Submesoscale frontal processes at the margin of a deep convection area: a case study in the NW Mediterranean Sea

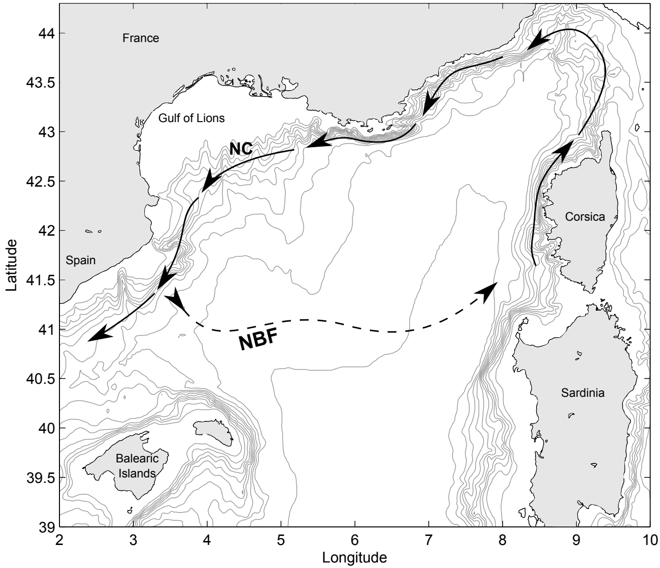
Anthony Bosse[1], P. Testor[1], L. Mortier[2],
P. Damien[3], C. Estournel[3], P. Marsaleix[3], L. Prieur[4]

[1] LOCEAN-IPSL, Paris, [2] ENSTA-Paristech, Palaiseau, [3] LA, Toulouse, [4] LOV, Villefranche/mer

EGO Cost action final symposium, Kiel, 16–17 juin 2014

Plan

Mean oceanic circulation of the NWMED:



Basin-scale cyclonic Gyre : Northern Current ∼ 1–2 Sv + North Balearic Front (high variability)

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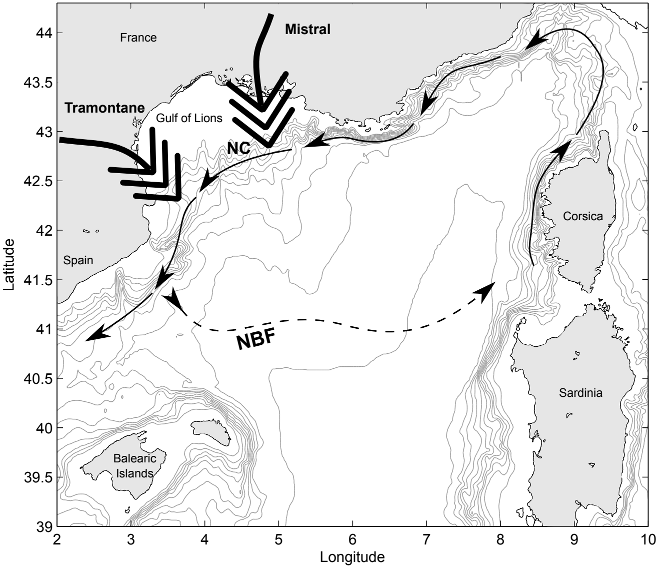

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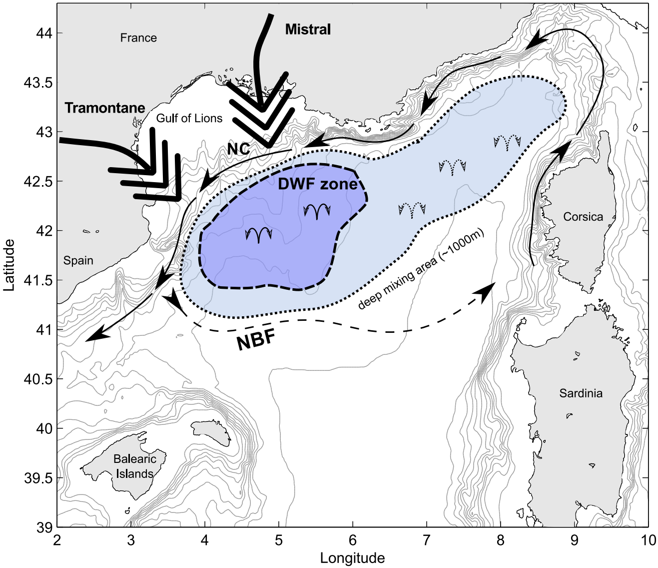

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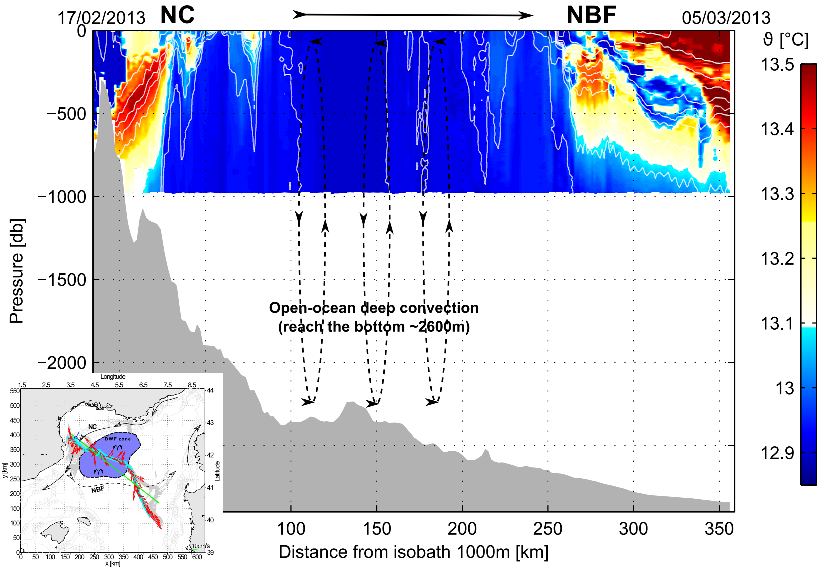
Vertical mixing can reach the bottom in the Gulf of Lions.

Open-ocean deep convection:



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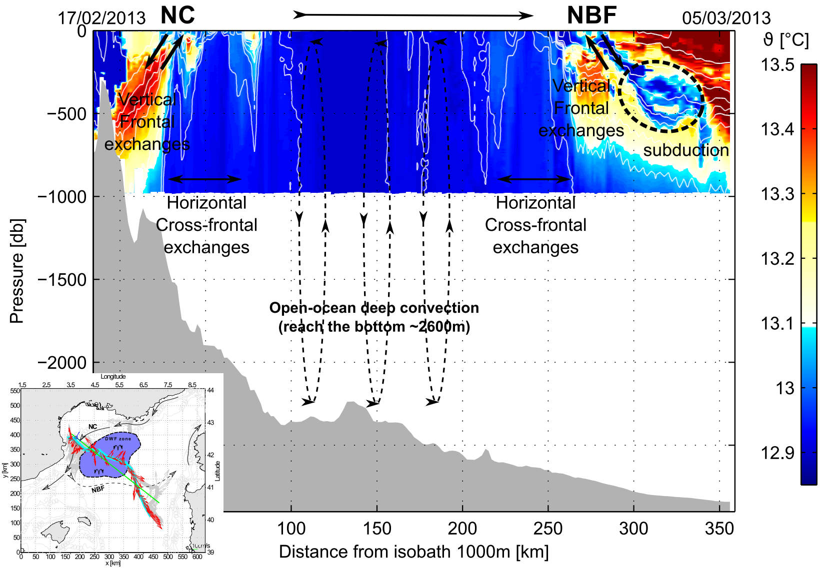

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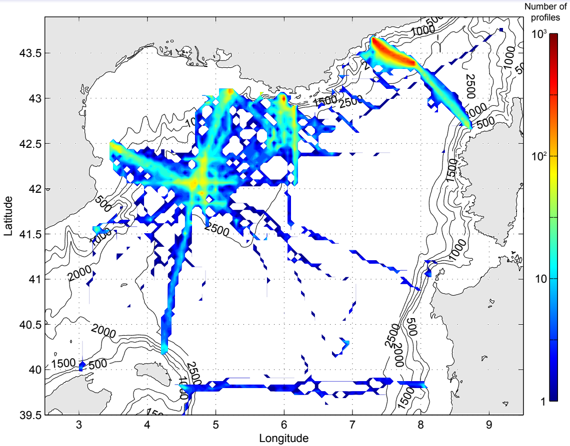
- > 90 deployments, > 25000 profiles down to 1000m)



- in the framework of european (MERSEA, PERSEUS, GROOM, TOSCA) and national projects (DOCONUG (UK), LIVINGSTONE (ANR, Fr), PABO (ANR, Fr), REI glider (DGA, France), IMEDIA (Fr), MOOSE - NW Med Observatory, INSU-ALLENVI, Fr since 2010).

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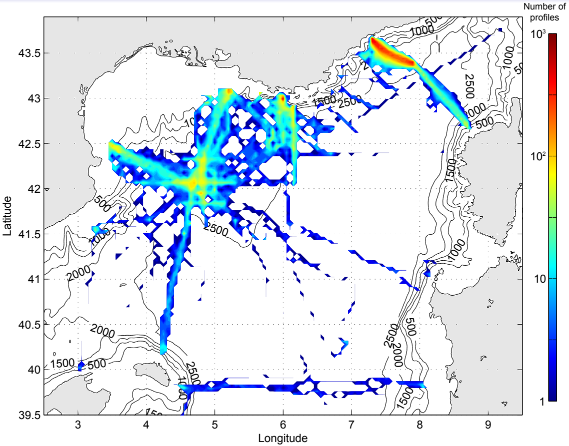
What can we learn from gliders about submesoscale frontal processes occurring at the margin of the deep convection area?



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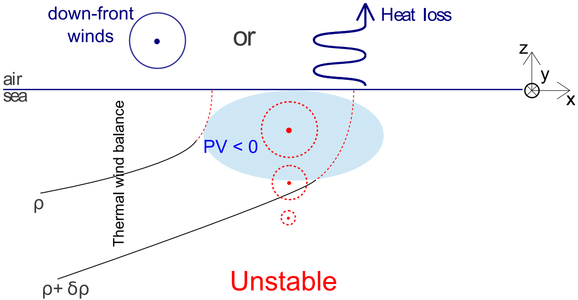
Mechanism of SI:

Definition: A fluid parcel with Potential Vorticity of opposite sign of the Coriolis parameter (<0 in the Northern Hemisphere) is unstable to along isopycnal perturbations.

In a 1D geostrophic framework, the Ertel's PV goes by:

$$q \equiv (f\hat{z} + \nabla \wedge u) \cdot \nabla \rho \propto f(f + \partial_x v)N^2 - (\partial_x b)^2 \quad \text{with } b \equiv -\frac{g\rho}{\rho_0} \qquad (1)$$

Surface forcing (through buoyancy loss or down-front winds) can extract PV by weakening the stratification ($N^2 \searrow$) and enhancing density fronts ($(\partial_x b)^2 \nearrow$)



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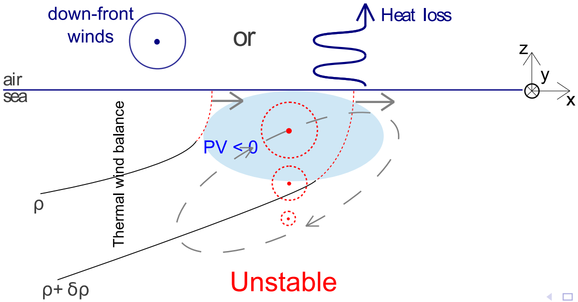

Once SI develops, fluids move along isopycnals on the vertical (x,z) plane and it tends to restratify the surface layer so that PV ~ 0 ($N^2 \nearrow$ and $(\partial_x b)^2 \searrow$).

Fast response : $O(f^{-1})$

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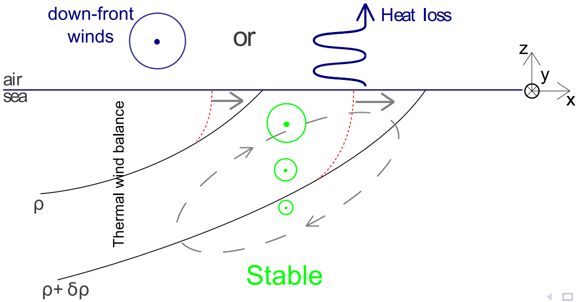

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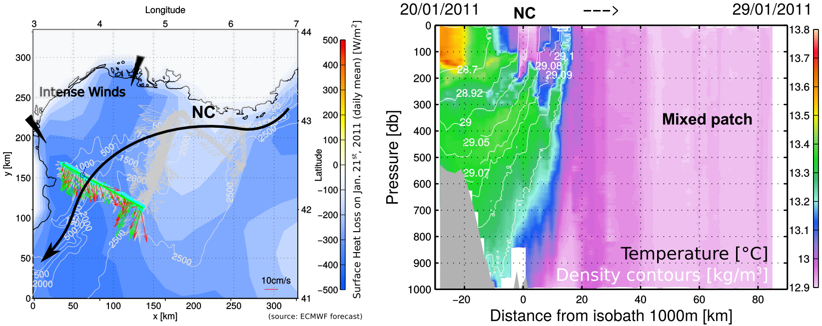
Glider section at the margin of the mixed patch



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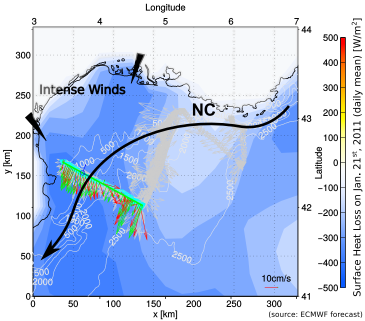
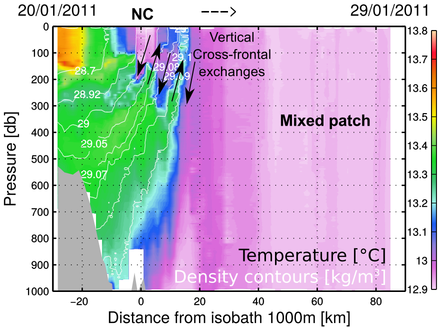




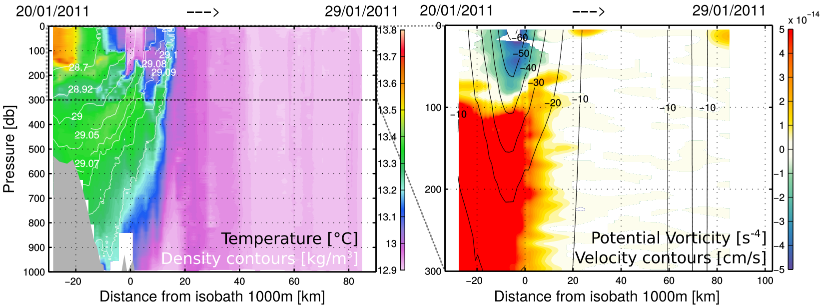
- glider deployment in winter 2011;
- intense winds → daily mean heat loss < -500 W.m^2;
- bottom-reached convection (data from the mooring LION);
- The potential temperature exhibits submesoscale variability at the NC front.

Can these vertical exchanges be the result of SI?

→ one can try to estimate the PV at the front.

Estimating the PV from gliders data:

- profiles are projected onto a section perpendicular to the NC path.
- geostrophic currents are estimated from the integration of the vertical shear (thermal wind balance: $f\partial_z v = -\partial_x b$) from a filtered density section[1] to filter out small isopycnal oscillations due to internal waves.
- the cross-section depth-average currents (estimated by the glider navigation) are taken as a reference.
- $PV = f(f + \partial_x v)N^2 - (\partial_x b)^2$

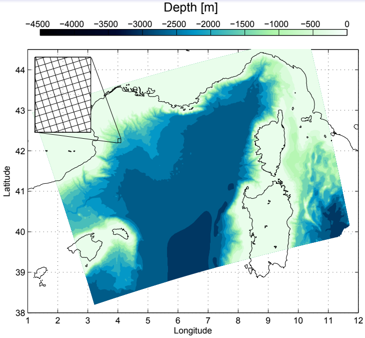


[1] gaussian running mean (σ=2km) of significant width $\sim$ 6km

Plan

The numerical model SYMPHONIE

- 3D primitive equation hydrostatic ocean model
- realistic configuration of the NWMed
- horizontal resolution of 1km, 40 σ-vertical levels
- surface forcing: ARPERA reanalysis from Sept 2010 to Dec 2011
- boundary conditions prescribed by Mercator operational model



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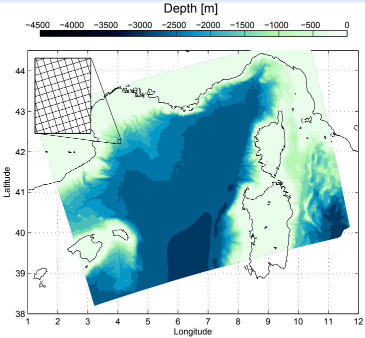
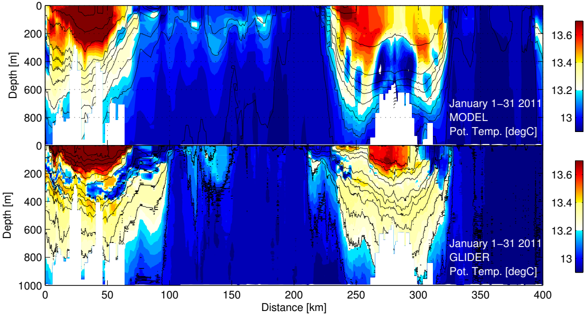
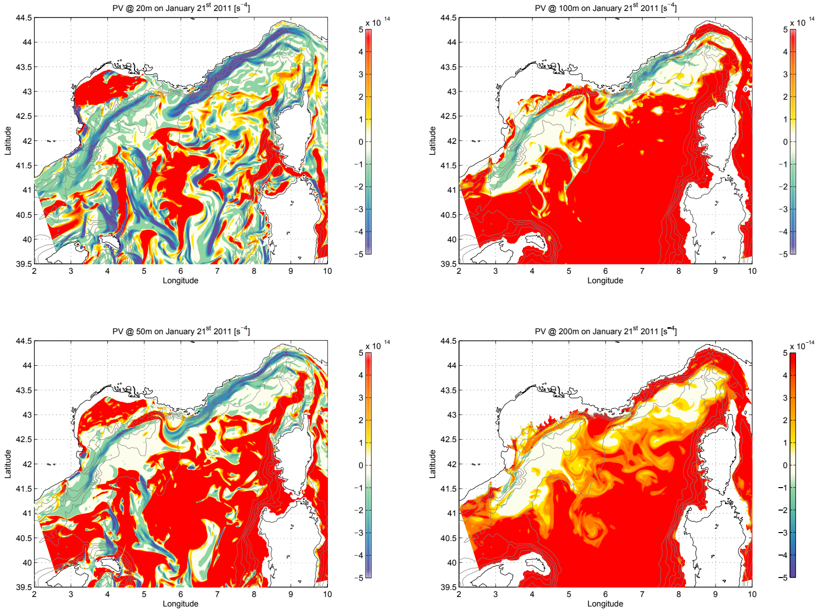




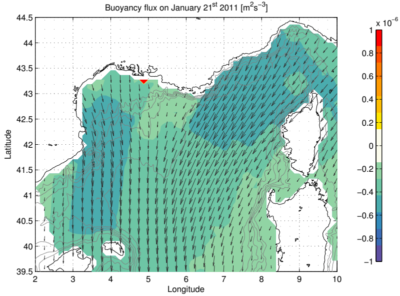
→ good representation of: deep convection and submesoscale frontal variability.

PV at different depths (20m, 50m, 100m and 200m)



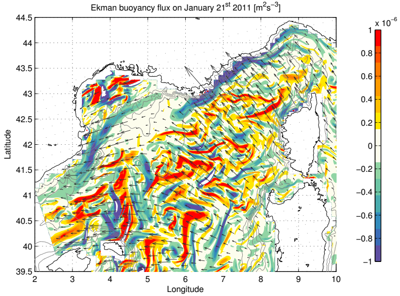
Surface buoyancy flux:

$$SuBF = \frac{g}{\rho_0}\left[\frac{\alpha}{C_p}Q_{net} + \rho_0 \beta S(E-P)\right]$$



Ekman buoyancy flux:

$$EkBF = \left[\frac{\hat{z}\wedge\tau}{\rho_0(f+\zeta)}\right]\cdot\nabla b$$



Down-front winds
$\Rightarrow$ dense waters onto lighter ones
$\Rightarrow$ high Ekman buoyancy flux correlated with PV < 0.

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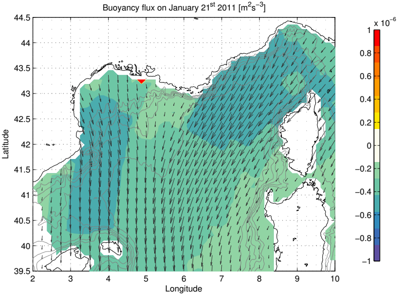

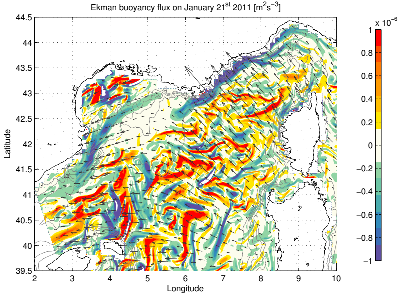

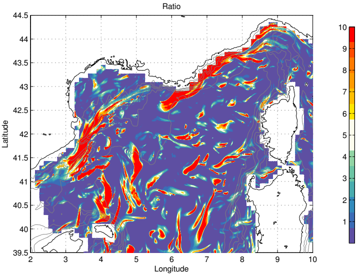

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⇒ dense waters onto lighter ones
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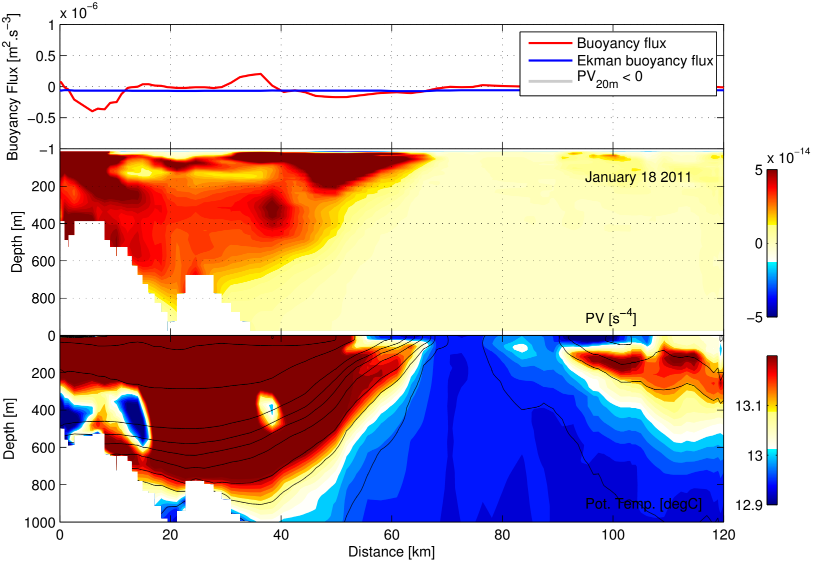
ratio: $\frac{H}{\delta_{ek}}\frac{\mathrm{EkBF}}{\mathrm{SuBF}}$ [Thomas, JPO 2005]

Effect on PV when MLD ↑

Ekman buoyancy flux ≫ Buoyancy flux

Development of frontal vertical motions



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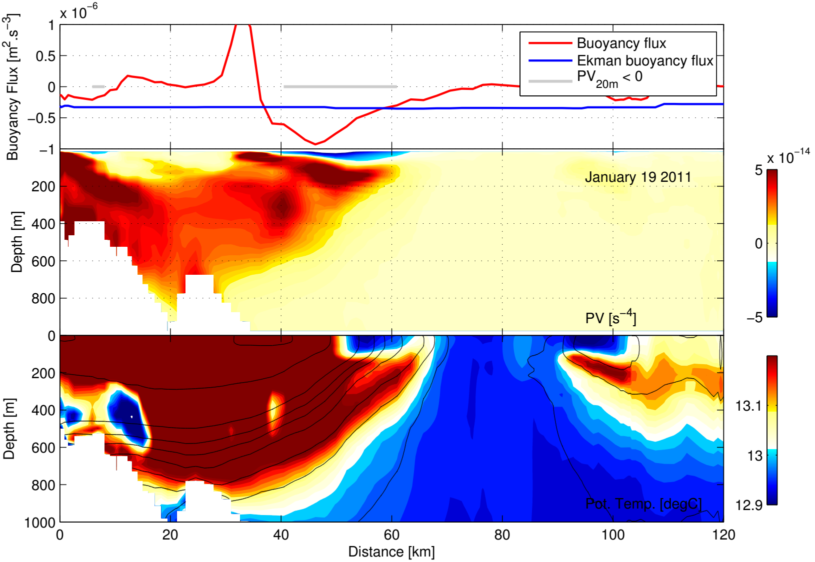

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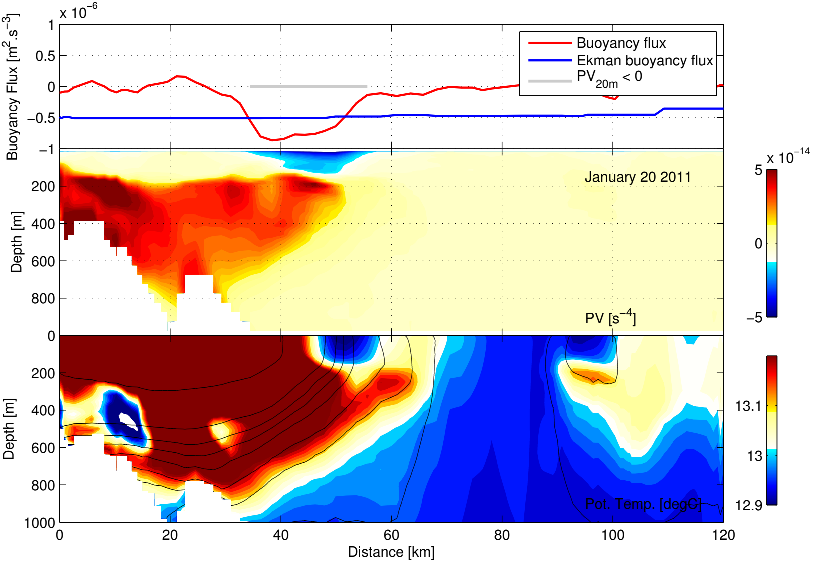

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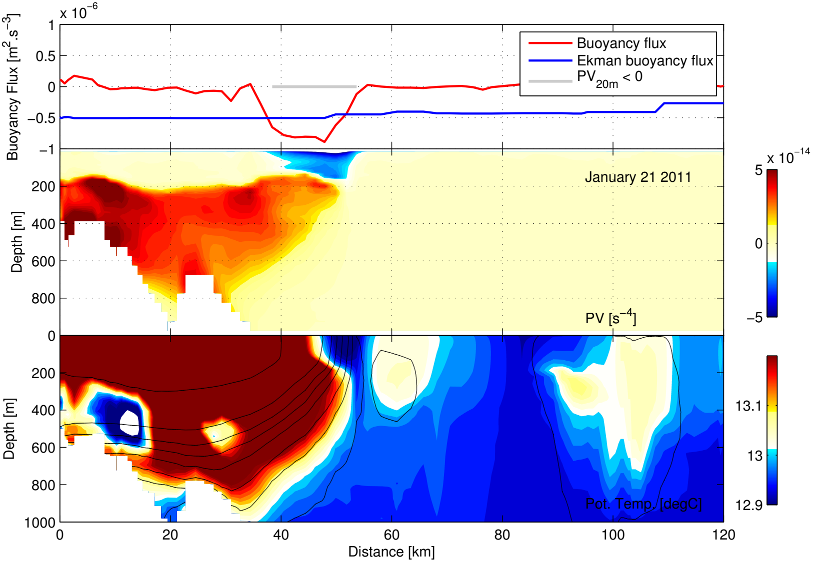

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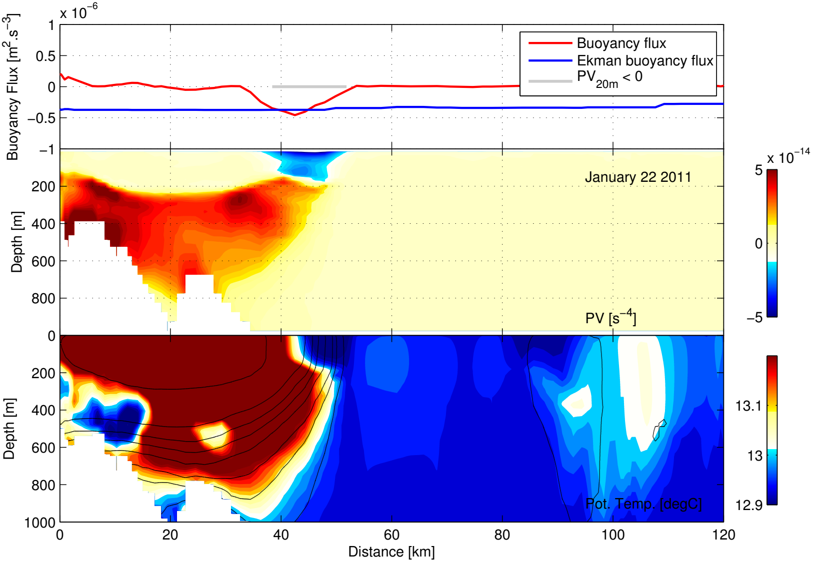

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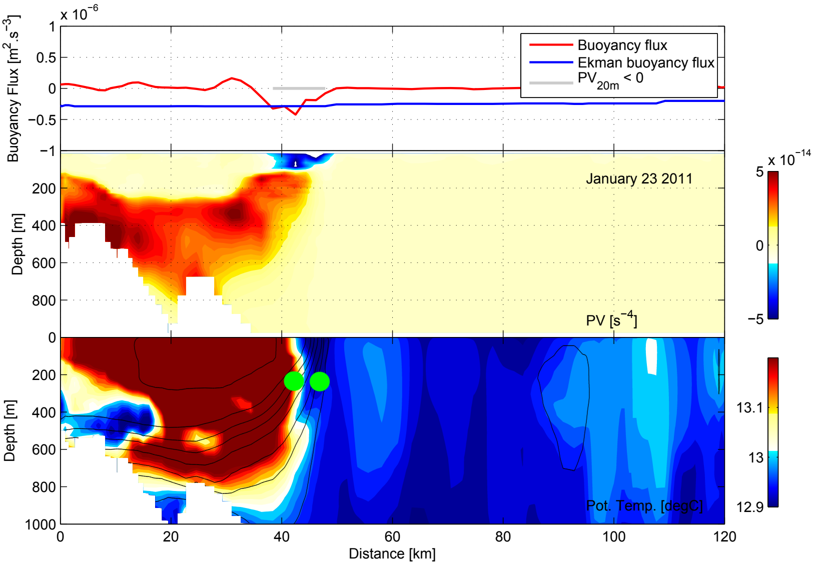

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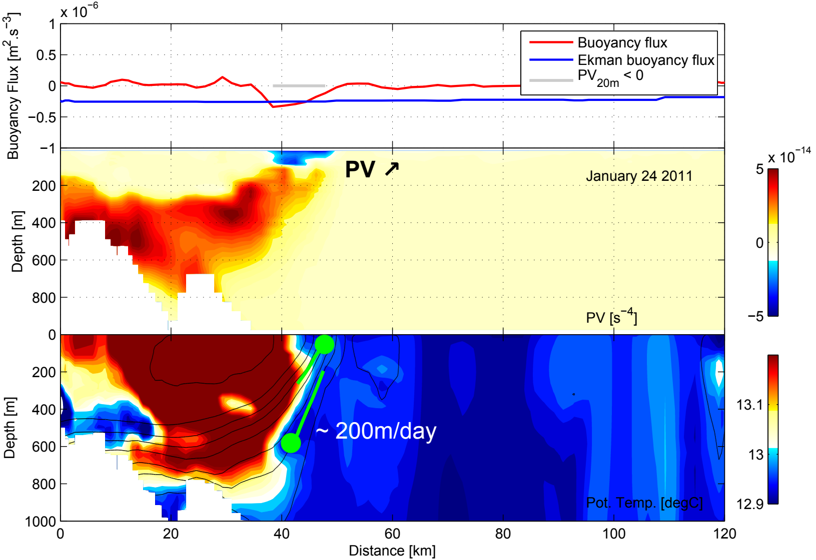

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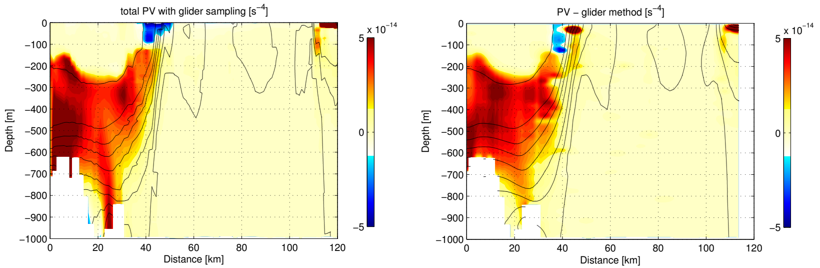

total PV (sampled like a glider) PV estimated using the glider method

⇒ Good general agreement on the PV.

⇒ Patches of negative PV are preserved!

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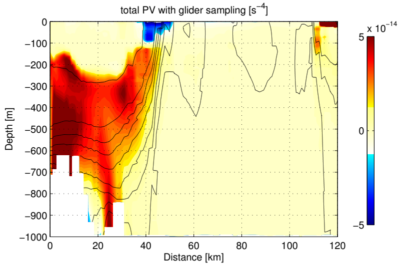

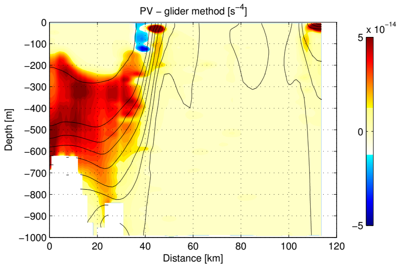

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Things to check:

- effect of the smoothing applied to compute cross-section currents
- effect of the projection (relative to the main current path)

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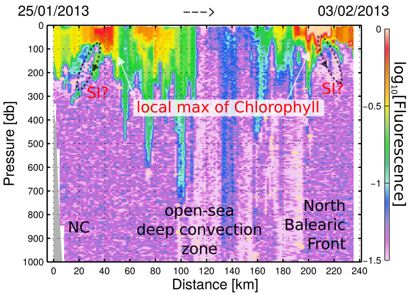

[North-South Chlorophyll section from glider Campe during ASICSMED deployment in Winter 2013.]

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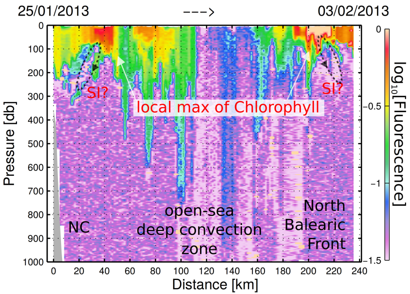

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Any questions?