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Application of mixed least-squares FEM to study sea ice dynamics

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The behavior of sea ice has been studied for many decades. In order to model its viscous-plastic behavior at scales spanning several thousand kilometers, different numerical models have been proposed. Based on the established approach in [1], this contribution presents a simulation model for sea ice dynamics to describe the sea ice circulation and its evolution over one seasonal cycle. In course of that, the sea ice concentration and the sea ice thickness are considered, of which the physical behavior is governed by transient advection equations. Here, the sea ice velocity serves as coupling field.

Recently developed approaches base on a finite element implementation choosing a (mixed) Galerkin variational approach, see e.g. [2] and [3]. But therein, challenges may occur regarding the stability of the numerically complex scheme, especially when dealing with the first-order advection equations. Thus, we propose the application of the mixed least-squares finite element method, which has the advantage to be also applicable to first-order systems, i.e., it provides stable and robust formulations even for non-self-adjoint operators, such as the tracer equations (for sea ice thickness and sea ice concentration).

For solving the instationary sea ice equation the presented least-squares finite element formulation takes into account the balance of momentum and a constitutive law for the viscous-plastic flow. The considered primary fields are the stresses $\boldsymbol{\sigma}$, the velocity $\mathbf{v}$, the concentration A_{ice} and the thickness $H_{ice.}$ In relation, four residuals are defined for the derivation of a first-order least-squares formulation based on the balance of momentum, the constitutive relation for the stresses, and two tracer-equations. Different approaches can be made with respect to the approximation functions of the primary fields, i.e., choosing e.g. conforming (H(div) interpolation functions) or non-conforming (Lagrangian interpolation functions) stress approximations, while Lagrangian interpolation functions are chosen for the remaining fields. In order to compare such approaches, the box test case is utilized, cf. [3], which is well described in literature.

References:

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