Next Generation Climate Science in Europe for Oceans
End-term Meeting

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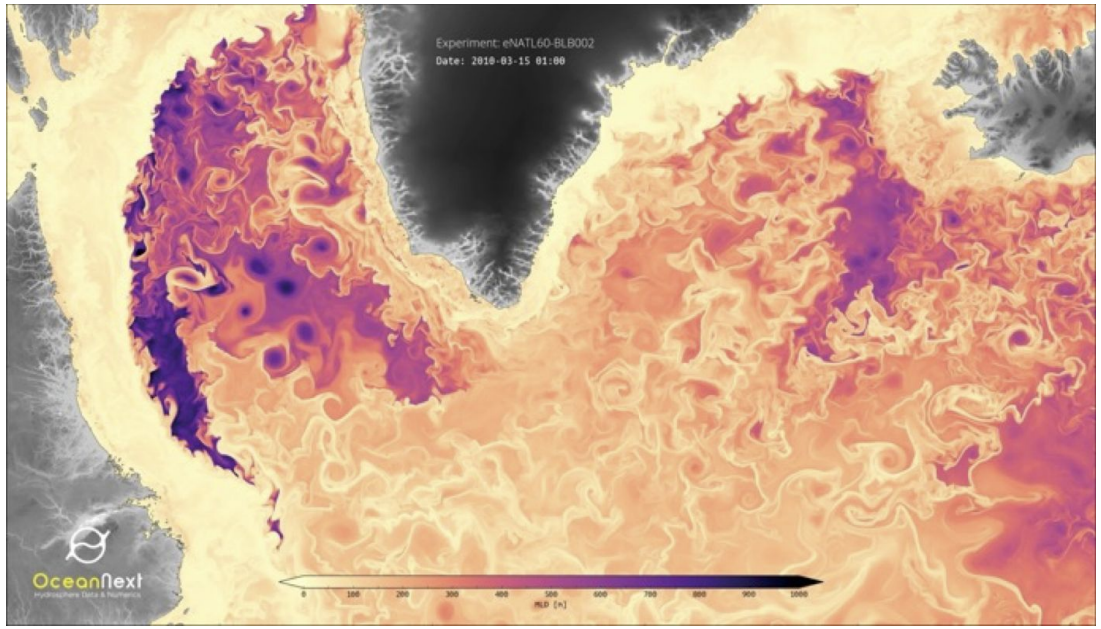
MixED LayEr heterogeneitY



29 April 2024

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Project Partners (countries, institutions, funding agencies) and their role

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NERSC
NANSEN ENVIRONMENTAL AND REMOTE SENSING CENTER
THE NANSEN CENTER · BERGEN · NORWAY

Finescale models
ice covered regions
WP1 WP2

LOPS

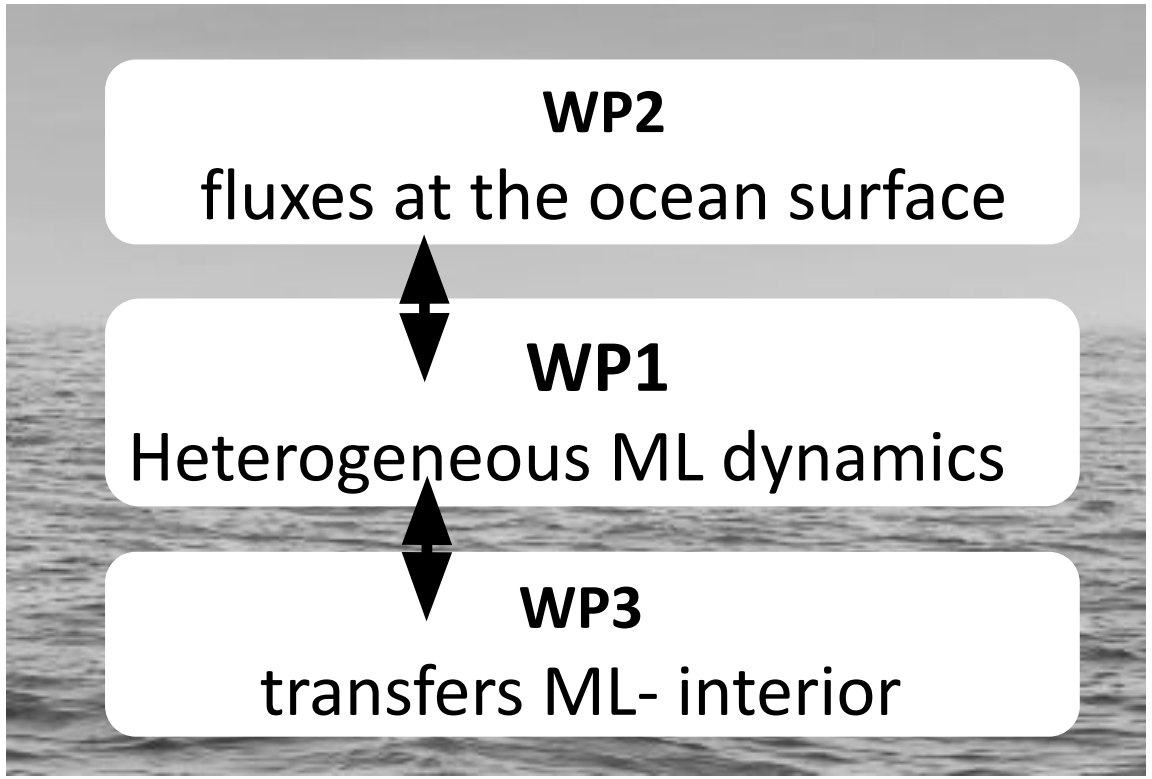
Finescale models
ice covered regions
Observations
all WPs

IGE
Institut des géosciences de l'environnement

Finescale models
all WPs

UCLouvain

Climate model
Ice covered regions
all WPs



INSTITUTE OF OCEANOLOGY OF RUSSIAN ACADEMY OF SCIENCES

Observations
WP2

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

Climate model
WP1 and WP3

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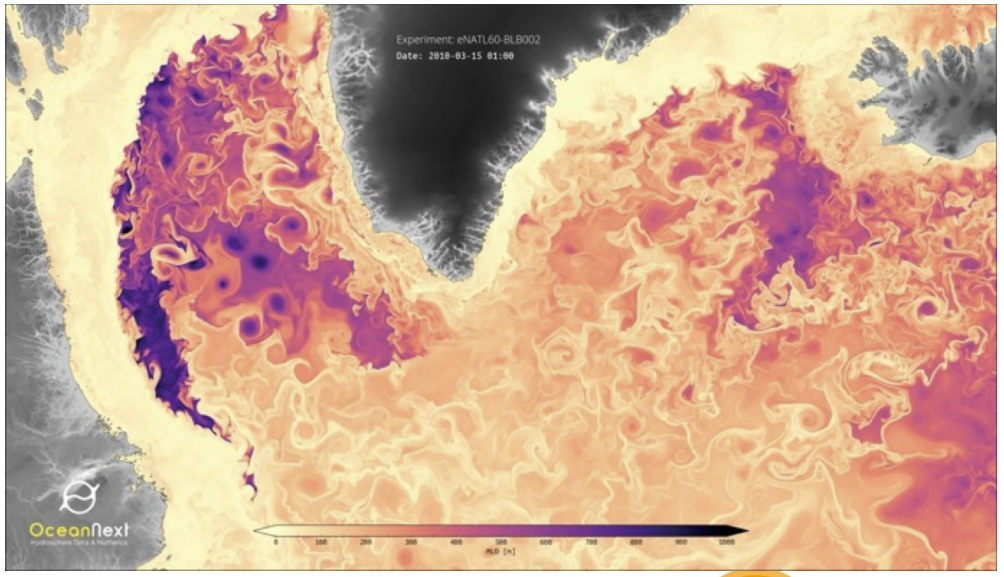
Hypothesis: Low-resolution climate models and 1D parameterizations fail because they do not take properly into account the spatial heterogeneity of mixed layer processes.

MEDLEY evaluates the spatial heterogeneity of fluxes and processes controlling the mixed layer properties and dynamics

Ultimate goal: take into account this heterogeneity to improve the representation of the mixed layer transfer function in climate models



keywords:
ocean mixed layer,air-sea fluxes
ocean eddies, mesoscale and submesoscale
ventilation,ocean-ice climate models

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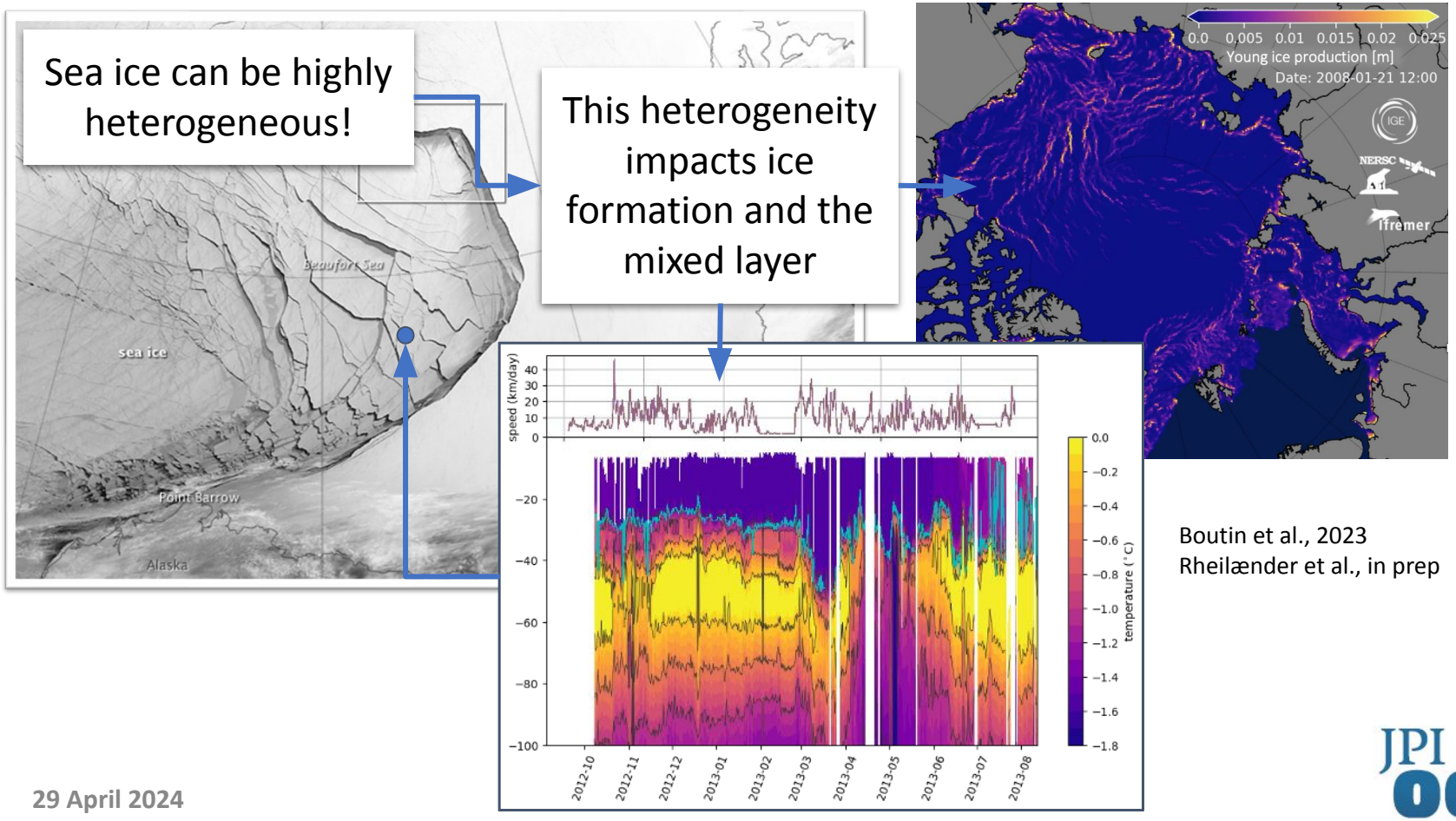
Mixed layer and sea-ice heterogeneity

Hypothesis: Poor representation of sea-ice heterogeneity in climate models results in an unrealistically homogenous and calm mixed layer below the ice in those models.



Boutin et al., 2023
Rheilænder et al., in prep

NEMO-neXtSIM can reproduce this heterogeneity and its impact on the ocean

- 20 to 30% of winter ice production take place in leads
- … with a 3%/decade trend in the last 20 years
- Large breakup events drive a deepening of the mixed layer
- We expect both effects to strengthen with less ice in the Arctic

The mixed layer and its interaction with sea ice : representation in models

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Impact of ocean vertical mixing parametrization on sea ice properties using NEMO-SI3 model over the Arctic Ocean

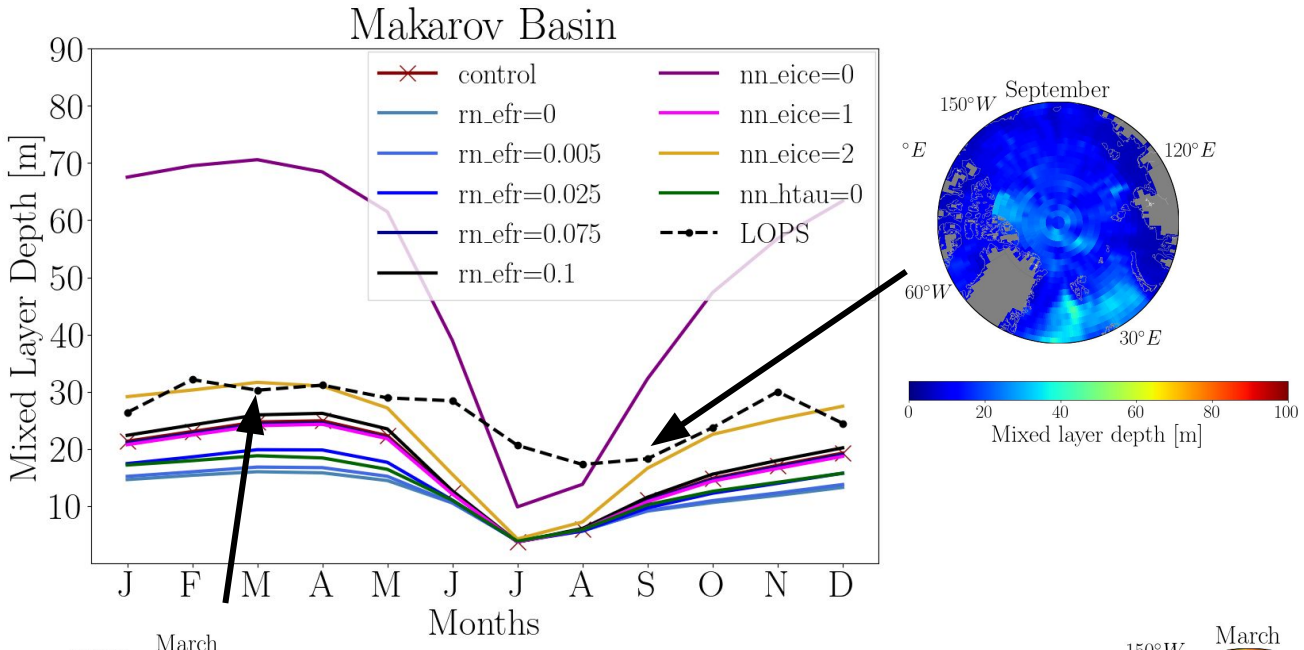
TKE Mixed layer penetration

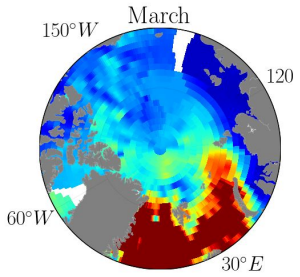
$$\bar{e}_{inertial}(t,z) = e_{surf}\ \chi\ f_r\ \exp(-z/h_\tau)$$

(Rodgers et al. 2014)

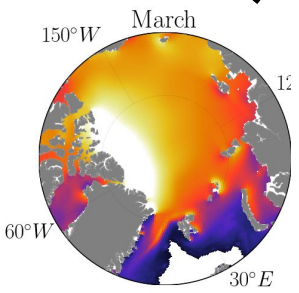
This ad-hoc parametrization aims to capture processes such as near-inertial oscillations and ocean swells, which influence the ocean's boundary layer density structure and are often not well-represented by the default TKE scheme.

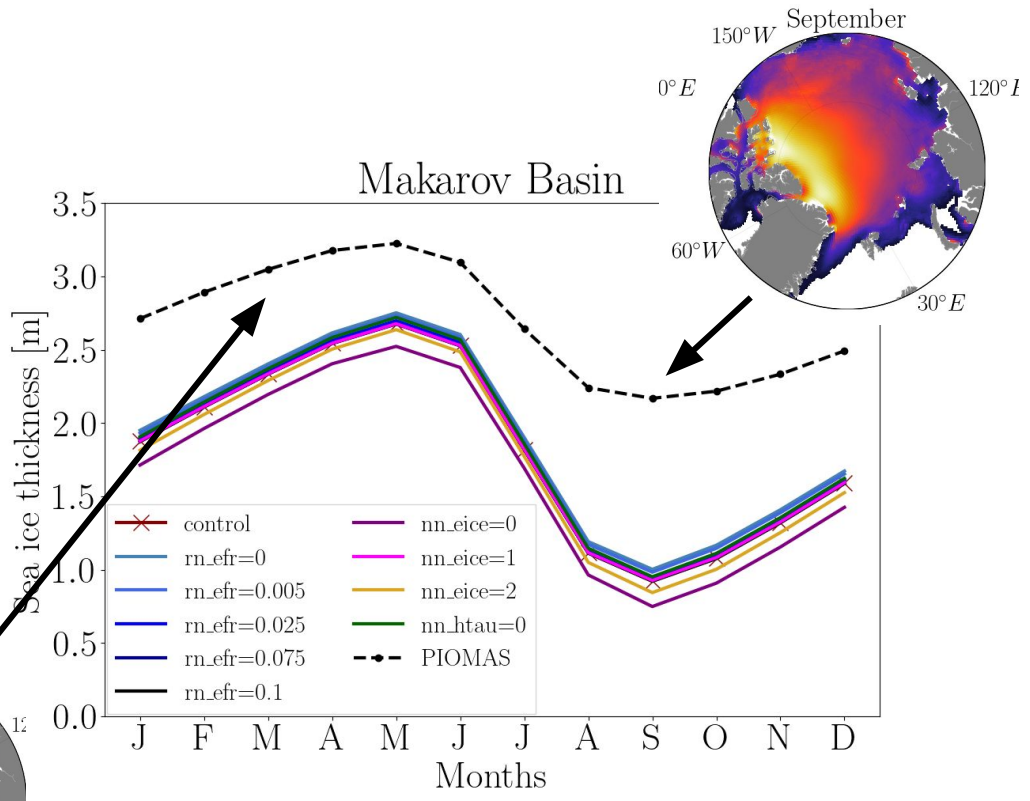
$\bar{e}_i = 0$ $\bar{e}_i \propto 1 - f_i$ $\bar{e}_i$ max





(De Boyer al. 2024)





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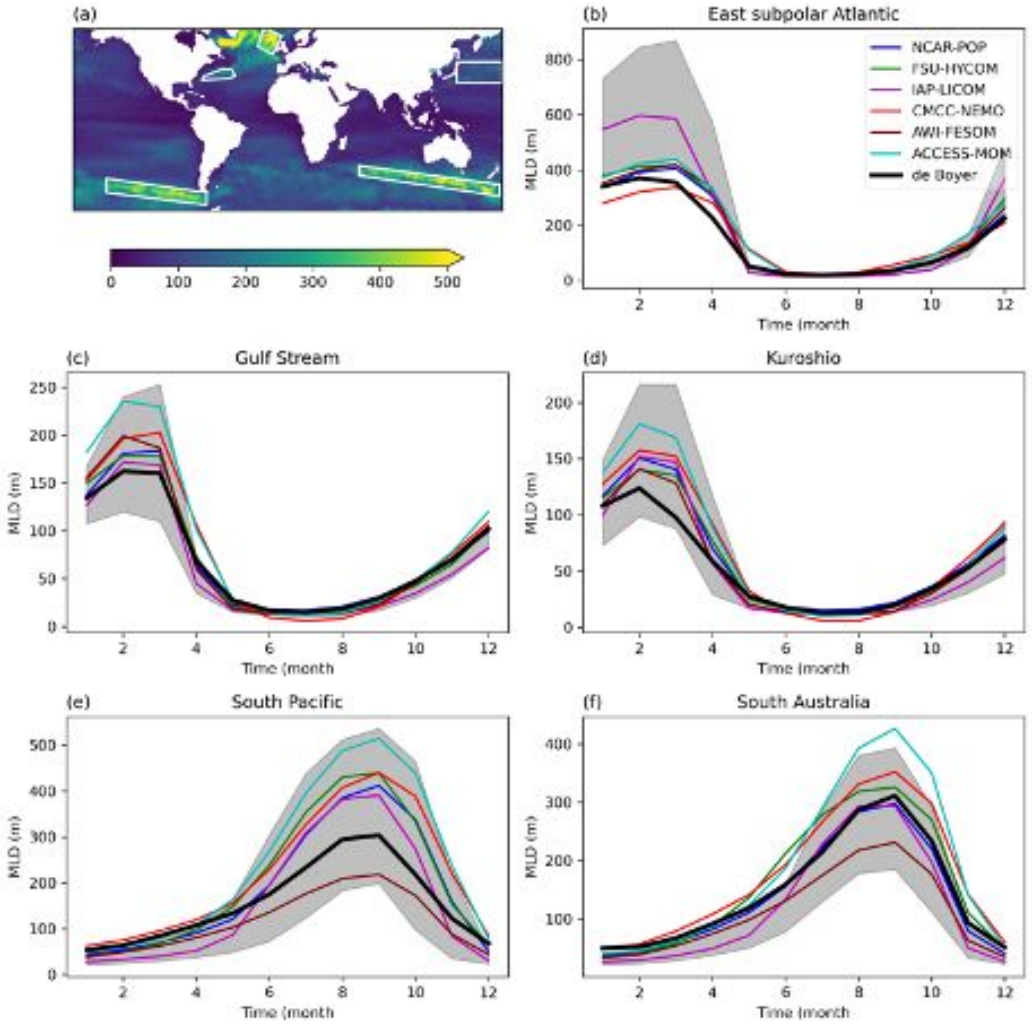
Mixed layer heterogeneity and its representation in models



Analysis of 6 pairs of OMIP forced global models

- Models reproduce well the asymmetric seasonal cycle (rapid restratification, slow destratification).
- High res model solutions are better in the Eastern Subpolar Atlantic, Kuroschio, Gulf Stream.
- No uniform improvement in the Southern Ocean
- Eddy rich models tend to have a shallower mixed layer compared with low resolution (1°) models.

(Treguier et al, GMD, 2023)

Eddies shape the mixed layer in the Labrador sea

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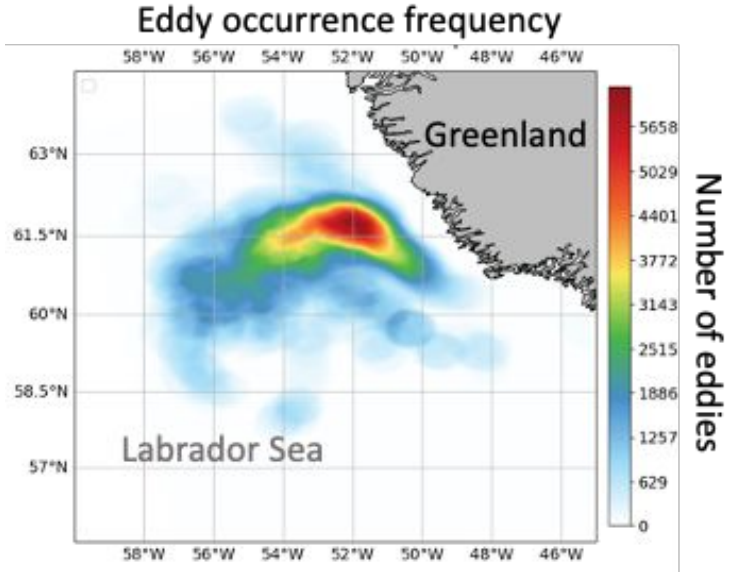
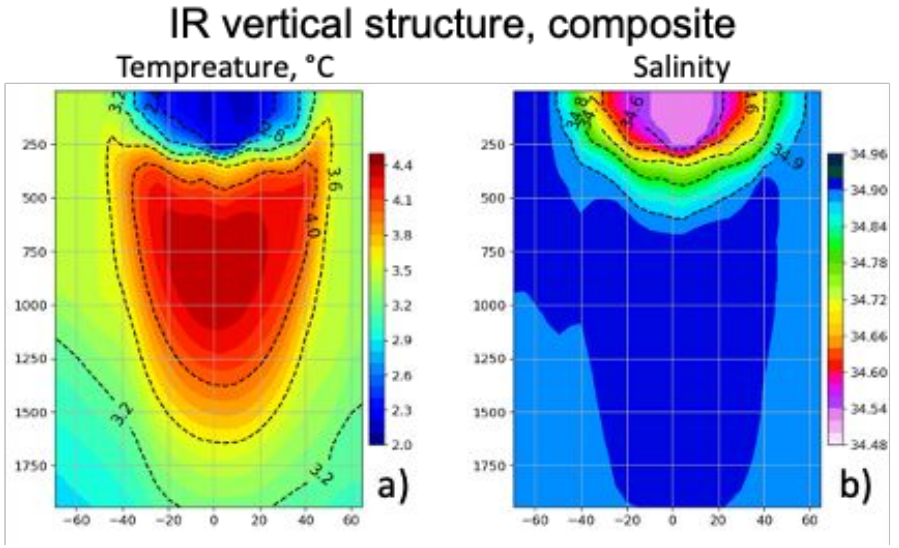
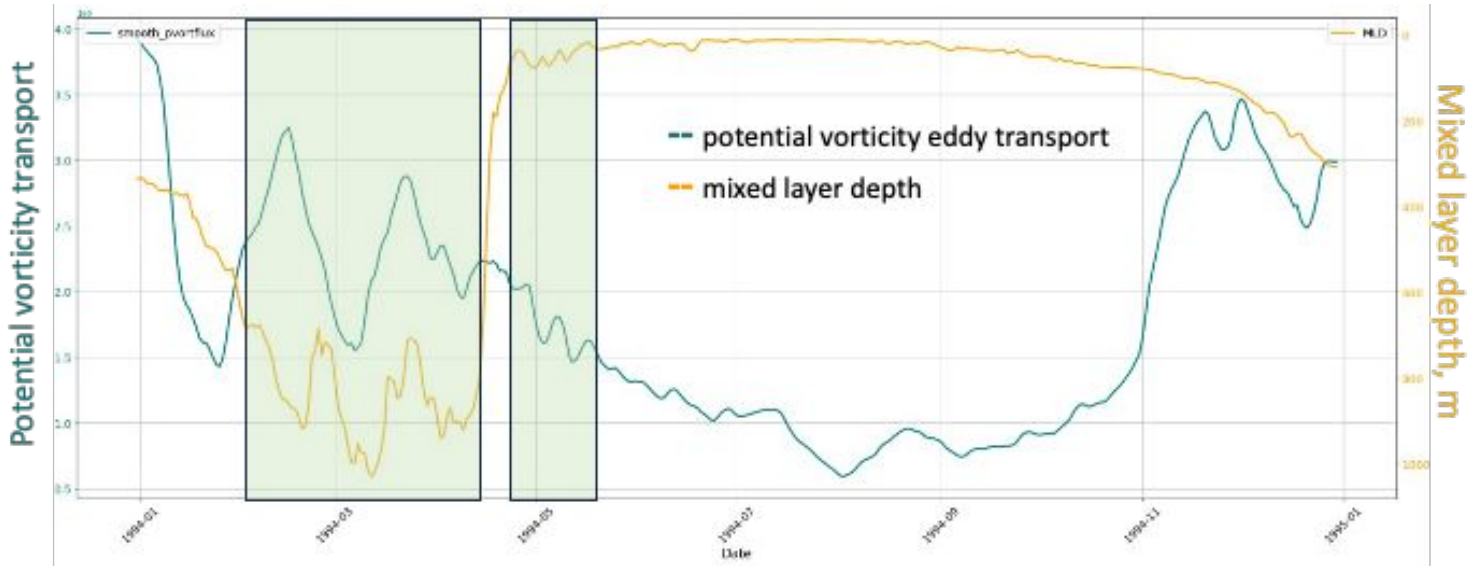


PV is a measure of water static stability:

$$PV = (\xi + f)N^2/g$$

Advection of static stability by IRs shifts MLD





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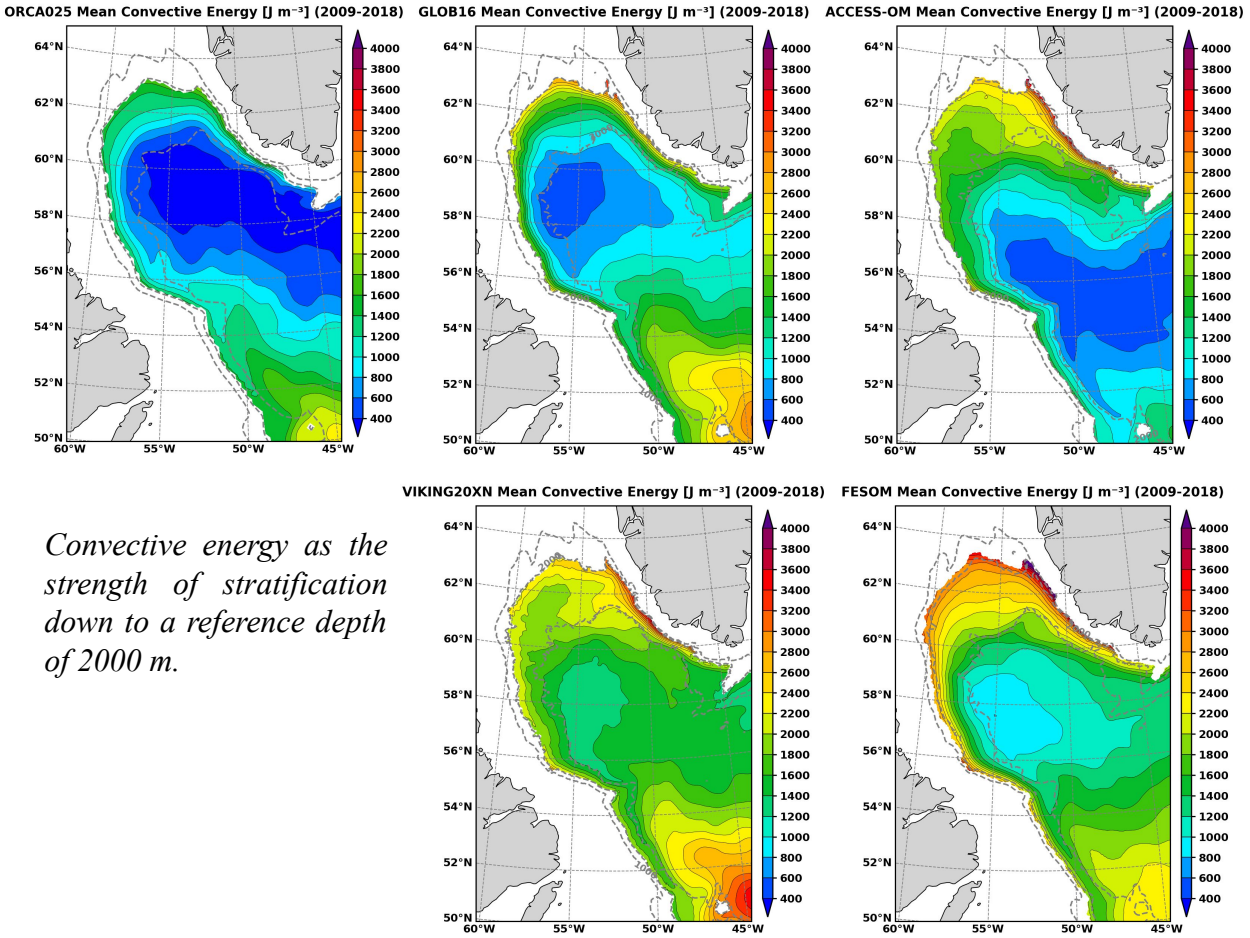
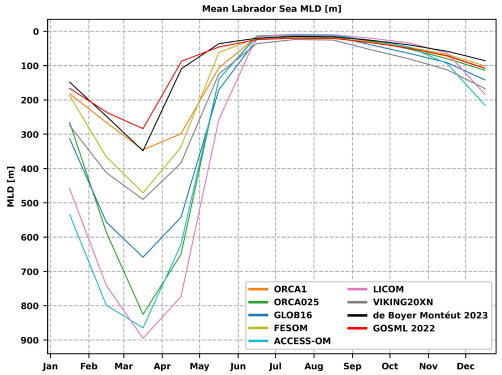
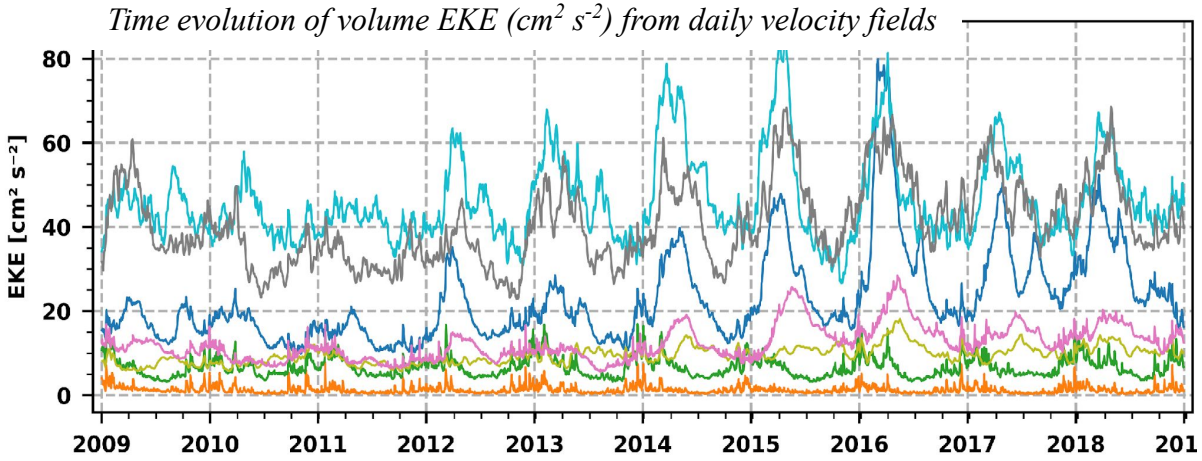
Mesoscale modulation of water formation in the Labrador Sea



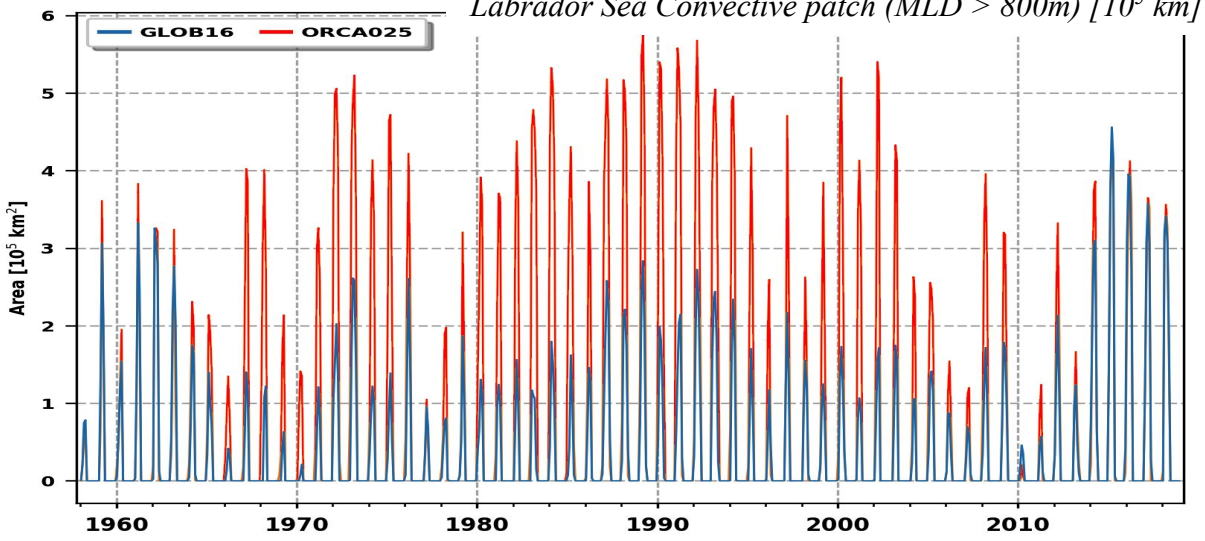
Convective energy as the strength of stratification down to a reference depth of 2000 m.



Time evolution of volume EKE ($cm^2\ s^{-2}$) from daily velocity fields



Labrador Sea Convective patch (MLD > 800m) [10^5 km]



- **EKE averaged on the 3D basin confirms the impact of mesoscale.**
- **With few eddies resolved, the ORCA025 interior remains very weakly stratified across a wide region. At high-res, with more mesoscale features and stronger eddy fluxes from the Greenland coast, the convective energy is *generally* higher, and the spatial extent of the weakly stratified region is limited within the interior of the Labrador Sea.**
- **Convective area decreases as resolution increases, which combined with the shallower MLD, induces a reduction of the convective patch and volume.**

Many scientific results not shown here!

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Eddies and sea ice interactions : observations, idealized models, OMIP

- Observed Spatio-Temporal Variability of the Eddy-Sea Ice Interactions in the Arctic Basin (Cassianides et al, JGR, 2023)
- Eddy-driven heterogeneity in sea ice during the ice-growth season (Moreno et al, in revision in GRL)
- Evaluation of the MLD in OMIP models in sea ice (Allende et al, 2023)

Methodological advances

Mixed layer reconstruction by machine learning (Pauthenet et al, 2022)
A framework for evaluating ocean mixed layer depth evolution (Legay et al, JAMES, in revision)

Eddies and mixed layer instabilities in the North Atlantic

The scales of baroclinic and mixed layer instabilities in the North Atlantic revealed by a filtering method applied to a 1/60° model (Serazin et al in preparation)

Global perspective

- A new climatology of the upper ocean pycnocline (Serazin et al 2023)
- Multidecadal trends of mixed layer depth in OMIP models (Treguier et al, in preparation)

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Conclusions

Some changes in plans

- Collaboration with Russia was delayed, but is ongoing
- Instead of a summer school, Mixed layer sessions were held at EGU for 3 consecutive years

Impacts

- New knowledge on the mixed layer heterogeneity in the global ocean, the Labrador Sea, and under sea ice;
- New datasets from observations for model validation (mixed layer depth, upper ocean pycnocline) ; a framework for evaluating MLD evolution in models
- Progress in understanding the role of parameterizations in the NEMO model
- Recommendations for the computation of mixed layer depth in CMIP

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