New developments and diagnostics related to the mass flux convective parameterization in the NEMO ocean model

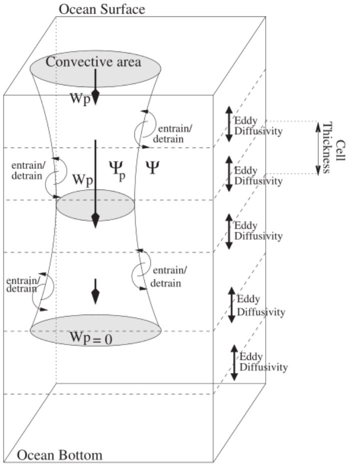
C. Pelletier[1] R. Bourdallé-Badie[1] H. Giordani[2] G. Samson[1] G. Garric[1] C. Perruche[1] É. Gutknecht[1]

EGU General Assembly, May 25th 2022 (**extra material**)

[1]Mercator Ocean International, Toulouse, France

[2]CNRM, Univ. Toulouse, Météo-France, CNRS, Toulouse, France

Mass-flux convection scheme



Giordani *et al.*, JAMES 2020

- **Purely convective** (no diffusion) parameterization transposed from **convective cloud atmospheric counterpart**.
- Surface buoyance loss (Q_{net}, *emp*) *or* vertical instability (ρ) $\Rightarrow$ intra-column **convective plumes**.
- Large-scale solution affected by **nonlocal convective fluxes** between plume and environment.
- Introduced and tested on **1D configs**; publicly available in **NEMO** $\geq$ 4.0.
- Compatible with any **purely diffusive** scheme, e.g.: **EDMF** = TKE + MFC.
- Works with active (θ, s) and passive (e.g., BGC) tracers.

$$\partial_t \psi = \underbrace{-\mathcal{K}\partial_z \psi}_{\text{diffusion}} + \underbrace{F_M \left(\psi_p - \psi\right)}_{\text{convection}}$$

$F_M \neq 0 \Rightarrow$ mass-flux convection active. ψ_p can sink really fast ($\approx 20\ \mathrm{cm\ s^{-1}}$) and then affect ψ through **plume-environment relaxation**.

ψ	tracer (θ, $s\dots$)
$\mathcal{K}$	vertical diffusivity (local, often from TKE)
F_M	mass flux (from entrainment/detrainment)
ψ_p	value of ψ within convective plume (potentially $\neq \psi$!)

Increments on implicit tridiagonal vertical diffusion-convection solver:

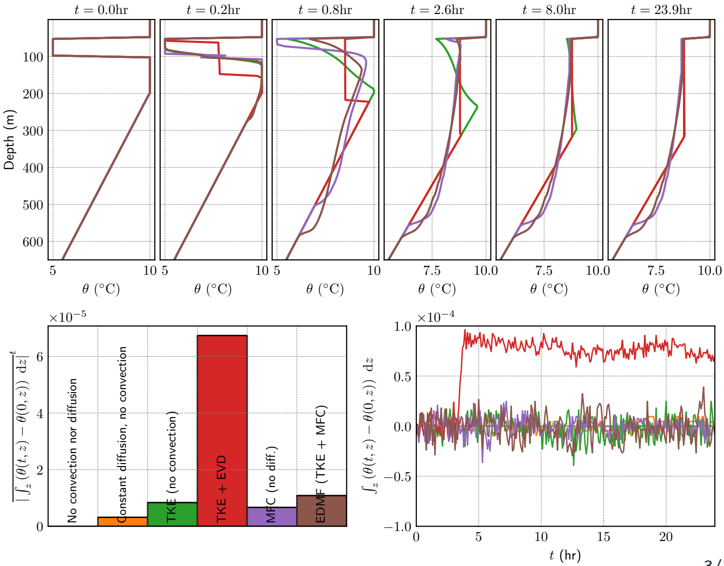
$$\begin{pmatrix} 1+\mathcal{S}^{k-1}+\mathcal{M}^{k-1}-\frac{F_M^{k-1}\delta_t}{\mathtt{e3w}^k} & -\mathcal{M}^{k-1}+\frac{F_M^{k}\delta_t}{\mathtt{e3w}^k} & 0 \\ -\mathcal{S}^k & 1+\mathcal{S}^k+\mathcal{M}^k-\frac{F_M^{k}\delta_t}{\mathtt{e3w}^{k+1}} & -\mathcal{M}^k+\frac{F_M^{k+1}\delta_t}{\mathtt{e3w}^{k+1}} \\ 0 & -\mathcal{S}^{k+1} & 1+\mathcal{S}^{k+1}+\mathcal{M}^{k+1}-\frac{F_M^{k+1}\delta_t}{\mathtt{e3w}^{k+2}} \end{pmatrix} \begin{pmatrix} \psi_{t+1}^{k-1} \\ \psi_{t+1}^{k} \\ \psi_{t+1}^{k+1} \end{pmatrix}$$

MFC discretized through a "downwind" scheme (other options unstable).

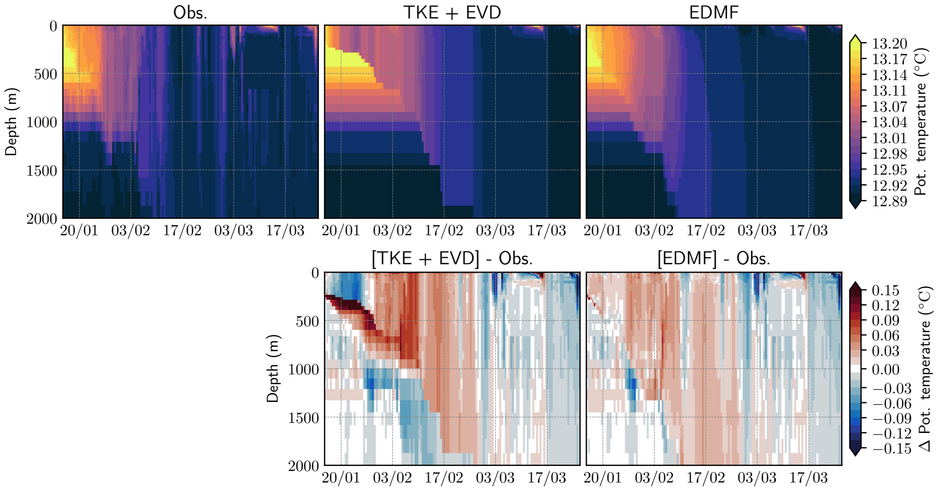
$$\mathcal{S}^k := \frac{\mathcal{K}_k \Delta t}{\mathtt{e3t}_k \mathtt{e3w}_k}, \quad \mathcal{M}^k := \frac{\mathcal{K}_{k+1} \Delta t}{\mathtt{e3t}_k \mathtt{e3w}_{k+1}}$$

Static instability numerical test

- 1D test, no forcing, **instatic initial conditions relaxation**.
- MFC **numerically sound**, EDMF sounder.
- Better (compared with EVD) **conservation properties**.
- **Smoother** (physically more realistic) vertical profiles.



ASICS testcase

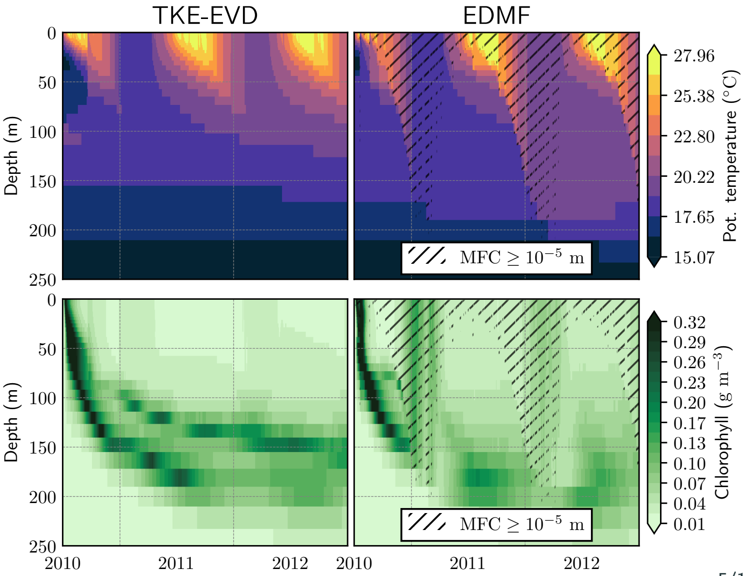


1D configuration developed within the HyMeX program, located at the Lions buoy (Med. sea).

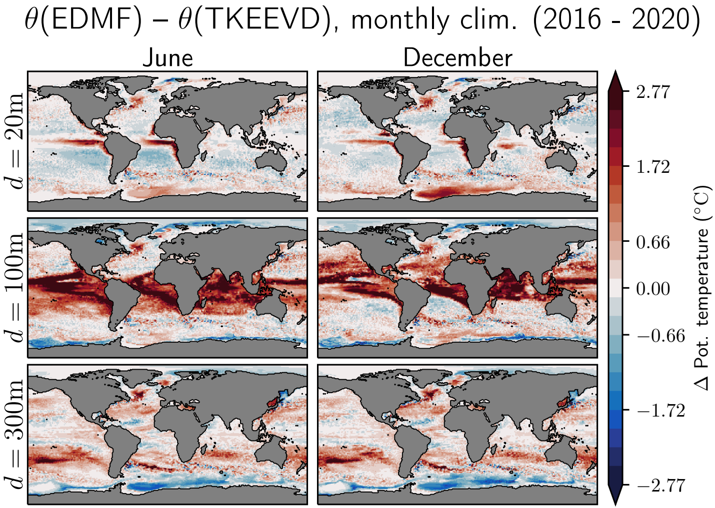
Bedrock-reaching (observed by ARGO) convection event on 09/02/2013 **well represented by EDMF** in this 1D config.

Application to biogeochemistry

- Tested in BATS (1D BGC-including config. in Bermudas).
- Plume-triggering episodes can be observed on PISCES outputs (see Chl aside).

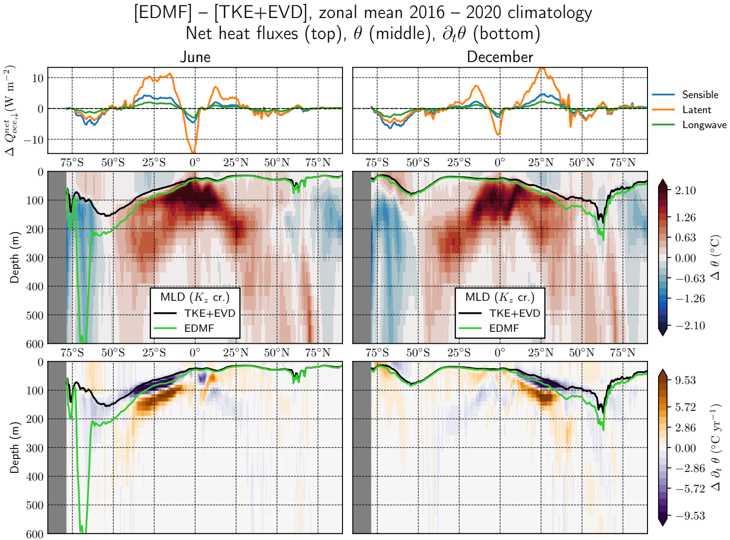


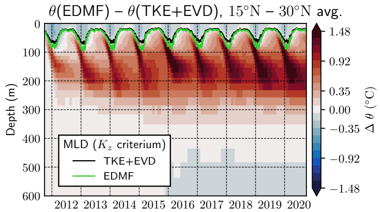
First results from global runs



- First comparisons (EVD vs. MFC) from **10-year forced iORCA025** experiments.
- Significant **subsurface warm differences** overcompensating pre-existing cold bias.
- MFC has more impact in the **tropics**, mildly stronger in the winter.

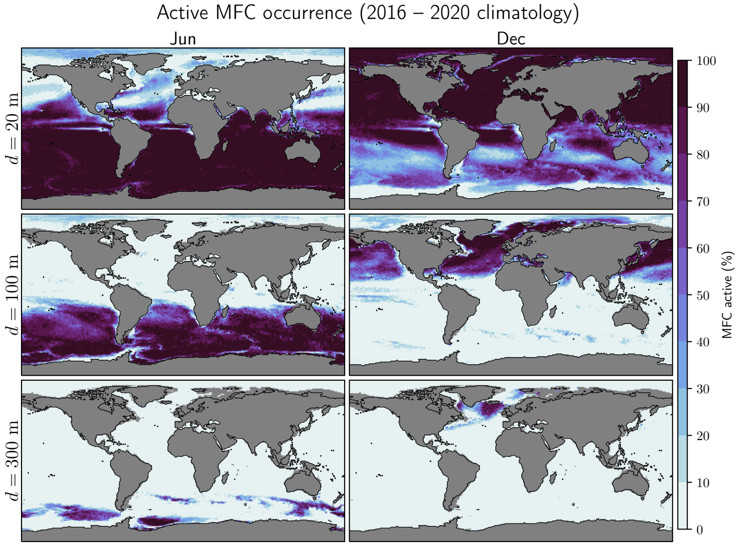
Zonally averaged temperature diagnostics





Tropics: surface heat **downwelled far below mixed layer** by MFC-driven wintertime heat accumulation.

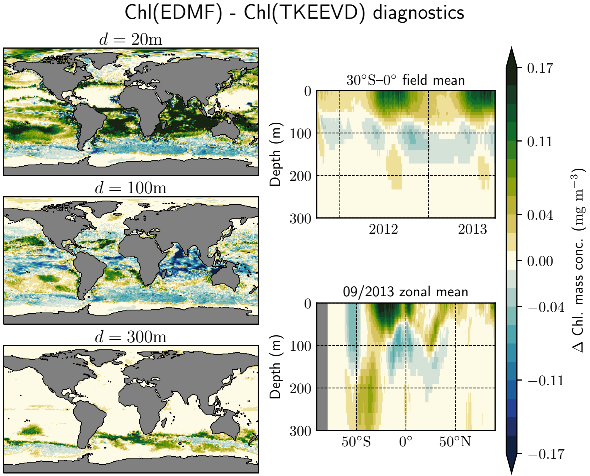
MFC scheme activity diagnostics



- MFC active at surface during winter almost all the time ⇒ need to adapt MFC-triggering **buoyancy surface condition** tuning to 3D context.
- Fairly often active **deeper in weakly stratified polar seas** (e.g. Weddell) ⇒ very sensitive to small local instabilities.

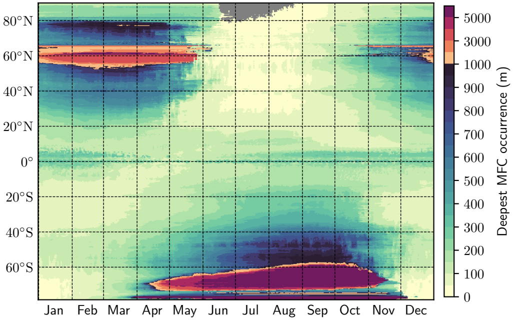
Future perspectives and tasks

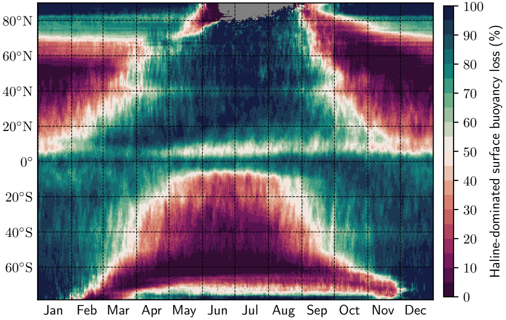
1. MFC scheme has been tuned from 1D testcases ⇒ **retuning necessary** for realistic applications. Generally speaking, the **scheme should be inhibited**.
2. Triggers Weddell sea polynya opening, **bedrock-reaching (3000+ m!)** convective events.
3. **NEMO-PISCES** (with biogeochemistry) iORCA025 experiments running now.



MFC depth diagnostics

EDMF run, 2016 - 2020 daily climatology





Weddell polynya opening