Future numerical developments in FESOM

FESOM2
Finite volumE
Sea ice-Ocean Model

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Many important extensions in the dynamical core of FESOM are planned.

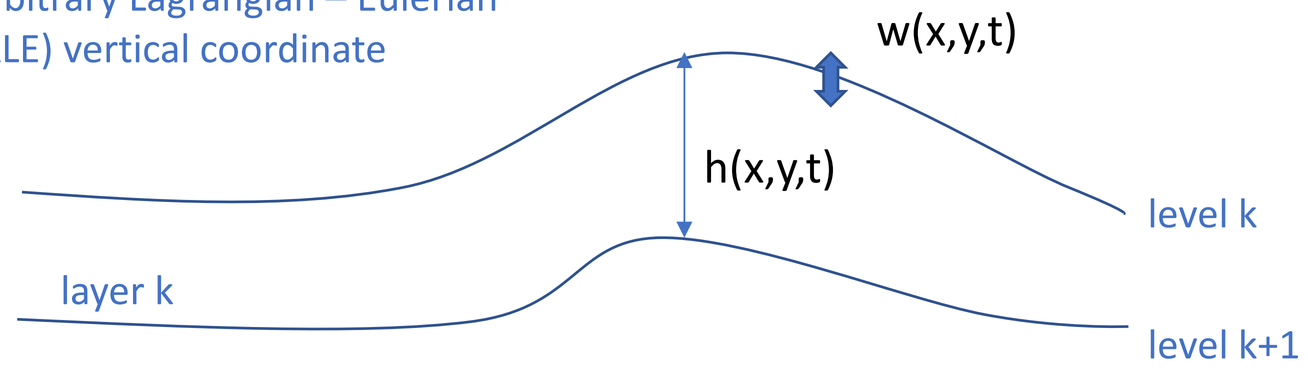
A part of activity is funded through TRR181 (Energy Transfer in Atmosphere and Ocean)

In last years our focus in the dynamical core part was on:

The Arbitrary Lagrangian Eulerian (ALE) vertical coordinate
and vertical mixing parameterizations (P. Scholz).

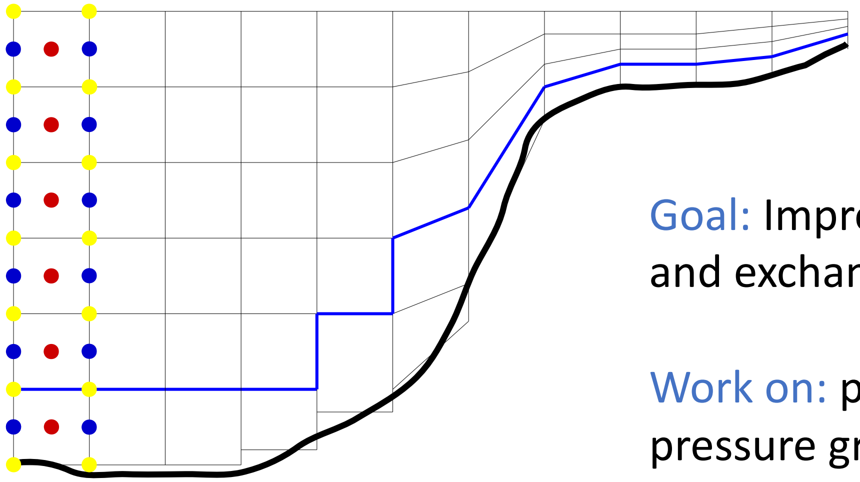
Viscosity, backscatter parameterization (S. Juricke) and advection

Arbitrary Lagrangian – Eulerian
(ALE) vertical coordinate



ALE vertical coordinate is a framework:
Many possibilities, but each requires additional work.
At present: Full free surface, z* vertical coordinate and partial bottom cells

We will work on:
Vanishing quasi-sigma (terrain following) coordinate

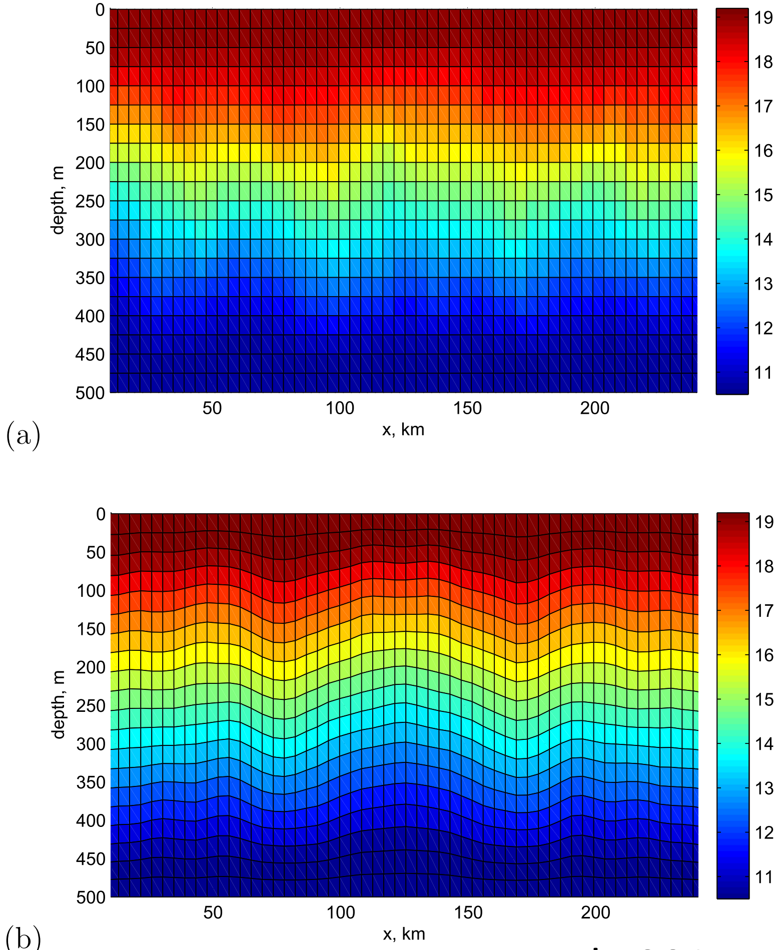


Goal: Improve representation of overflows and exchanges between shelf and deep ocean

Work on: parameterizations (vertical and eddy mixing), pressure gradient errors, stability.

Time line: Within TRR181

Erosion of isothermal surfaces in
z vs. isopycnal coordinate models



Petersen et al., 2015

Use ALE to enforce that deep layers approximately follow isopycnals

Goal: Reduce spurious mixing, increase stability and time step

Steps:

- Time stepping (workflow) algorithm
- Monotone layer thickness advection
- High-order finite-volume pressure gradient force computation
- Design of layer motion algorithms

There are good examples (MPAS-o and MOM6) to follow

z-tilde vertical coordinate: Split div **u** into high and low frequency component. High -> thickness update,
Low -> vertical exchange velocity.

Time line: TRR181 and beyond

New time stepping algorithms:

Split-explicit method to solve for surface elevation instead of implicit method and iterative solvers

Motivation: Reduced dissipation (New algorithms with reduced damping were proposed recently)

Runge-Kutta time stepping in 3D part

Motivation: Better stability and monotonicity of solutions (NEMO, MOM6, new models of the atmosphere)

Momentum advection: Vector-invariant form and high-order flux form will be added.
Motivation: at high resolution the exchanges between MKE and EKE are strongly affected by damping build in momentum advection.

Time line: 2021 (split-explicit), RK – depending on the ALE activity, momentum advection 2021-2022.

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Advanced multi-tracer techniques:

1. Advection depending on tracer type
2. Other (than FCT) technologies to ensure nearly monotone solutions (slope limiting or WENO)
3. Algorithms optimized for multiple tracers (conservative remapping)
4. Longer time steps for passive tracers (questionable for eddy resolving simulations)
5. Mesh agglomeration techniques (9 cells combined to one in NEMO => more than 10 times reduction in costs)

Advection in FESOM:
3rd or 4th order methods +FCT for T,S

Using 2nd order for passive tracer +FCT will make advection 25% cheaper

Using matrix form of advection operator may bring further speed up.

Motivation: Increase throughput for runs with biogeochemistry.

Time line: 1 – 2021, 2 – TRR181 , 3, 4, 5 - ???

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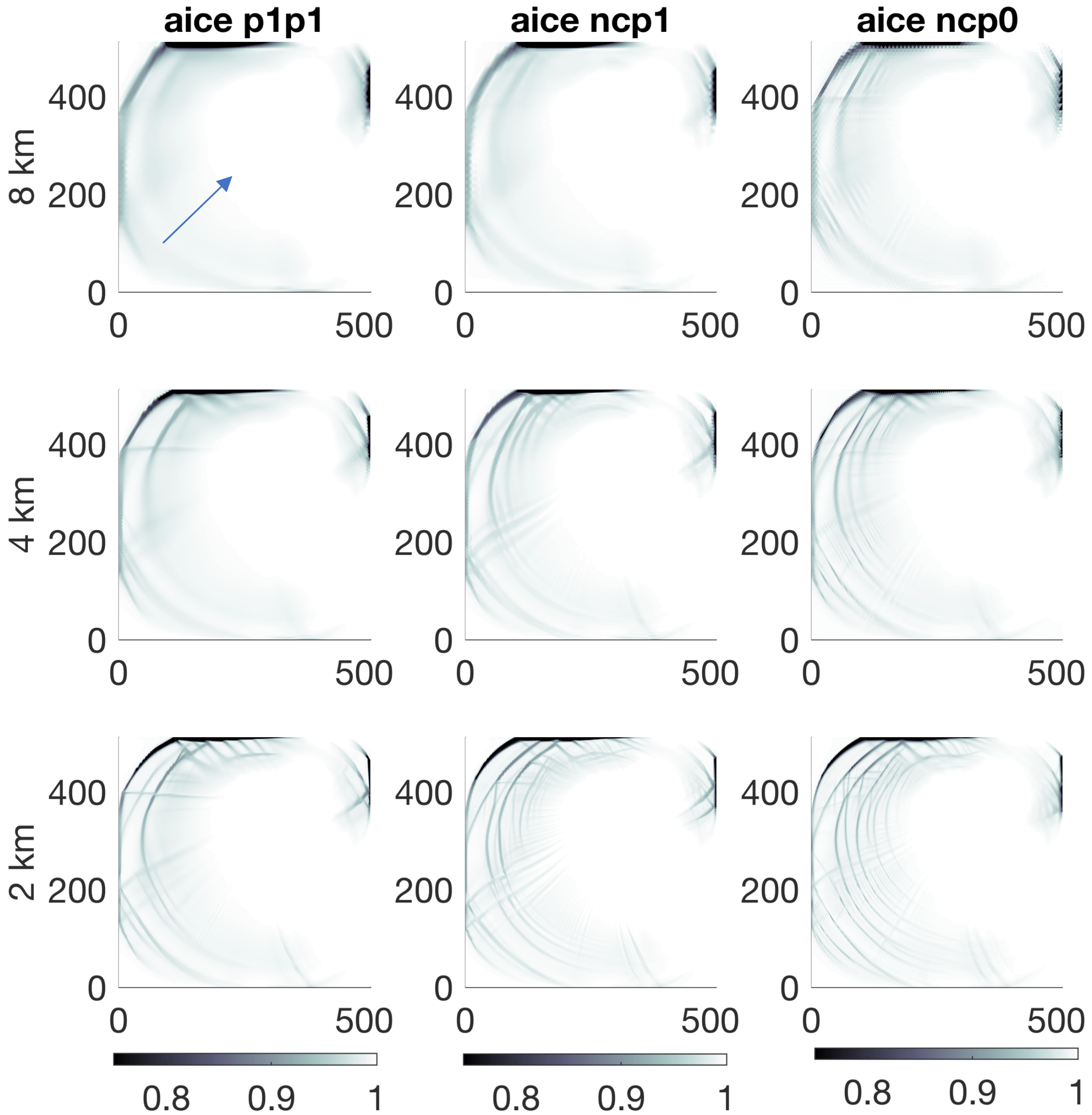
Sea ice concentration in tests



Higher effective resolution in sea-ice dynamical core (more LKFs)

Time line: 2021

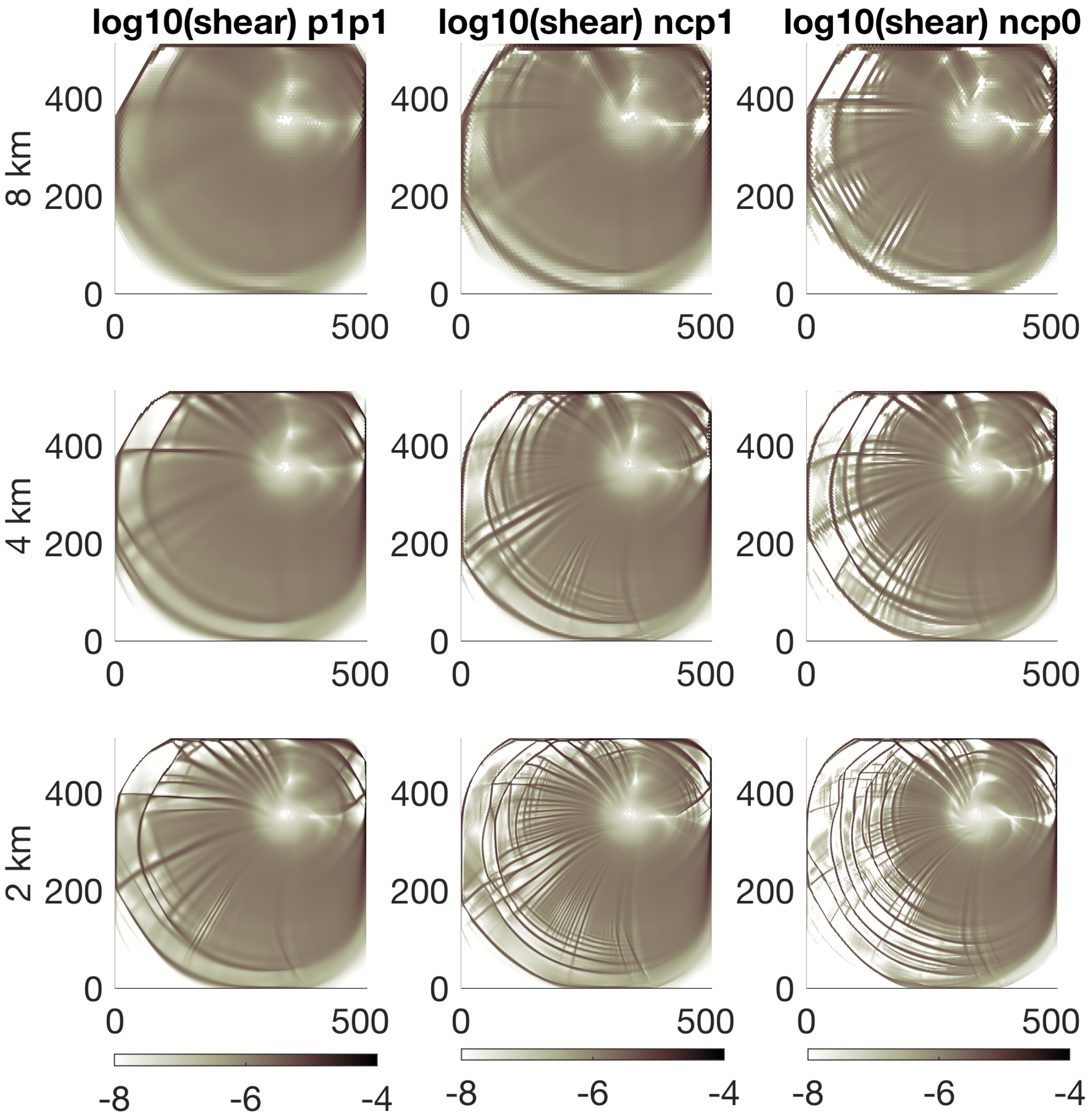
(velocity, scalar)
p1p1=(node, node)
ncp1=(edge, node)
ncp0=(edge, elem)

Sea ice breaks under the action of a moving cyclone (arrow). The domain is 512 by 512 km.

There are many other things (mixed meshes, parameterizations, …, modularization)

But:
Purely numerical part is only a fraction of effort needed to make the new technology practically useful.

More joint work is needed to fill it with life.


log10(shear) p1p1
log10(shear) ncp1
log10(shear) ncp0
8 km
4 km
2 km
400
200
0
0
500
-8
-6
-4