Postdoc subject : Parallel mesh adaptation for sea ice dynamic modelling.

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Location: Inria Bordeaux, Talence, France.
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Duration: 1 year renewable.

Understanding the dynamic of sea ice is of major importance in a global warming context. In particular, the withdrawal and thinning of Arctic sea ice is well documented, which has major environmental consequences as well as consequences on the ice dynamic itself. **The aim of the project is to enhance the computational capabilities of a sea ice dynamic model by leveraging mesh adaptation methods.** It involves a team of mathematicians from Bordeaux, France and a team of geophysicists from Grenoble France.

We consider the sea ice model neXtSIM [3], developed at Nansen Environmental and Remote Sensing Center (Bergen, Norway) and Institute of Environmental Geosciences (Grenoble, France), a novel model aimed at modelling complex sea ice dynamic in a large range of scales, from local short-term predictions to global climate prediction simulations. The specificity of neXtSIMis the use of a purely Lagrangian advection formalism on fully unstructured meshes coupled with a novel rheologic frameowrk, that has given promising results [4], see Fig. 1. Such a Lagrangian approach results in strongly deformed meshes over time, in particular in the vicinity of cracks due to the ice displacement. A remeshing step is thus necessary to locally replace stretched or invalid mesh elements and restore the quality of the mesh. However, unlike the rest of the code that was parallelised recently for distributed memory architectures using MPI, the remeshing stage remains sequential, thus strongly impacting the performance of the code. Besides, the current remeshing does not yet take advantage of modern anisotropic mesh adaptation techniques [2], that aim at optimising the size and orientation of the mesh elements to minimise a certain numerical error estimate, see Fig 2, and makes it possible to reduce the computationnal cost while increasing the accuracy. The goal of the collaboration is to leverage these methods to accelerate simulations to be able to repeat easily large-scale high-resolution simulations and study the ice trajectories statistically.

The role of the postdoc will be to study theoretical, algorithmic and parallel implementation aspects of anisotropic mesh adaptation in neXtSIM. The main identified tasks are :

1. Study error estimates for sea ice dynamics. The litterature contains many numerical error estimates to drive mesh adaptation in more or less specific contexts. Existing error models will have to be benchmarked, and a novel estimate derived if need be.

2. Design and implement a mesh adaption algorithm in neXtSIM. This includes the development of a parallel version of remshing software MMG2D. MMG [1] is an open-source remeshing software suite supported by an industrial consortium hosted at Inria. The 3D version is already parallelised and will be used as a basis for the parallelisation of the 2D code.

3. Demonstrate the efficiency of the approach by running large scale simulations.

References

[1] MMG Platform – Upgrade your meshes. `https://www.mmgtools.org`.

[2] F. Alauzet and A. Loseille. A decade of progress on anisotropic mesh adaptation for computational fluid dynamics. *Computer-Aided Design*, 72:13–39, 2016.

[3] P. Rampal, S. Bouillon, E. Ólason, and M. Morlighem. nextsim: a new lagrangian sea ice model. *The Cryosphere*, 10(3):1055–1073, 2016.

[4] P. Rampal, V. Dansereau, E. Olason, S. Bouillon, T. Williams, A. Korosov, and A. Samaké. On the multi-fractal scaling properties of sea ice deformation. *The Cryosphere*, 13(9):2457–2474, 2019.

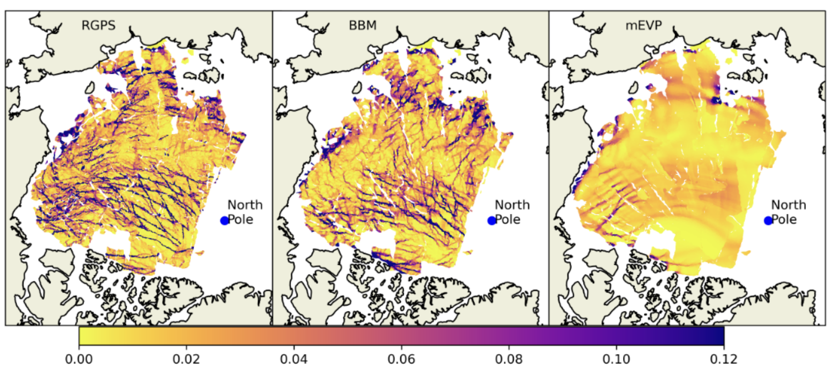

Figure 1: Shear deformation field (/day) of the Arctic sea ice computed over 3 days circa Feb. 2nd 2007 from satellite data (left), and output by neXtSIMusing the new rheology model (center) and standard "state-of-the-art" rheology model from the literature.

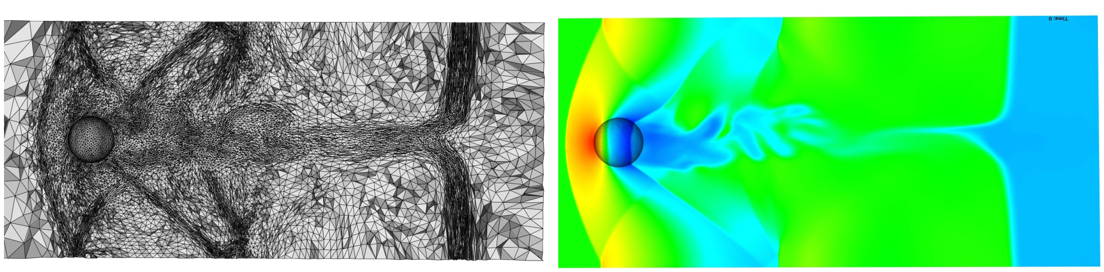

Figure 2: Adaptive simulation of a translating ball in a 3D shock tube (compressible Euler equations). Snapshots of the adapted tetrahedral mesh (left) and density field driving the adaptation (right).