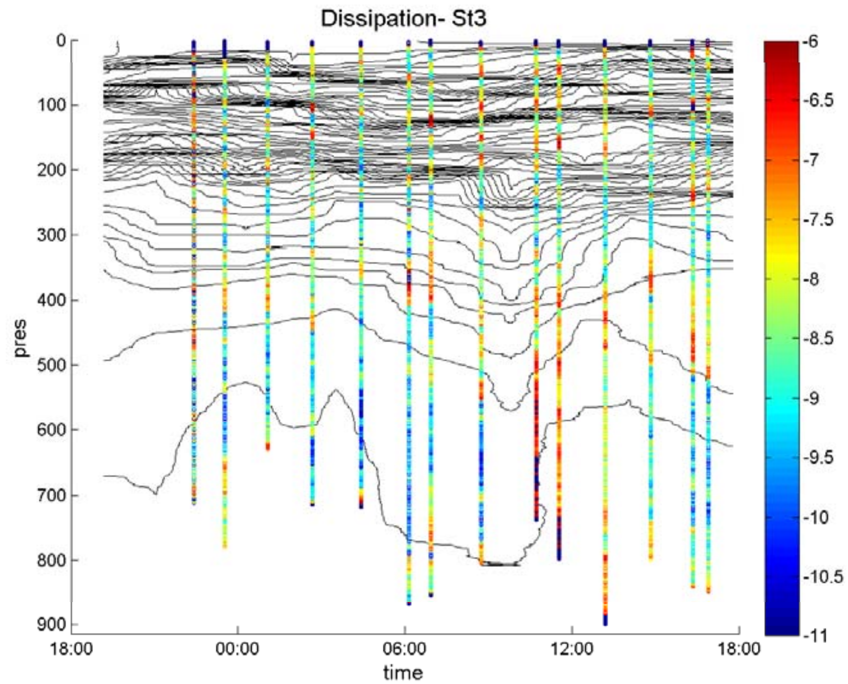
➢Spots of strong dissipation / internal tide and solitary wave

Evidence of strong internal tides and dissipation in Halmahera s

Dissipation with shear superimposed



Dissipation
with isotherms superimposed

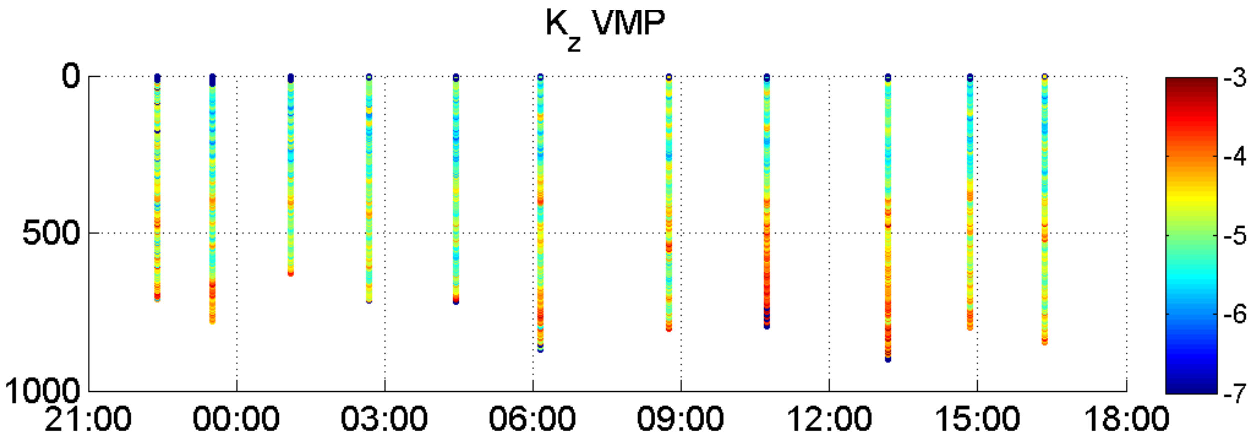


- ➢ dissipation/ strong shear ~[100m- 200m]
- ➢Deeper: strong correlation between isotherm displacement and dissipation

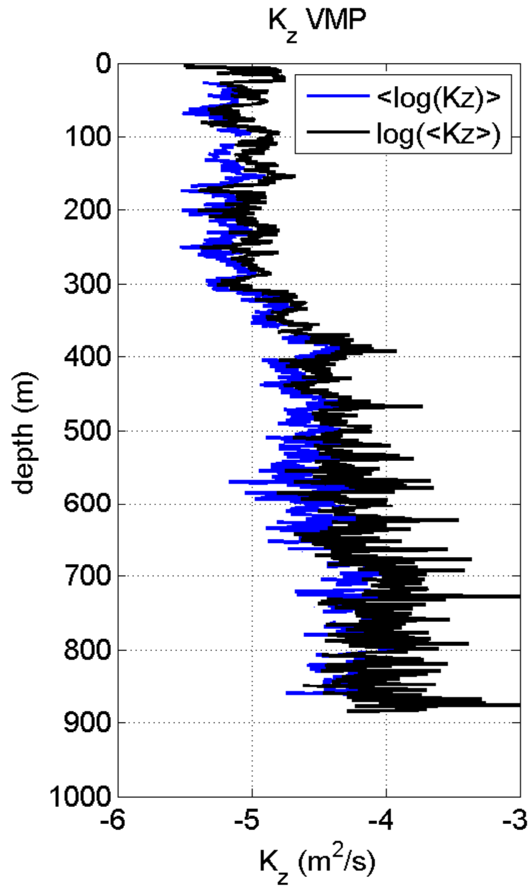
Turbulent diffusion coefficient -Station 3-

Shih et al (2005) relationship – valid for strongly turbulent regimes
- $\varepsilon/(\nu N^2) > 100$

$$K_\rho = \nu\left(\frac{\varepsilon}{\nu N^2}\right)^{\frac{1}{2}}$$



Mean profile



- Averaged values within [4.10^-6; 5.10^-4]m^2/s
- Increasing with depth

Station2: Overview of the dynamics

- Dominant semi-diurnal oscillation in the upper 500m only

- Still large amplitude: up to ~0.4m/s

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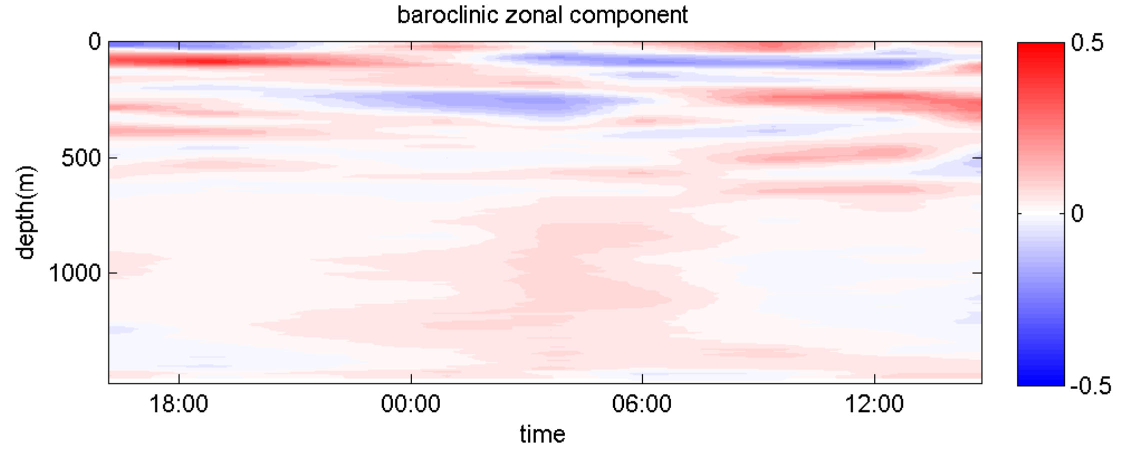
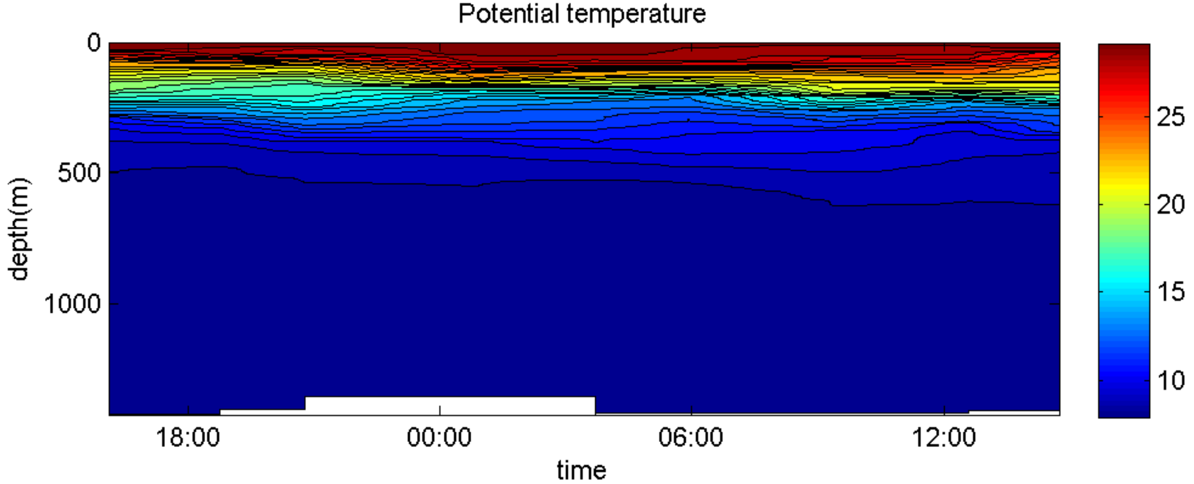
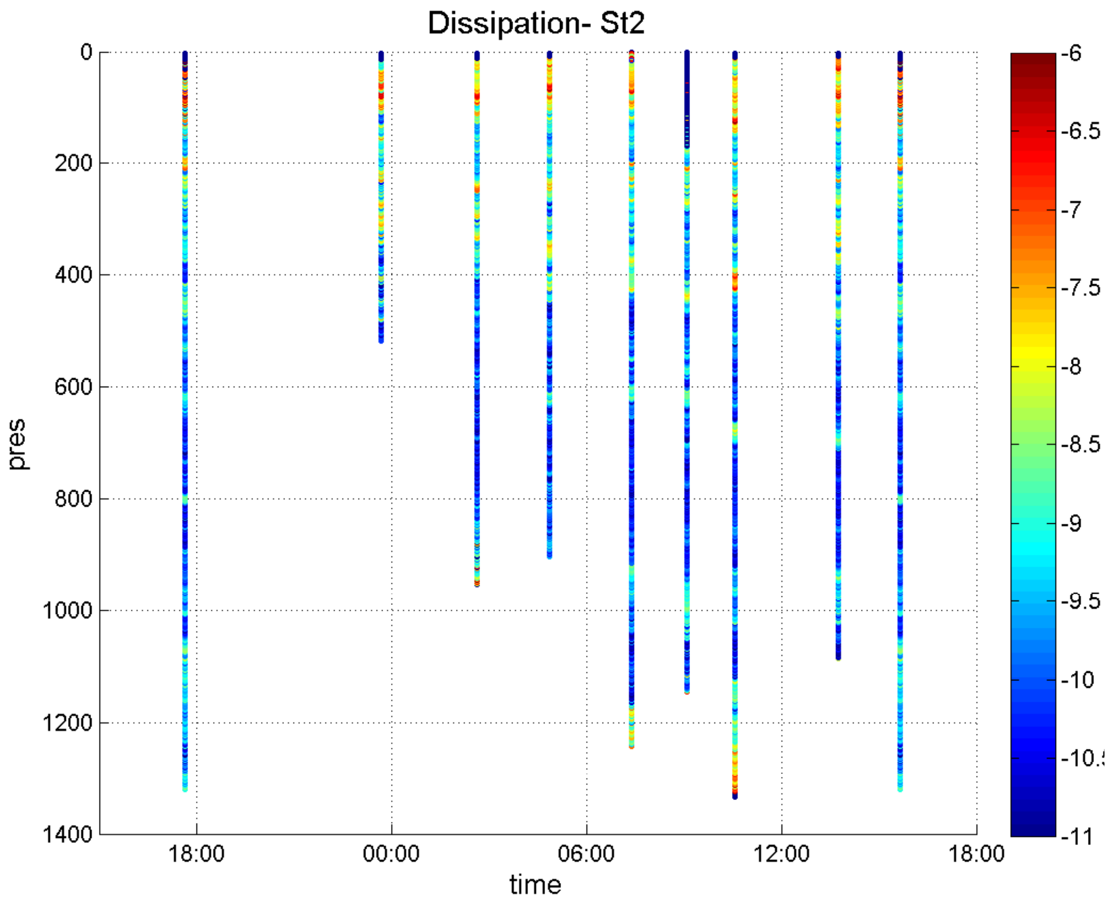
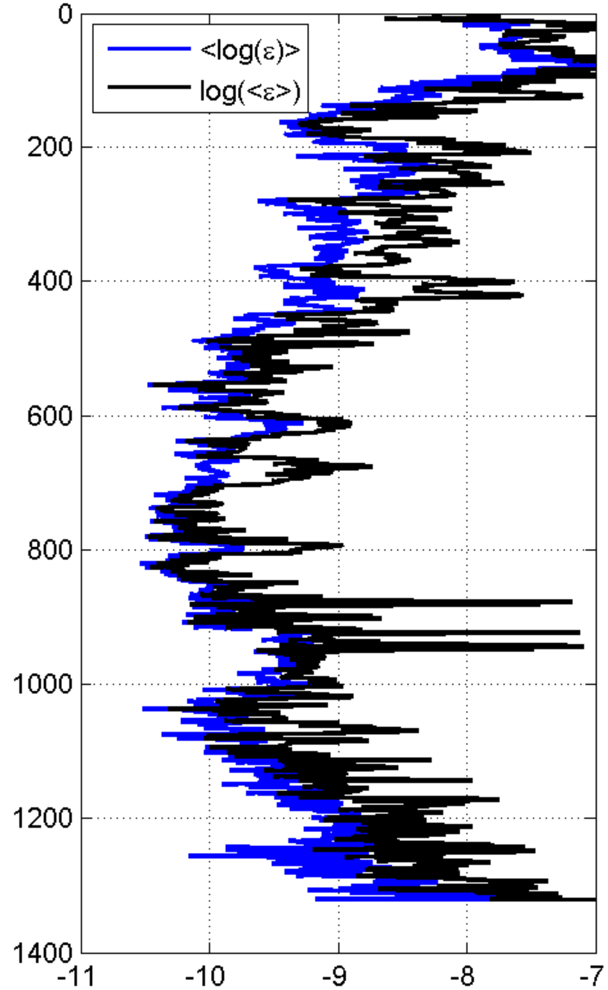




Kinetic energy dissipation at Station 2



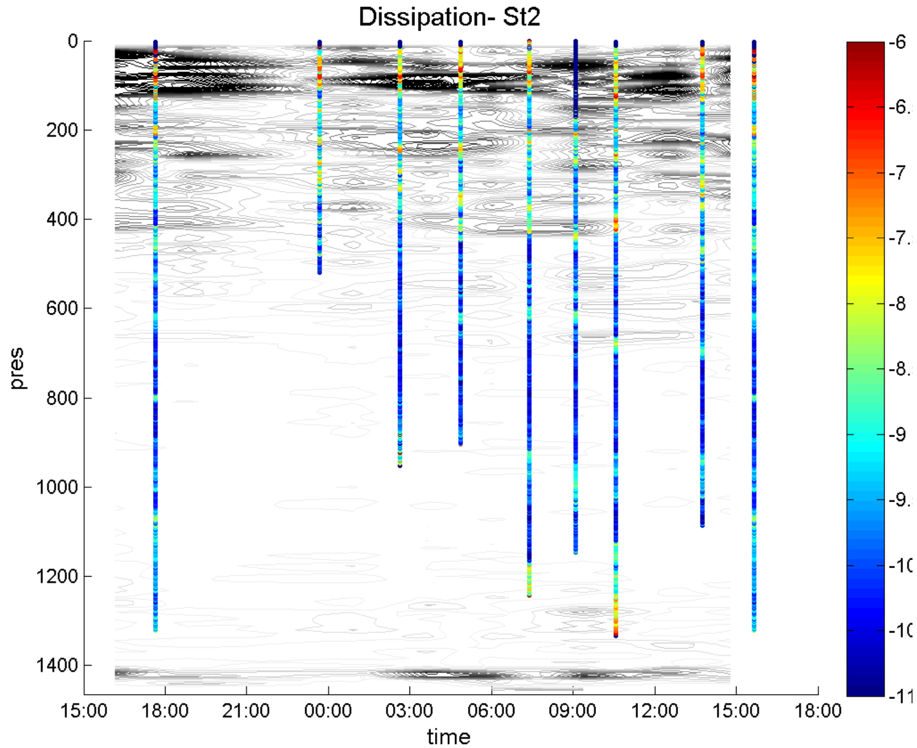
Mean pro



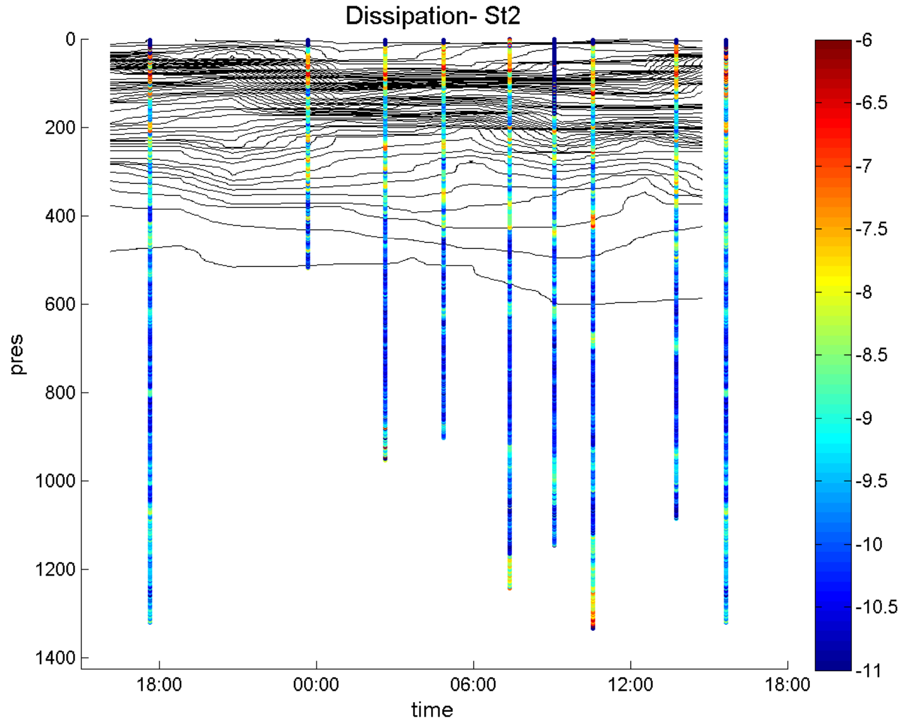
- Spots of strong dissipation in the upper ocean
- Increase in dissipation above the bottom
- Smaller values within [5 10^-10; 10^-7]W/kg

Internal tides and dissipation in Halmahera sea (st. 2)

Dissipation with shear superimposed



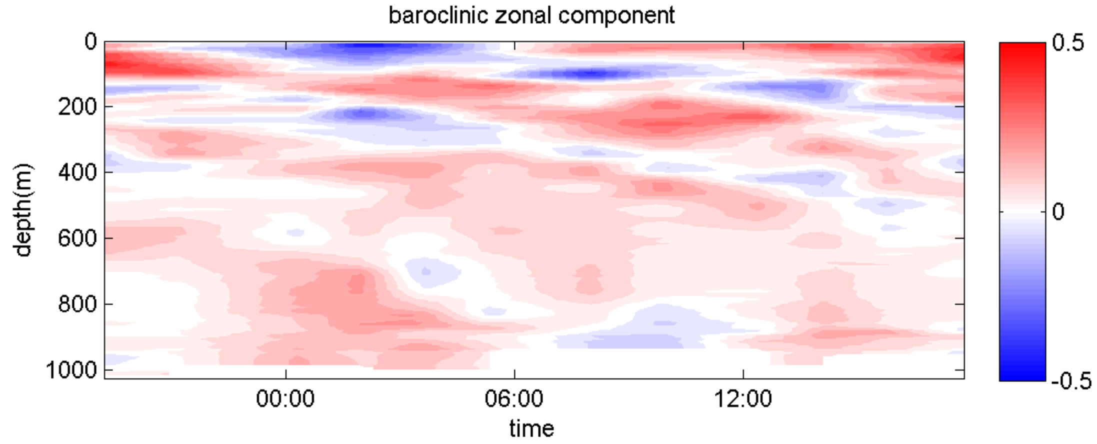
Dissipation
with isotherms superimposed



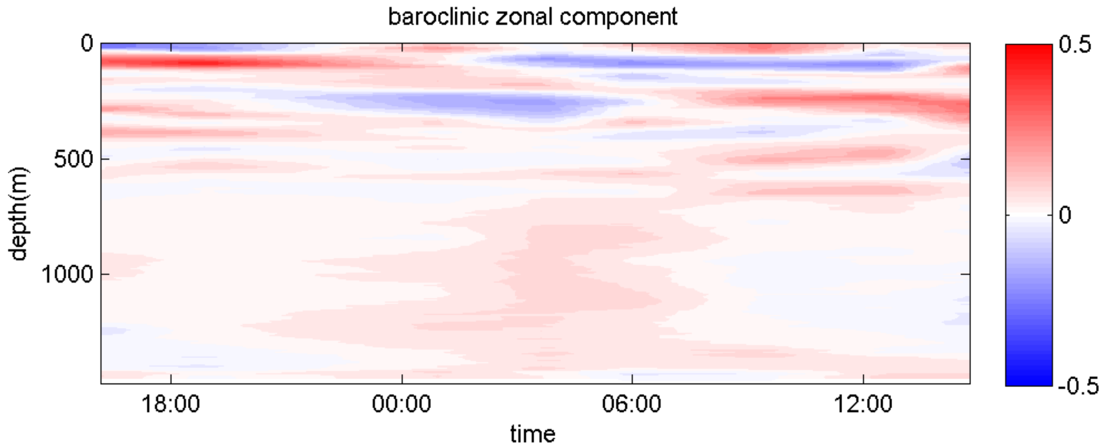
➢ a few spots of high dissipation values/ strong shear ~[100m- 400m]

Contrasts between Stations 2 and 3

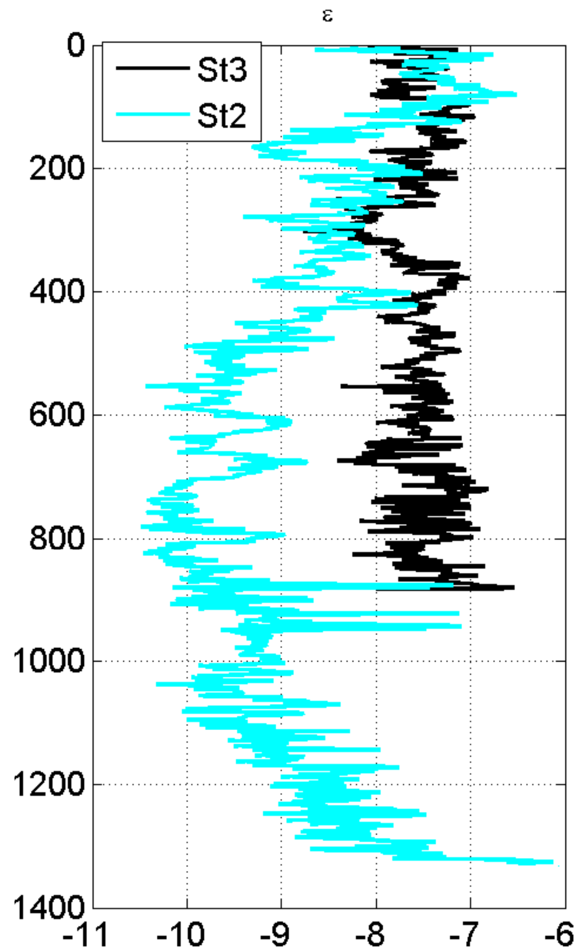
St.3



St.2



Dissipation



- Strong internal tides responsible for an increase in dissipation of 2 orders of magnitude

Summary of preliminary results and further analyses

- Strong internal tides in Halmahera sea with a dominant semi-diurnal component,
Nonlinear dynamics leading in some cases to the formation of solitary waves
Further analysis required: mechanism of formation of these waves

- Contrasts in internal tide energy between regions over straits and shelf slope and deeper regions (cf Stations 3 and 2)
Determination of energy fluxes at the different stations required for further interpretation

- Strong dissipation, [10^-8,10^-7]W/kg, associated with the internal tide signal

- Parameterization to be inferred: tests of fine-scale parameterizations and scaling under present investigation

- Idealized numerical simulations over S1-S3 section

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