

Contrasts in turbulent vertical fluxes of nutrients across the permanent Lofoten Basin Eddy in the Nordic Seas

EGU - General Assembly

Session OS1.3 – The ocean surface mixed layer: multi-scale dynamics and ecosystems in a changing climate

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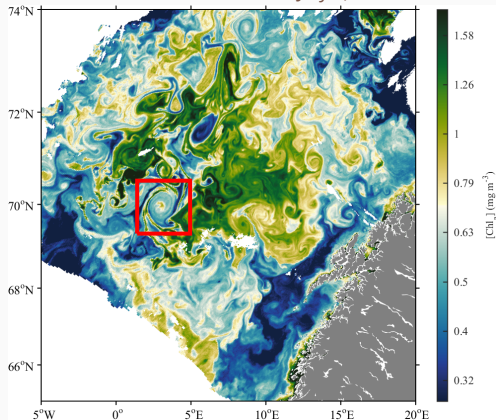
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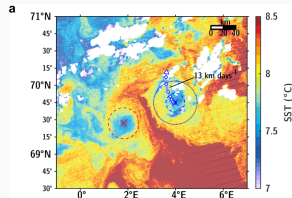


The Lofoten Basin of the Nordic Seas

L2 MODIS at 1 km on July 7, 2005



- Intense mesoscale activity (10-50 km) in the Lofoten Basin
- controls heat/salt exchanges between N/S and slope/open-ocean

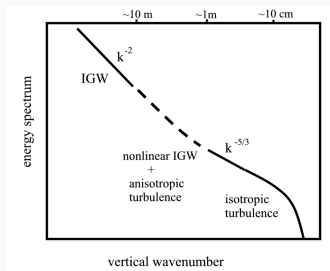
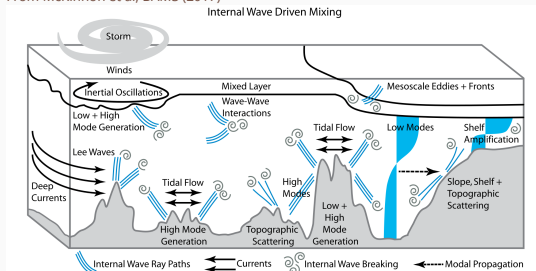


- **Permanent anticyclone (LBE)** Yu et al (2017), Fer et al (2018), Bosse et al, Sci Rep (2019)
- Strong **interaction** between LBE and mesoscale eddies
- LBE traps NIW : enhance mixing at the bottom Fer et al, 2018

⇒ How does the LBE influence turbulence near the surface?

Measuring turbulence: how to and what for?

From McKinnon et al, BAMS (2017)

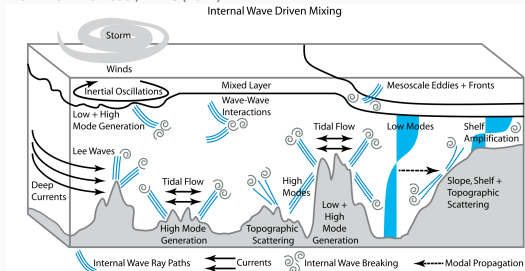


Energy cascade in the ocean:

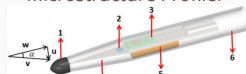
Dissipation at centimetric scale, where viscous effects transforms KE into heat.

Measuring turbulence: how to and what for?

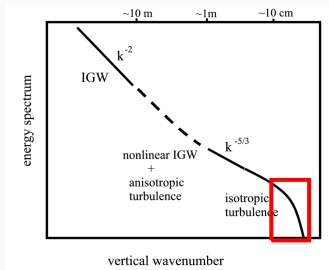
From McKinnon et al, BAMS (2017)



Microstructure Profiler



1. Nylon sensing head
2. piezoresistive sensor chip
3. printed circuit board
4. triangle cantilever beam
5. half-cylinder gasket
6. stainless steel shell



Energy cascade in the ocean:

Dissipation at centimetric scale, where viscous effects transforms KE into heat.

Oxborn-Cox model:

Measure of dissipation rate ϵ allows to quantify vertical diffusivity: $K_z = \epsilon N^{-2}$.

[The mixing efficiency Γ is classically considered as 0.2

Parametrization by Bouffard and Boegman, DAO (2013) is here used]

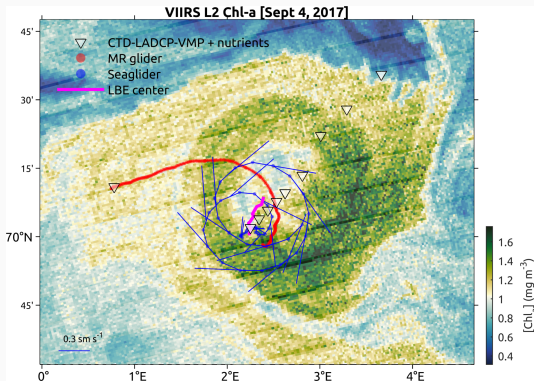
Dissipation of energy at microscale

Microstructure turbulence

▷ Quantify the role of **small-scale mixing to vertical transfers** (nutrients, heat, ...) and its modulation by mesoscale structures.

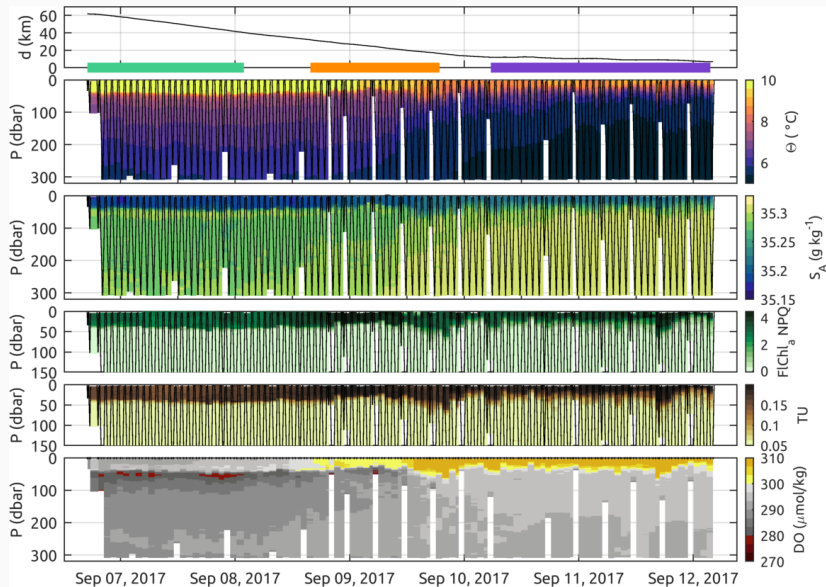


Microrider mounted on Slocum glider

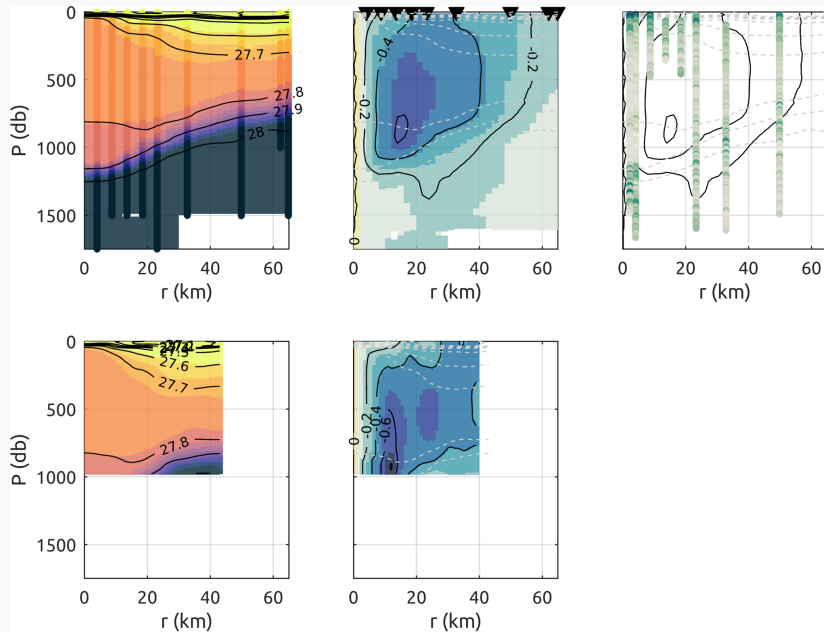


5-day, 212 profiles 0–300m (with Microrider) + CTD/VMP/LADCP (" nutrients)

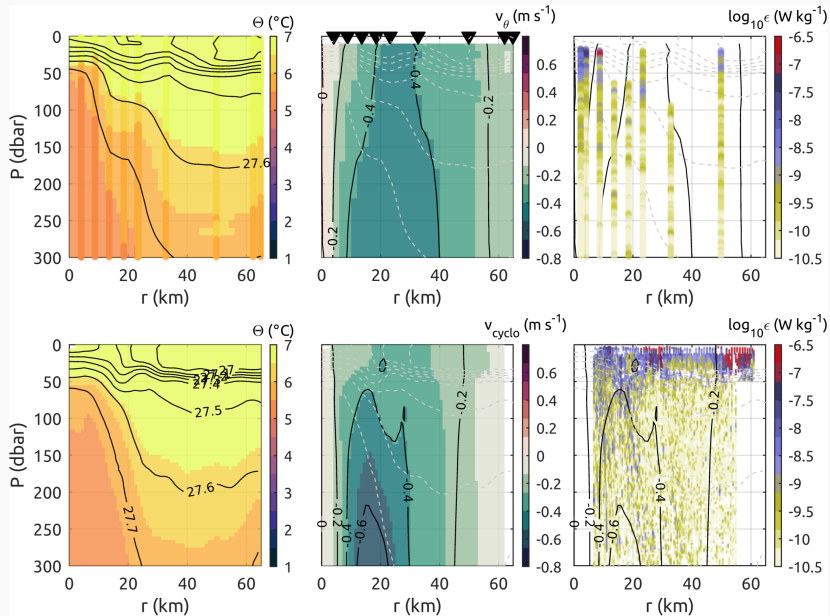
Slocum glider mission



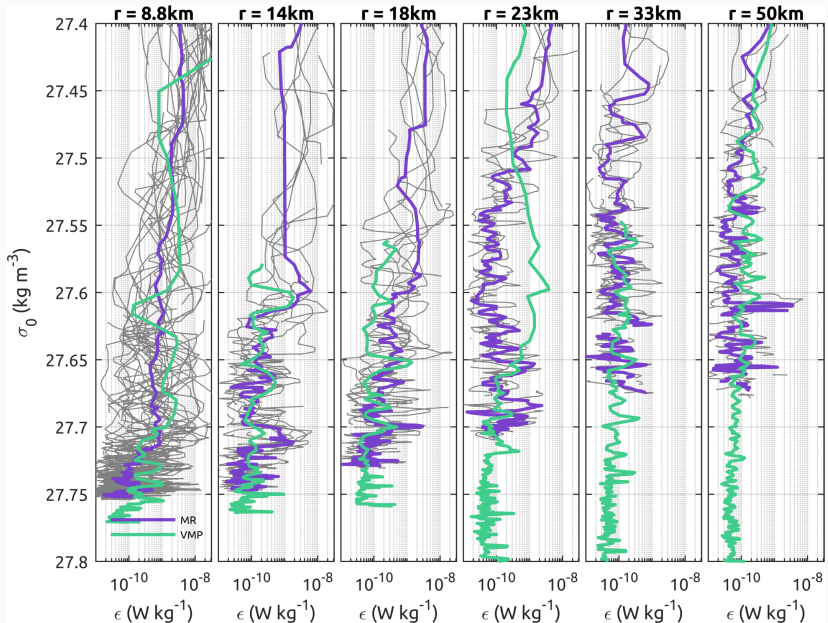
Dissipation rate of TKE



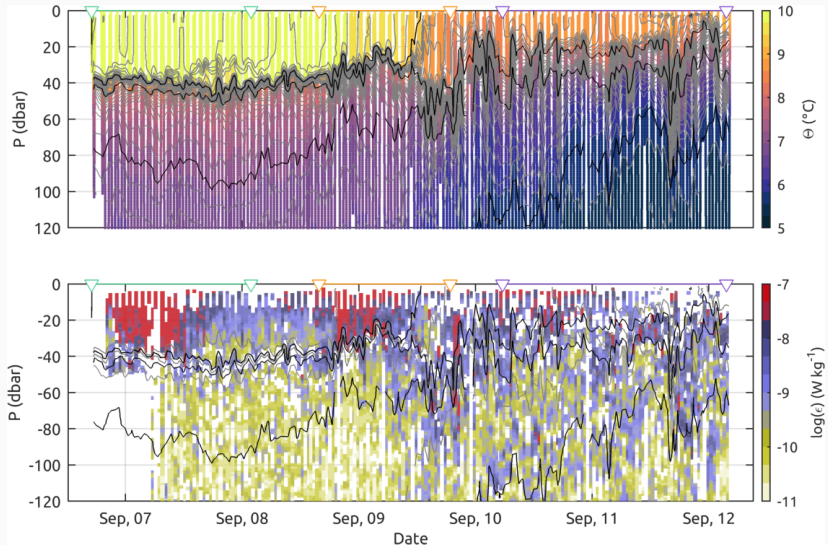
Dissipation rate of TKE



Turbulence : Microrider vs VMP

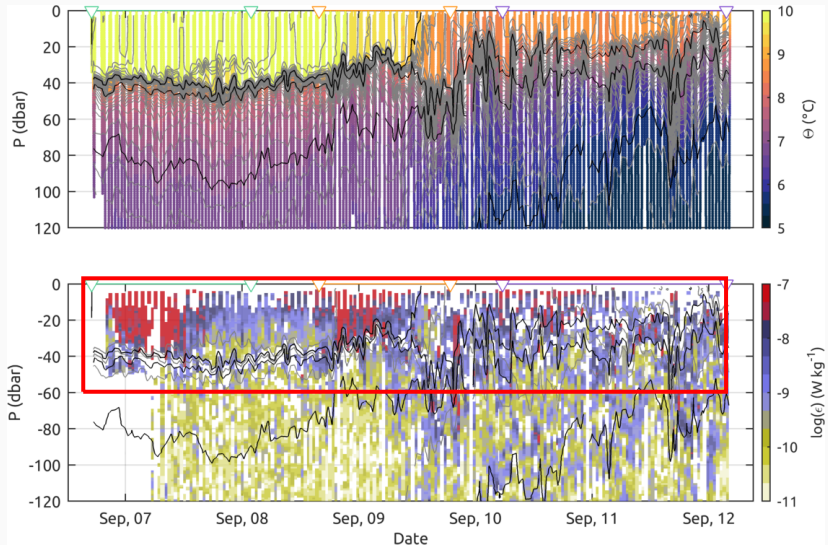


Dissipation rate of TKE (surface zoom)



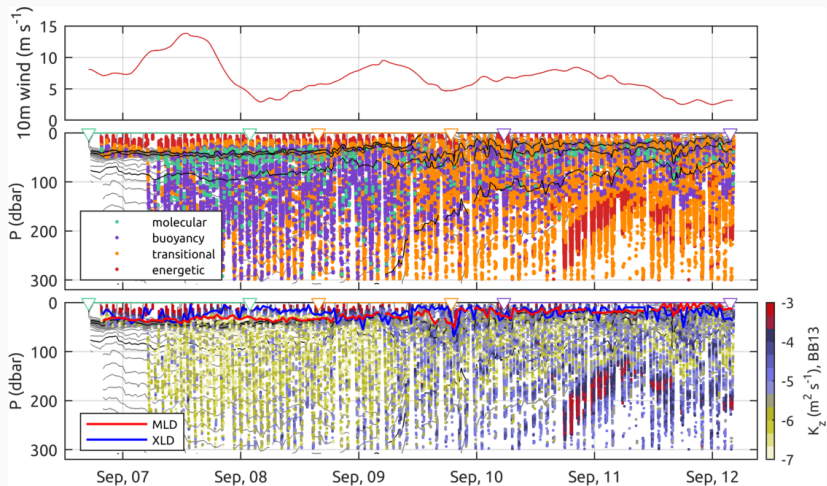
Important variability of ϵ in the surface layer
Isopycnal outcropping at the rim, large displacements in the core

Dissipation rate of TKE (surface zoom)



Important **variability** of ϵ in the surface layer
Isopycnal **outcropping** at the rim, **large displacements** in the core

Vertical diffusivity K_z

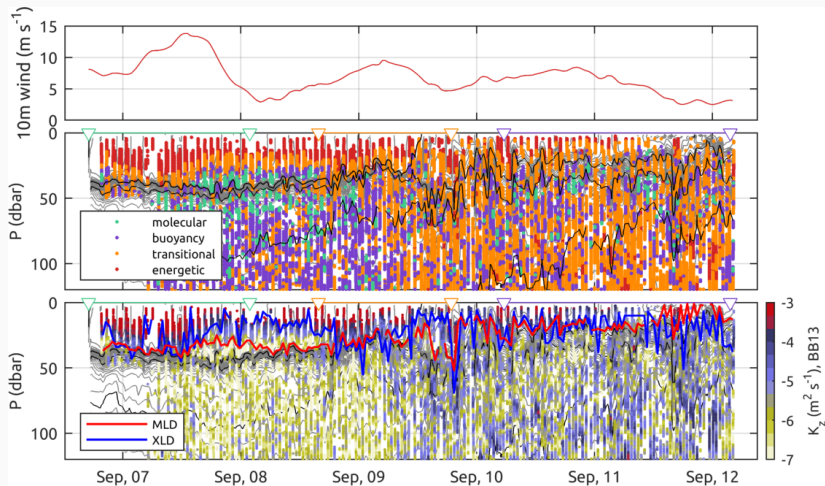


Winds : from $\sim 30\text{kn}$ to calm conditions (wind from ERA5 re-analysis)

Mixing regimes defined from Bouffard and Boegman (2013)

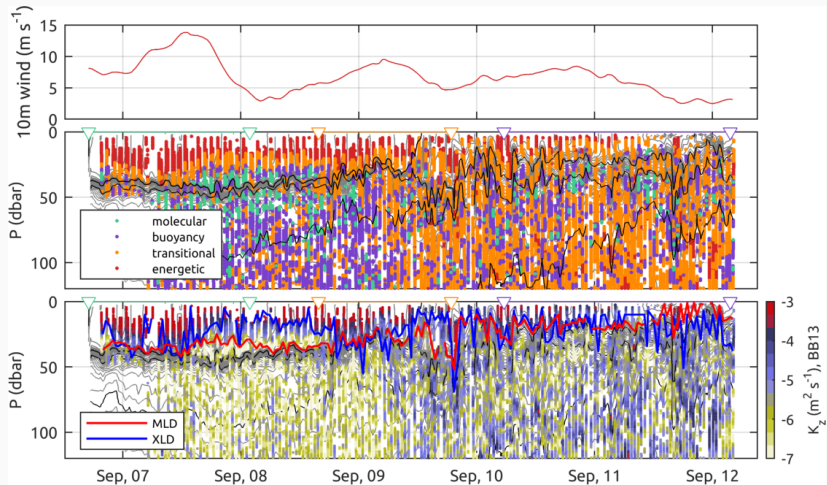
→ more turbulence below $< 100\text{ m}$ in LBE

Vertical diffusivity K_z (surface zoom)



Mixed layer does not match layer of active mixing under calm conditions. (MLD from 0.03 kg m^{-3} density criterion, XLD where $\epsilon < 3 \cdot 10^{-9} \text{W kg}^{-1}$)

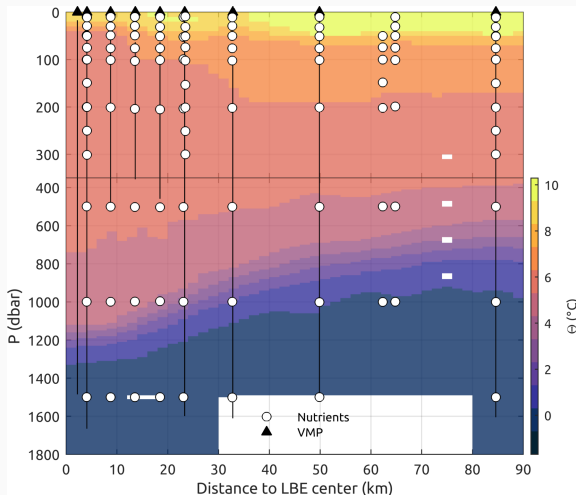
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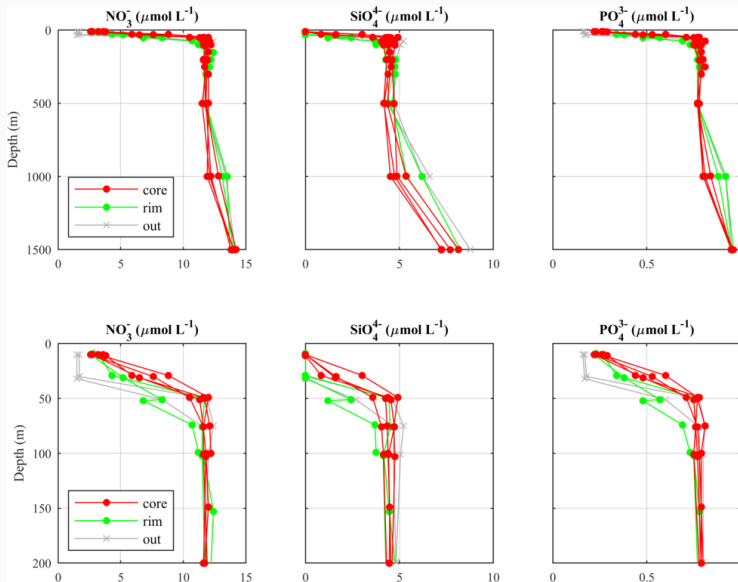
$$\text{Turbulent vertical fluxes of nutrients: } F = K_z \partial_z C$$

Nutrients sampling across the LBE



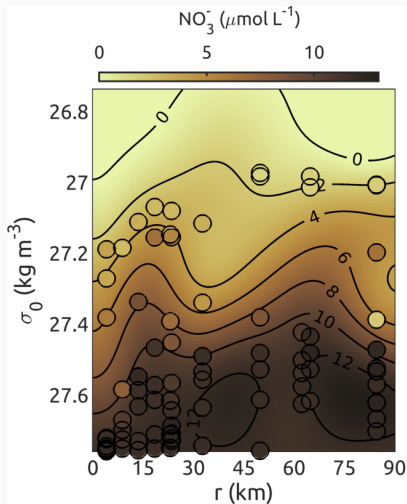
- Nutrients (Nitrate, Phosphate, Silicate) @ stations across the LBE
- Samples every 25m in the top 100m to resolve the nutriclines

Nutrients samples



Lower concentration at depth and shallower nutriclines in the LBE core.

Reconstruction of nutrient distribution

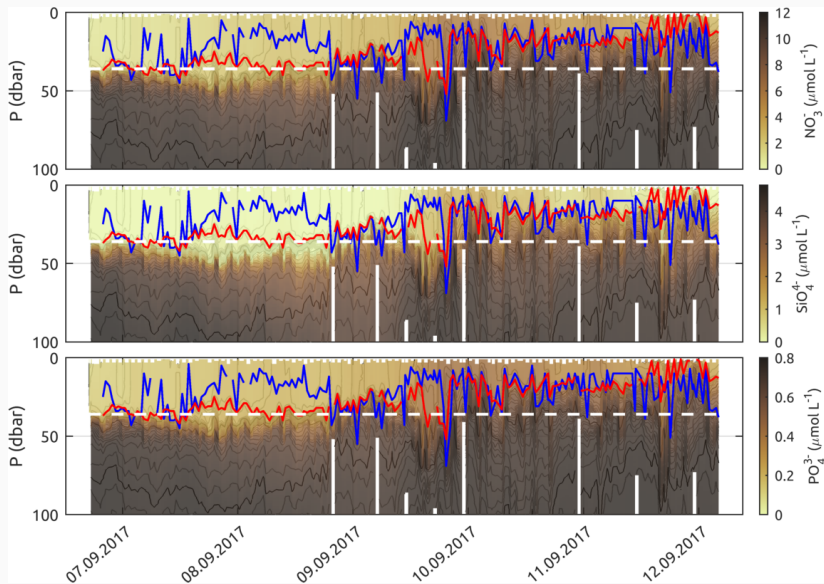


→ Optimal interpolation of nutrients samples on σ levels

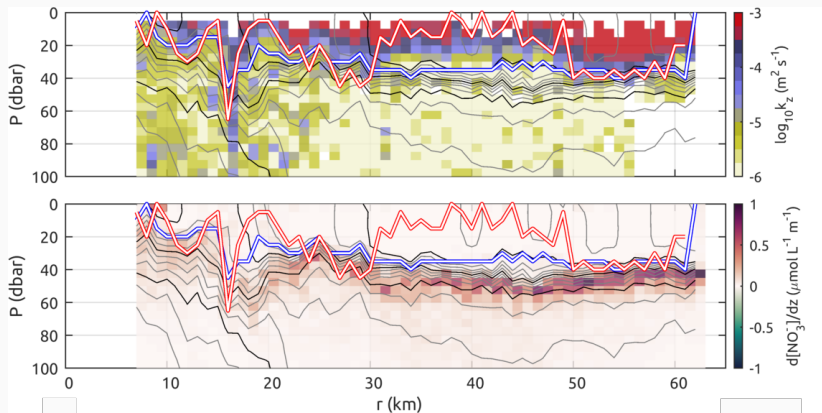
→ $[C] = f(\sigma_0, r)$

C inferred from σ_0 and r

Nutrient distribution

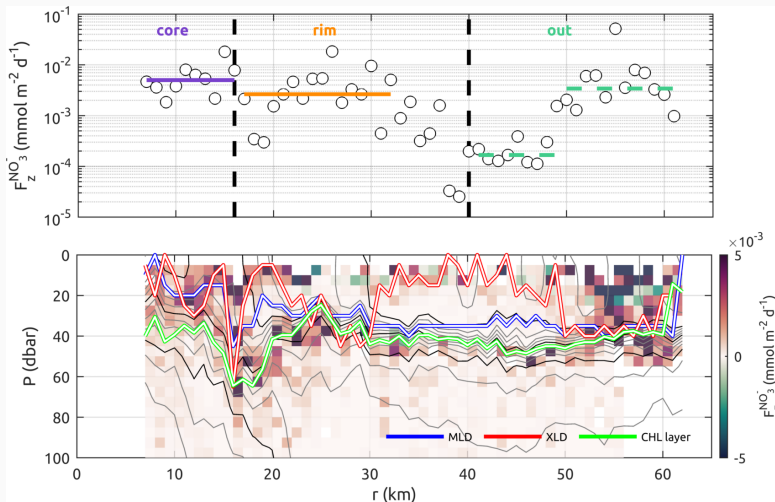


Diffusivity, gradients and fluxes



- Near-surface k_z enhanced during strong winds ($r > 50\text{km}$)
- XLD and MLD different during calm periods, except in LBE
- k_z varies sharply outside LBE, higher values inside LBE at depth
 - Nutriclines sharper outside LBE
 - Nutriclines more diffuse and closer to surface in LBE

Turbulent fluxes into the mixed layer



- Fluxes are of same order of magnitude, but in different layers (closer to surface inside LBE)
- ⇒ Vertical turbulent nutrient fluxes across the ML (core and rim) = $O(10 \times)$ outside during calm period (wind < 10 m/s)

Conclusion and perspectives

Take home:

- ▶ Turbulent nutrients fluxes are **one order of magnitude higher in the LBE** (after a wind event)
- ▶ The response of **turbulent mixing to wind is strongly impacted by the mesoscale**

Further analysis:

- ▶ Assess other sources of nutrients fluxes in the LBE (vertical velocities, ...) and implications for primary production.
- ▶ Ship and L-ADCP to infer source of high dissipation.



Thanks for your attention!
Questions?