Analysis and optimization of Schwarz algorithms for ocean - sea ice - atmosphere coupling

Master research internship proposal

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Keywords PDEs, Schwarz algorithm, numerical simulation, ocean-sea ice-atmosphere interactions

Context Earth system models are at the heart of climate projections for the coming decades. These models are in fact made up of different numerical components (ocean, atmosphere, soils, ice caps, etc.) that interact with each other through boundary conditions. This coupling is achieved by ad hoc algorithms, one of the consequences being a lack of synchronization between the models.

This defect can be corrected by iterations. Current coupling methods can indeed be interpreted as a single iteration of a Schwarz algorithm, which should therefore be brought to convergence to obtain the exact solution. Recent works have implemented such a Schwarz algorithm in the two French climate models, and have shown that the lack of synchronization of the usual coupling methods impacts the representation of high frequency phenomena in the climate models, but also seems to have significant consequences on the longer term statistics.

One objective is now to implement this Schwarz algorithm in an operational way in climate models. However, to do so, we must reduce its cost and thus accelerate its convergence. If this is on the way to being achieved for the ocean-atmosphere coupling, a very specific difficulty appeared during the test simulations at the edge of the sea ice zones, i.e. in the transition regions between open ocean and sea ice. In these regions, we have indeed observed a very slow convergence of the algorithm, which requires dozens of iterations.

Objectives In this context, the objective of this work is to analyse and optimize the Schwarz algorithm for this coupled ocean - sea ice - atmosphere problem. A first step will consist in deriving a simplified 1-D vertical system of equations retaining most of the slow convergence phenomena. This system will then be analyzed from the point of view of Schwarz methods, in order to understand the observed slow convergence, and to imagine possible improvements. Numerical experiments will be performed. Implementations will also perhaps be performed in a 1-D version of the Météo-France climate model and/or in the full 3-D IPSL climate model, depending on the availability of our colleagues in these labs.



Prerequisites some knowledge in PDEs and numerical analysis, programming skills

References

Marti O., S. Nguyen, P. Braconnot, S. Valcke, F. Lemarié and E. Blayo, 2021 : A Schwarz iterative method to evaluate oceanatmosphere coupling schemes. Implementation and diagnostics in IPSL-CM6-SW-VLR. *Geoscientific Model Development*, 14, 2959-2975, https://doi.org/10.5194/gmd-14-2959-2021.

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