Comparison of different calving laws using a level set method

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Objective

To study numerically, using Elmer/Ice, different calving laws in a MISMIP configuration [Asay-Davis et al., (2016)].

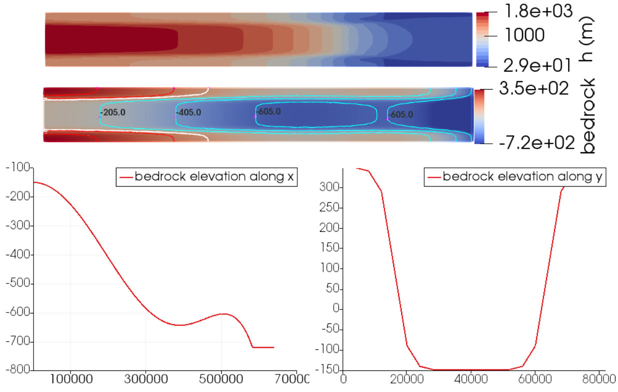

Figure: First row: Initial ice thickness; second and third rows: bedrock profile of the MISMIP+ configuration [Asay-Davis et al., (2016)].

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Level-set function

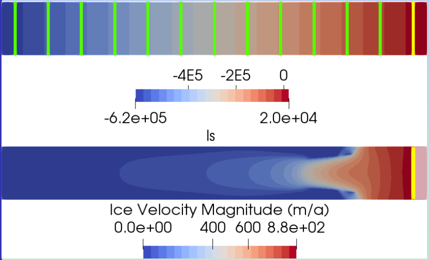

Figure: Top: Schema of the levelset function to represent the calving front in yellow. The equally spaced isolines are in green. Bottom: Ice velocity (SSA Aprox.)

The level-set function, ϕ:

- Distance to the front at $\phi = 0$
- Is signed as:

$$\phi(\vec{x}) : \begin{cases} < 0, & \text{if } \vec{x} \in \Omega_i \\ = 0, & \text{if } \vec{x} \in \delta\Omega_i \\ > 0, & \text{otherwise} \end{cases}$$

- Defines a mask for elements.
- Evolves $v_{front} = (\vec{v}_{ice}^{\perp} - c)$:

$$\frac{\partial \phi}{\partial t} + (\vec{v}_{ice}^{\perp} - c) \cdot \nabla \phi = 0 \quad (1)$$

Ice Sheet MISMIP+: Constant calving rate

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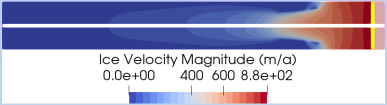
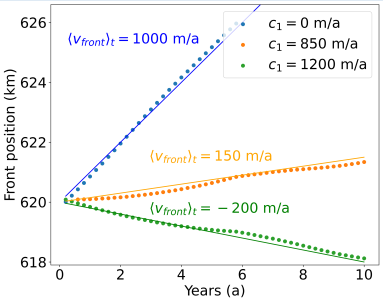
To test our solution we made three numerical experiments, departing from $x_c = 620km$ for a calving rate:

$$c = \begin{cases} c_1, & \text{if } z_{bed} < 0, \\ 0, & \text{otherwise} \end{cases}$$

with z_{bed} the bedrock elevation; with the following values:

$$c_1 : \begin{cases} = 0, \text{ then } v_{front} = v_{ice}, \text{ advance} \\ < v, \text{ then } v_{front} > 0, \text{ advance} \\ > v, \text{ then } v_{front} < 0, \text{ retreat} \end{cases}$$

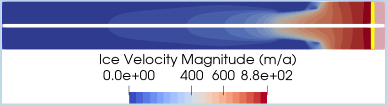


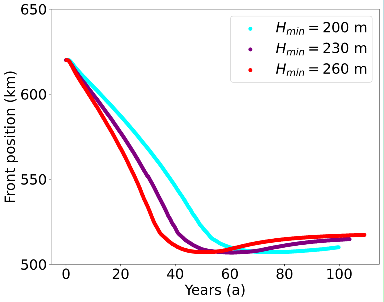


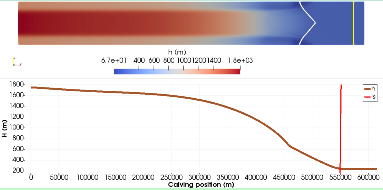
Test case: Cutoff based on thickness

Based on [Nick et al., (2010)], departing from $x_c = 620km$, we test the following calving law:

$$c := \begin{cases} 0, & \text{if } z_{bed} \geq 0 \\ \frac{H_{min}}{H} v_{ice}, & \text{otherwise} \end{cases}$$







Test case: Cutoff based on thickness and water depth

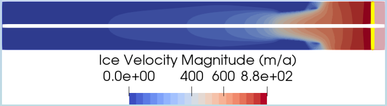
Based on [Ultee and Bassis, (2017)], departing from $x_c = 620$ km, we test the following calving law:

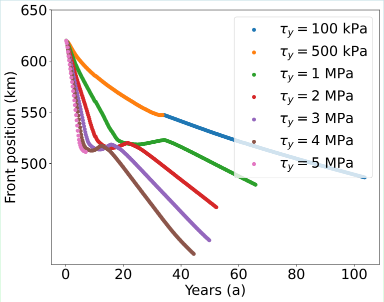
$$c := \frac{H_{min}}{H} v_{ice}$$

with H_{min} given as:

$$H_{min} = 2\frac{\tau_y}{\rho_i g} + \sqrt{\frac{\rho_w D^2}{\rho_i} + 2\frac{\tau_y}{\rho_i g}}$$

with, D, the water depth, ρ_i, the ice density, ρ_w the water density, and τ_y the stress value.





Conclusions and perspectives

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- Levelset implementation validated using a constant calving rate
- Two additional calving laws implented and tested using MISMIP+ setup
- Implementation of more realistic calving laws to come! Work in progress!
- Application to a real setup to come! Work in progress!

Thank you

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Evolution of the “central” grounding line position vs time

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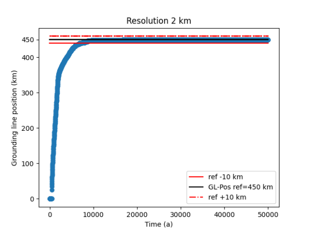

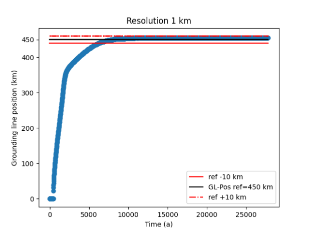

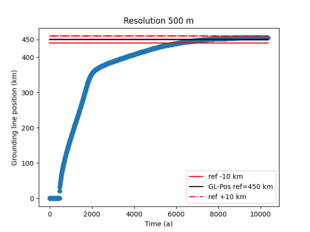

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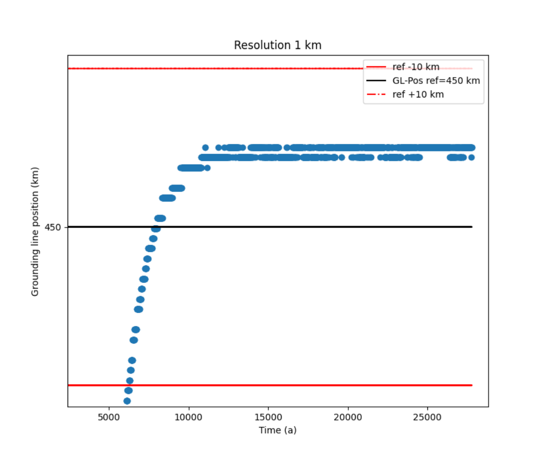

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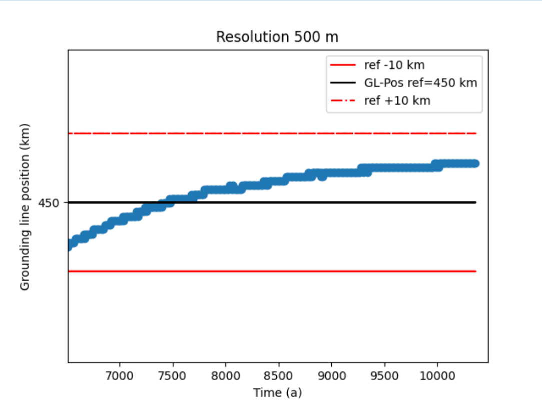

Impact of the calving position on the central ice velocity.

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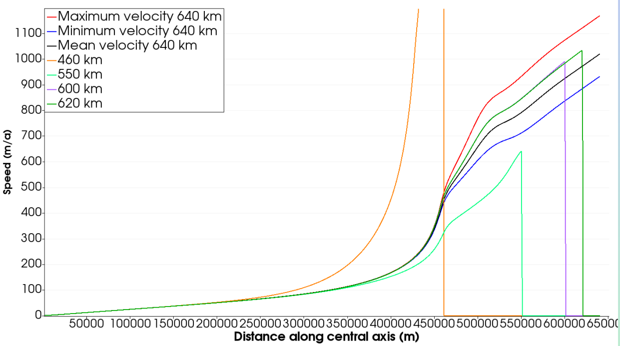

Figure: Comparison with the: maximum (red), minimum (blue), and average (black) velocity values for a calving front placed at 640 km.

Departing from any position after 600 km leads to a configuration with front velocities that remain in the normal oscillations of the fron velocity.