An Eddy-Diffusivity-Mass-Flux Parameterization in NEMO

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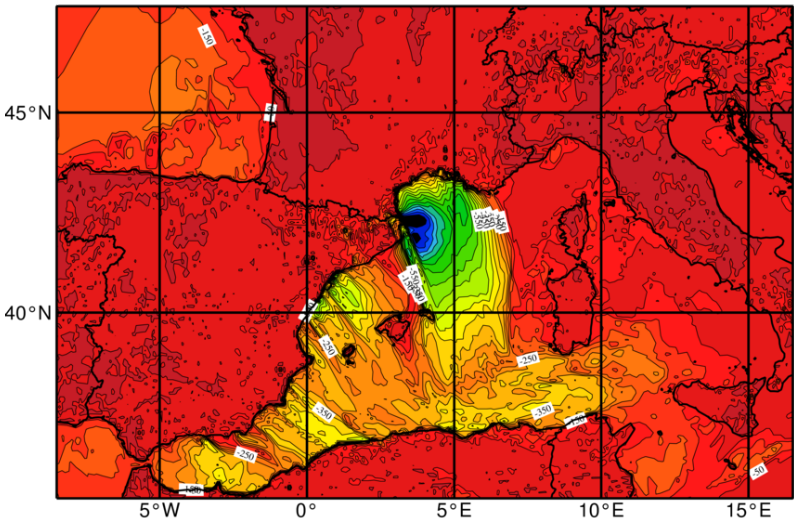
outlines

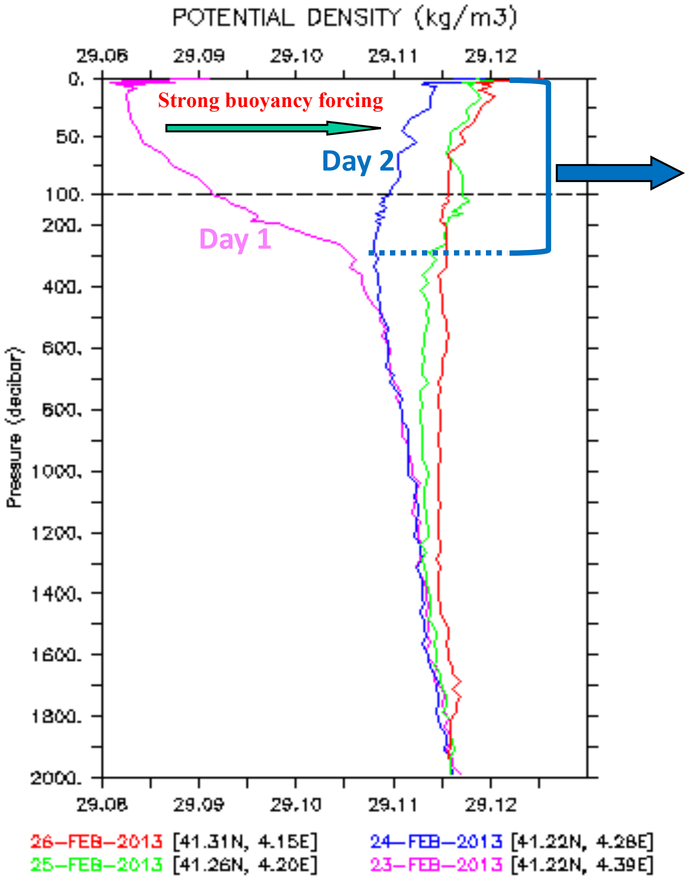
- Description of Eddy Diffusivity Mas Flux scheme (EDMF)
- Analytic 1D experiment of Marshall & Schott 1999
- 3 layers 1D test
- NEMO 1D Reference test case: PAPA station
- Conclusions and Perspectives

Example of strong unstability in the ocean

Latent Heat Flux (W/m2)
Arome model (Météo-France)
Date: 20130314



Flux can be greater than 1000 $W.m^{-2}$



Day 2
unstable
profiles
over 300 m

ARGO data

Description of Mass flux convection

- **Eddy-Diffusivity Mass-Flux (EDMF).**

Origin: Atmospheric scheme (Siebesma and Teixeira, 2000; Hourdin et al., 2002; Soares et al., 2004; Siebesma et al., 2007; Pergaud et al., 2009 …) implemented in LMDZ, Meso-NH, AROME, ARPEGE … models for the shallow convection

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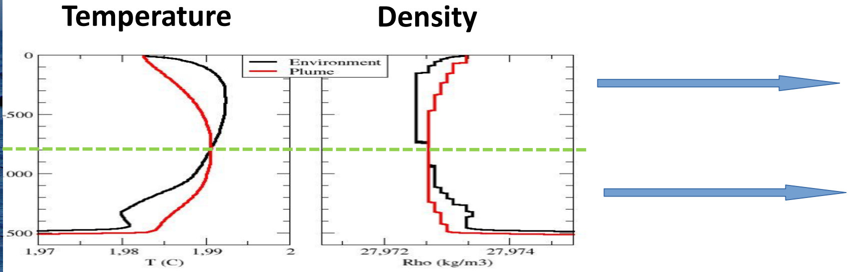

Temperature **Density**

Acceleration

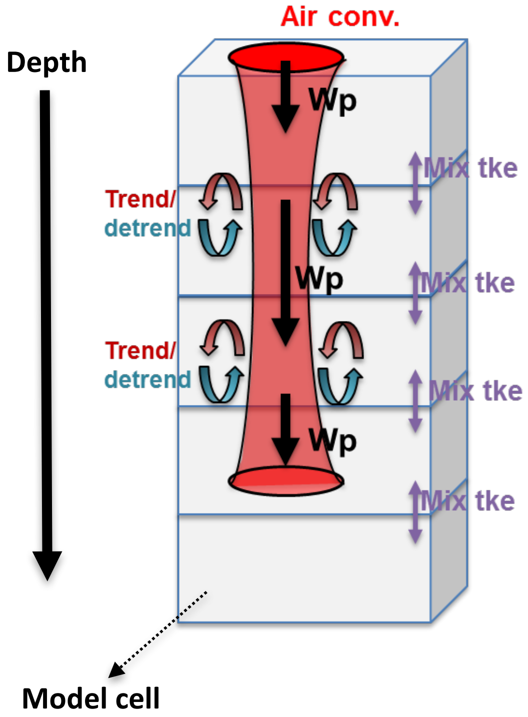
Deceleration

2 phases depending on the work of floatability term

Idea: implement the same parameterization in ocean

Scheme of EDMF

Scheme of vertical mixing



Equations of the Mass flux convection

(ψ= tracers ; ψ_p= tracers of the plume)

$$\frac{\partial \psi_p}{\partial z} = \epsilon_t(\psi_p - \psi)$$

Tracers properties

(ε_t = trend/detrend coef. for tracers)

$$\frac{1}{2}\frac{\partial W_p^2}{\partial z} = \alpha F_b(\psi, \psi_p) + \epsilon_w \frac{1}{W_p^2}$$

Convective velocity

(ε_w = trend/detrend coef. for dynamic)

$$\frac{1}{Ap}\frac{\partial Ap}{\partial z} = \frac{-1}{Wp}\frac{\partial W_p}{\partial z} - pent + cdet$$

Convective area

$$FM = -W_p Ap$$

Mass flux term

Convective velocities (W_p) can reach 10cm.s^{-1} ⇔ Order of model vertical velocities (W) is 0.1 cm.s^{-1}

The uniformed mixing scheme in NEMO

MERCATOR OCEAN INTERNATIONAL

METEO FRANCE

LOCEAN

Temporal advance of uniformed vertical mixing equation

$$\left(\frac{\partial\psi}{\partial t}\right)_{edmf} = \frac{1}{\rho}\frac{\partial}{\partial z}\left(\underbrace{-K\frac{\partial\psi}{\partial z}}_{Diffusion}\underbrace{-M\left(\psi_p-\bar{\psi}\right)}_{Convection}\right)$$

Local and non-local approach solved at the same time, both by an implicit method: a unified method of mixing

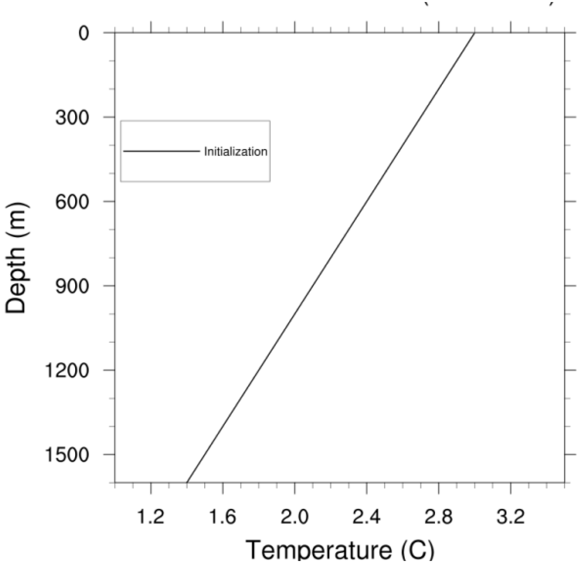
Tridiagonal System for a tracer ψ :

$$\begin{pmatrix}\psi(k-1)\\ \psi(k)\\ \psi(k+1)\end{pmatrix}^{t} = \begin{pmatrix} Diff(k)+\boxed{\frac{\mathrm{FM(k-1)\Delta t}}{\mathrm{e3t(k)}}} & Diff(k+1)+\boxed{\frac{\mathrm{FM(k)\Delta t}}{\mathrm{e3t(k)}}} & 0 \\ Diff(k-1) & 1+Diff(k)+\boxed{\frac{\mathrm{FM(k)\Delta t}}{\mathrm{e3t(k)}}} & Diff(k+1)+\boxed{\frac{\mathrm{FM(k+1)\Delta t}}{\mathrm{e3t(k)}}} \\ 0 & Diff(k-1) & Diff(k)+\boxed{\frac{\mathrm{FM(k+1)\Delta t}}{\mathrm{e3t(k)}}} \end{pmatrix}\begin{pmatrix}\psi(k-1)\\ \psi(k)\\ \psi(k+1)\end{pmatrix}^{t+\Delta t}$$

Adding Mass flux scheme => adding terms in the tridiagonal matrix and in RHS

1D analytical study case: Marshall & Schott 1999 (M&S-99)

Initial condition in temperature

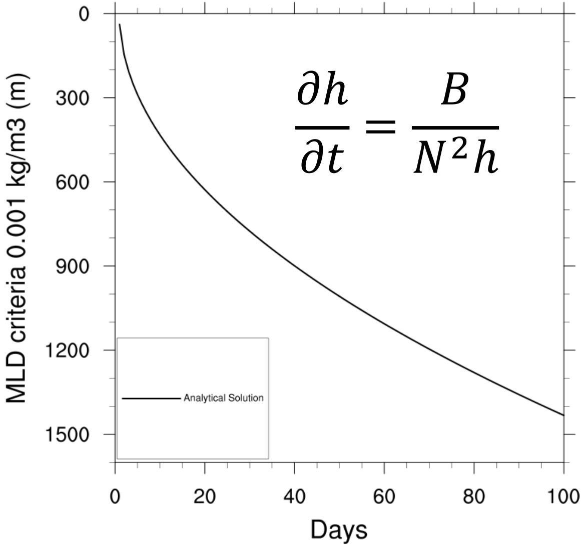


Constant salinity : 35 PSU

EOS linear

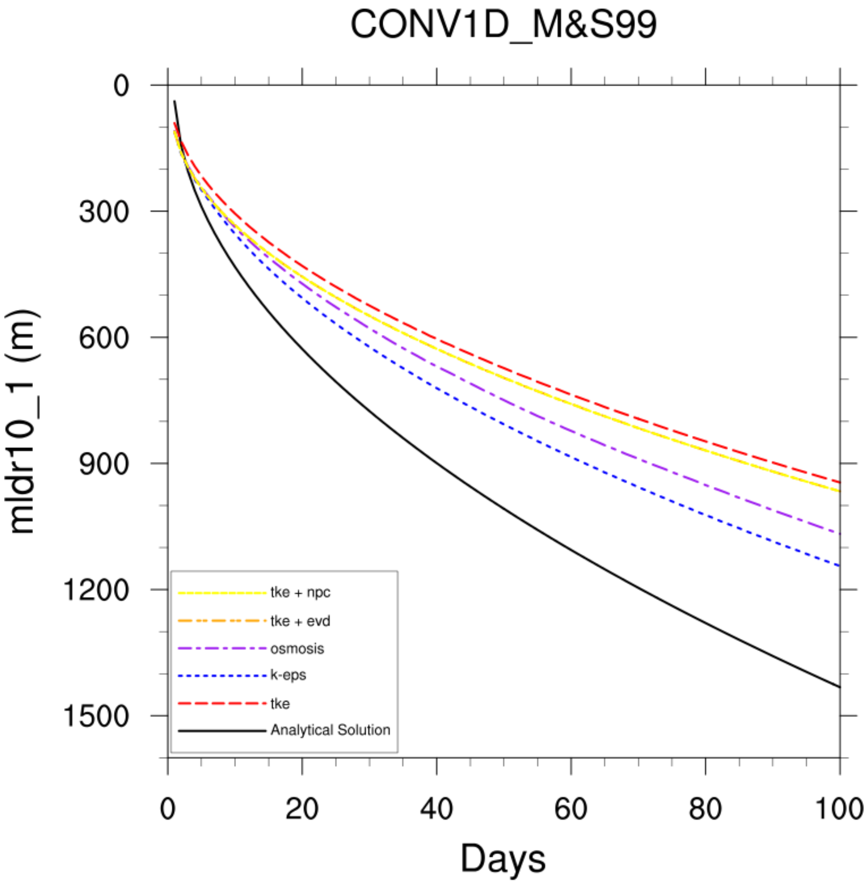
Forcing: F_b = **-200** W/m^2

Analytical MLD



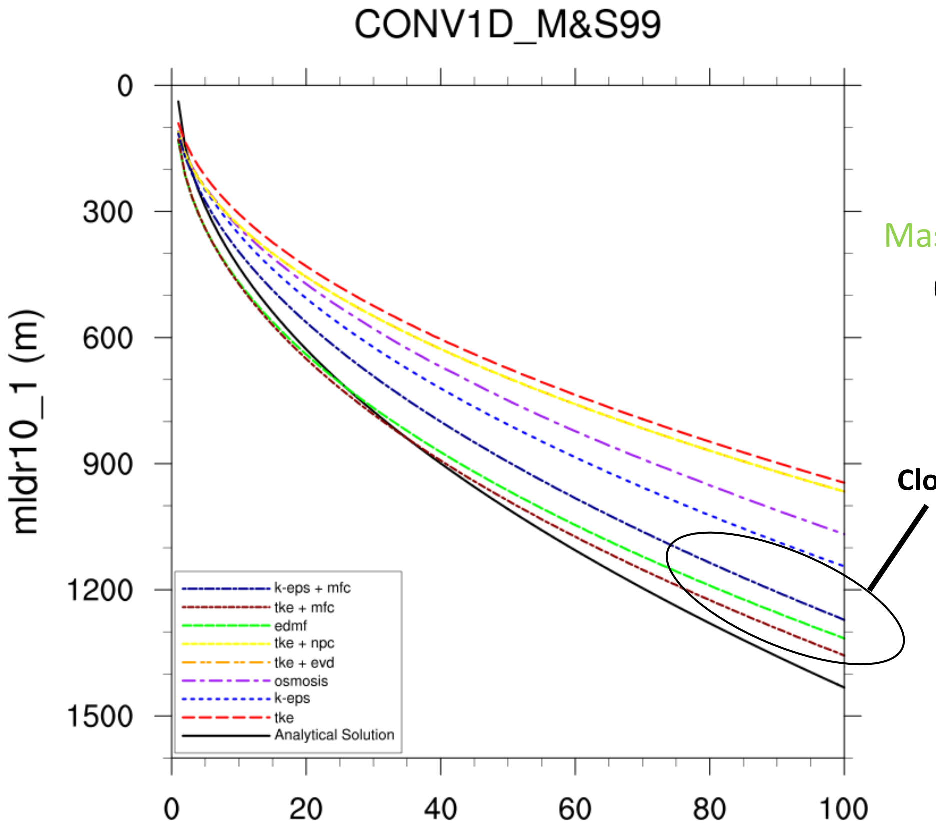
$$\frac{\partial h}{\partial t} = \frac{B}{N^2 h}$$

1D M&S-99 with NEMO vertical schemes



Standard mixing closures in NEMO4

1D M&S-99 with NEMO vertical schemes

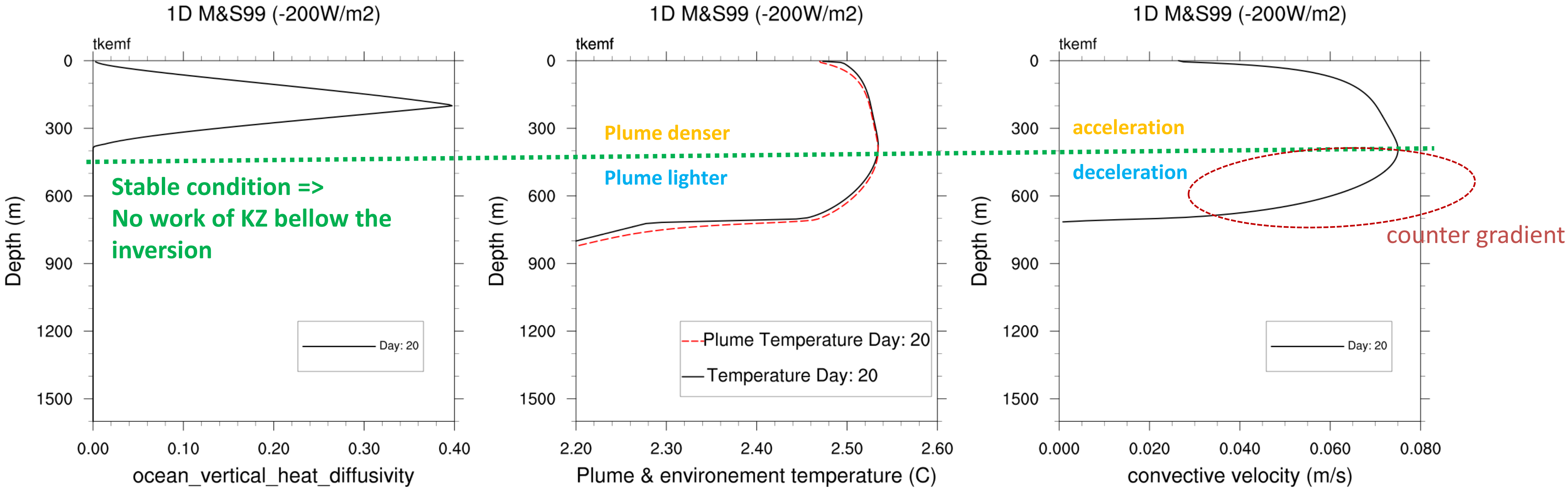


Closures with MF scheme

Standard mixing closures in NEMO4
+
Mass Flux ; TKE + Mass Flux ; k-ε + Mass Flux
(Mass Flux tuning : ε_t=0.05 and ε_w=0.)

- With MF MLD deeper
- Deepening too strong during the first 30 days with MF and tke+MF
- MLD not enough deep of 200-300m after 100 days in all closures with MF

Mass flux, counter gradient work:
example after 20 days simulated with TKE + MF



Stable condition =>
No work of KZ bellow the inversion

Plume denser

Plume lighter

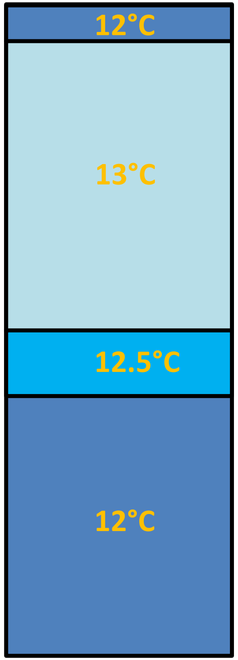
acceleration

deceleration

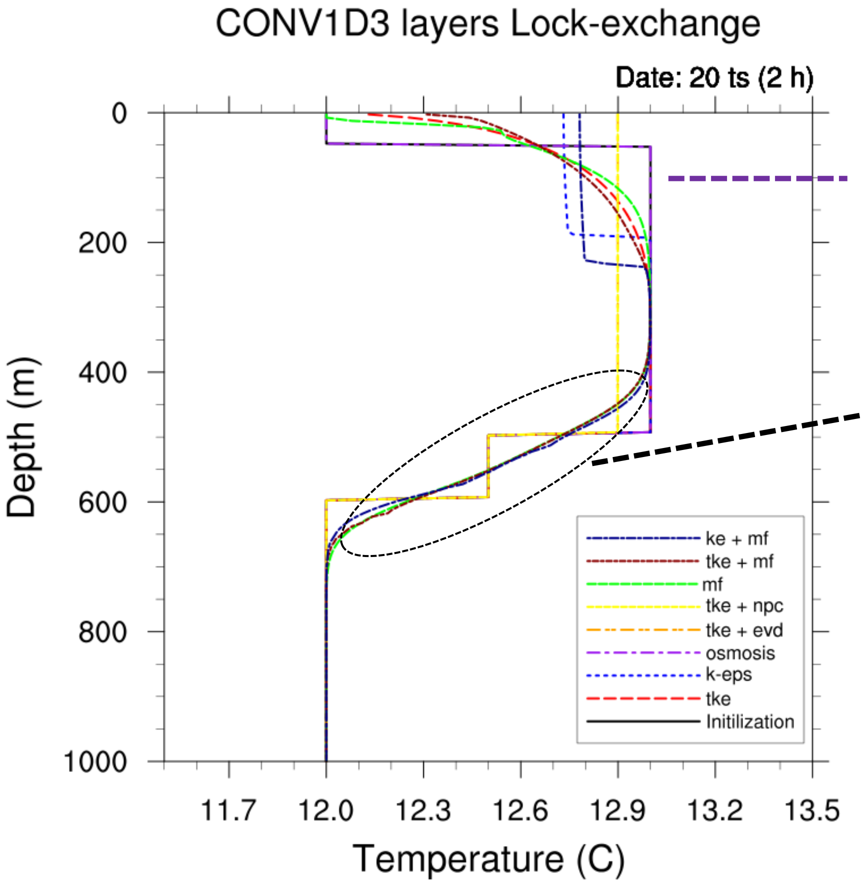
counter gradient

1D 3 layers vertical lock exchange experiment

Unstable initial condition



Constant salinity
EOS linear



No atmospheric forcing => no work done by osmosis (tuning ?)

Only closures with MF scheme break the stratification

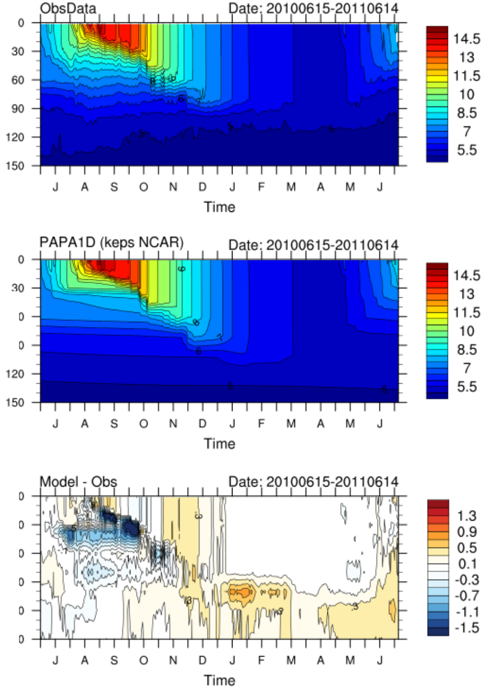
Results at PAPA station

Data

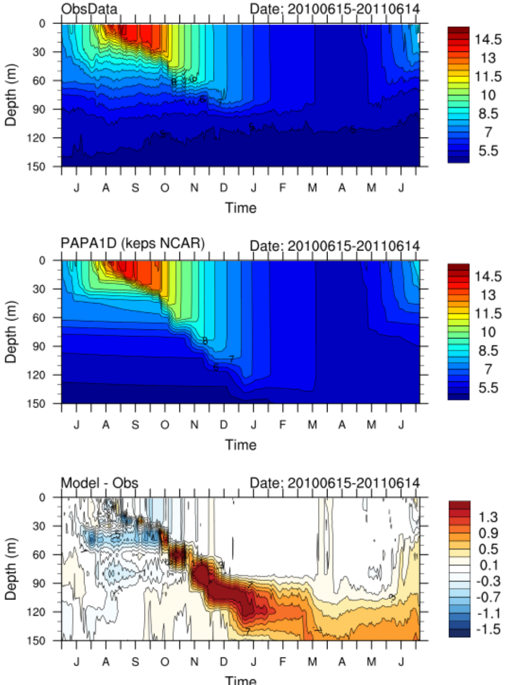
Model

Model - Data

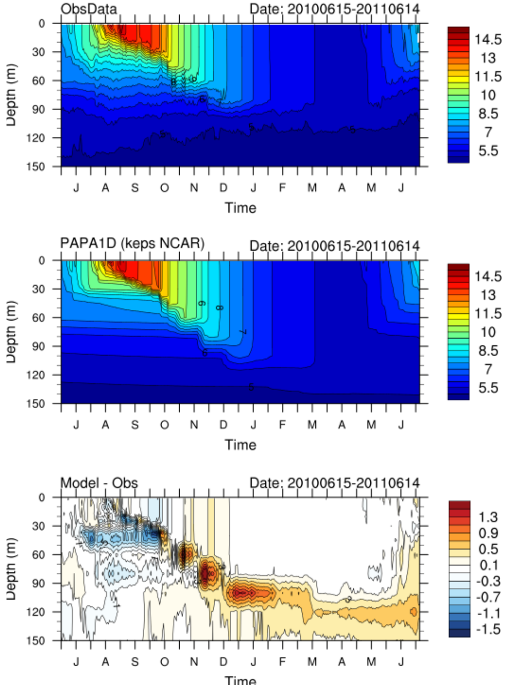
Reference NEMO4 simulation (k-epsilon closure)



Simulation k-epsilon+MF (ε_t=0.05 and ε_w=0.)

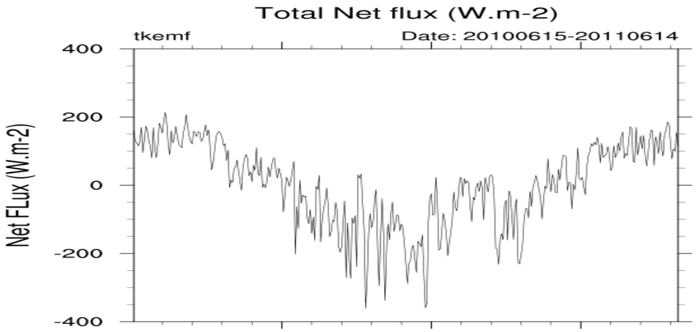


Simulation k-epsilon+MF (ε_t=0.05 and ε_w=0.025)

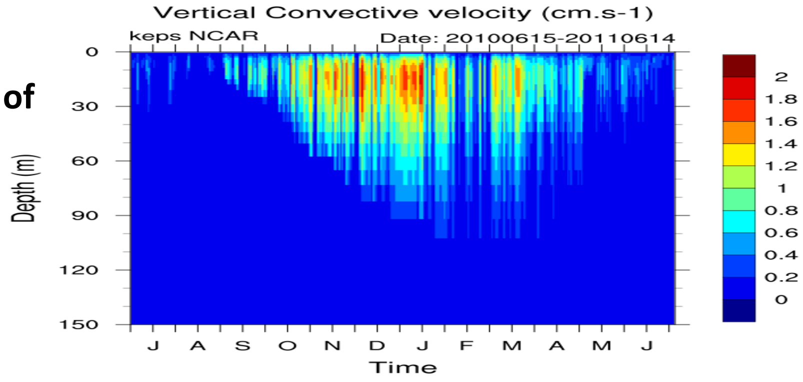


Results at PAPA station: Plume representation

Net heat flux at PAPA station



Vertical velocity of the convective plume



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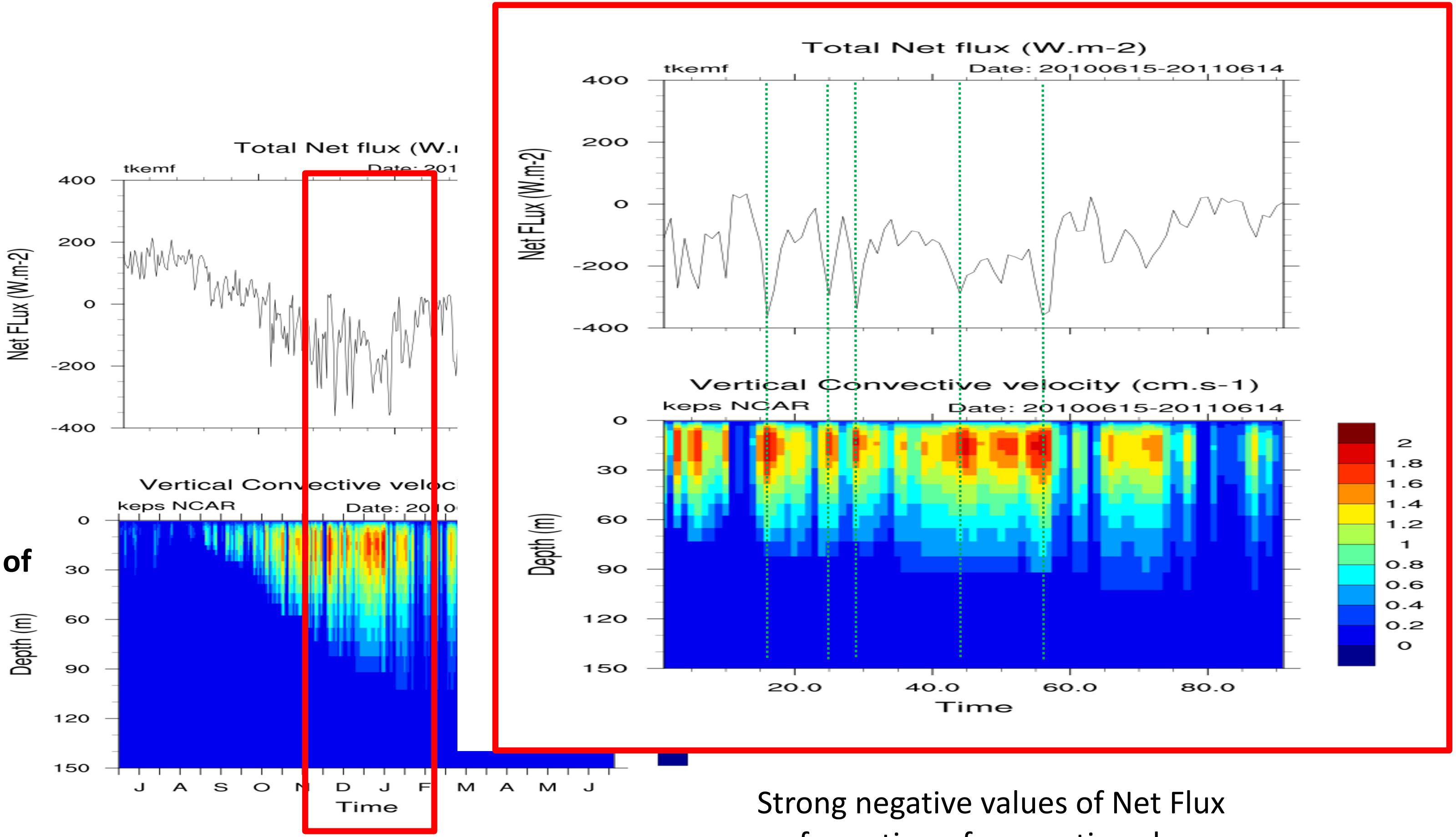

Strong negative values of Net Flux => formation of convective plumes

Conclusions & Perspectives

- ✓ Context of a uniformed, local and non-local mixing, has been established with an EDMF approach
- ✓ Analytical and realistic 1D sensitivity experiments show promising results

- ➢ Adjust trend/detrend term and initial convective Area with L.E.S. simulations
- ➢ Apply the EDMF scheme in realistic 3D simulations. Focus on deep convection and overflow
- ➢ Apply dynamical quantities (velocity, tke) in the Mass flux scheme
- ➢ Use the vertical mass flux in BGC model