

High fidelity modeling of iceberg capsizes

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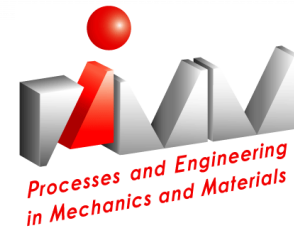
Anne Mangeney, IPGP-UPC

Olivier Castelnaud, PIMM-ENSAM

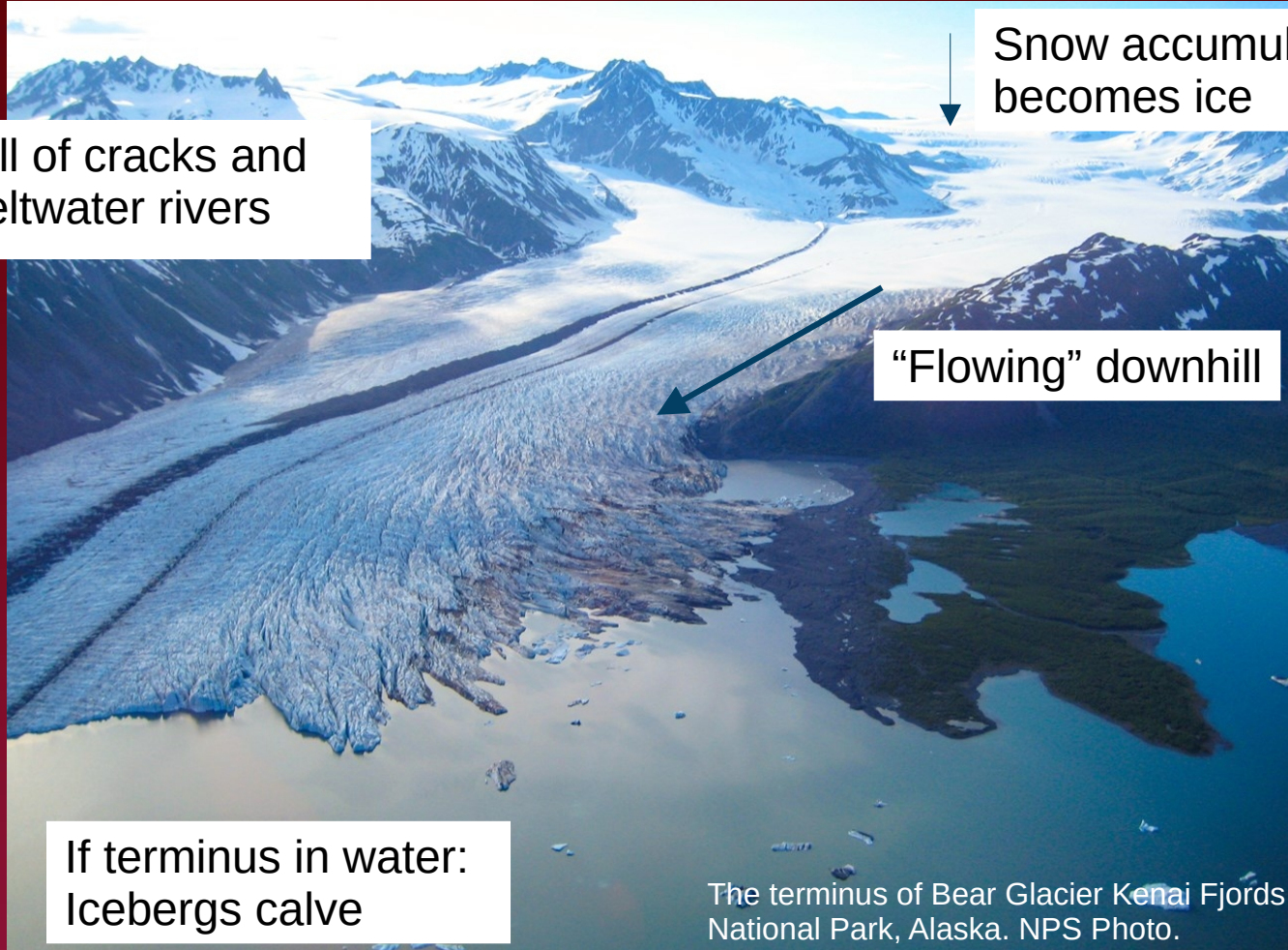
Jean-Baptiste Thiebot, Hokkaido University



**AGENCE
INNOVATION
DÉFENSE**



What is a glacier and Why do we care ?



Full of cracks and meltwater rivers

Snow accumulates and becomes ice

“Flowing” downhill

If terminus in water:
Icebergs calve

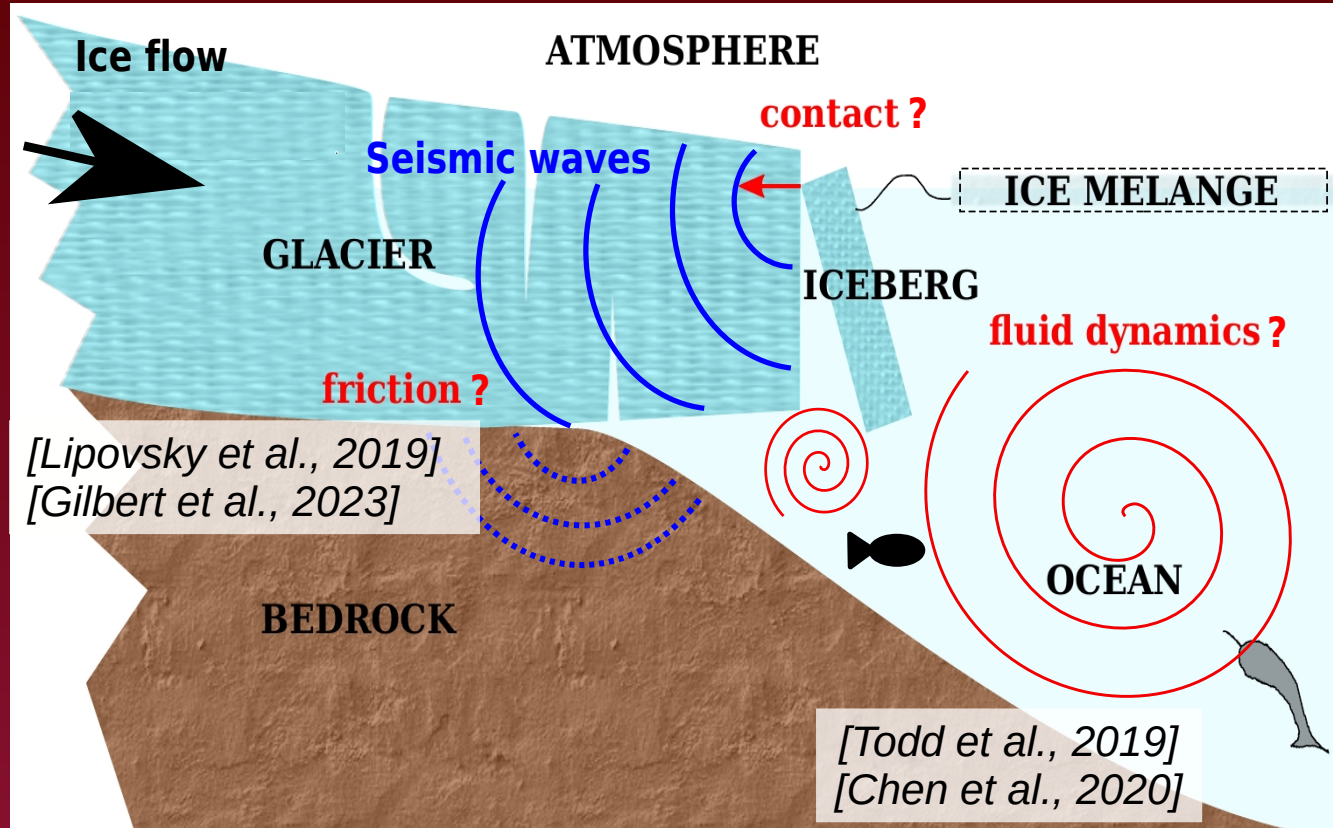
The terminus of Bear Glacier Kenai Fjords National Park, Alaska. NPS Photo.

Glaciers:
Contain 70% of Earth's fresh water

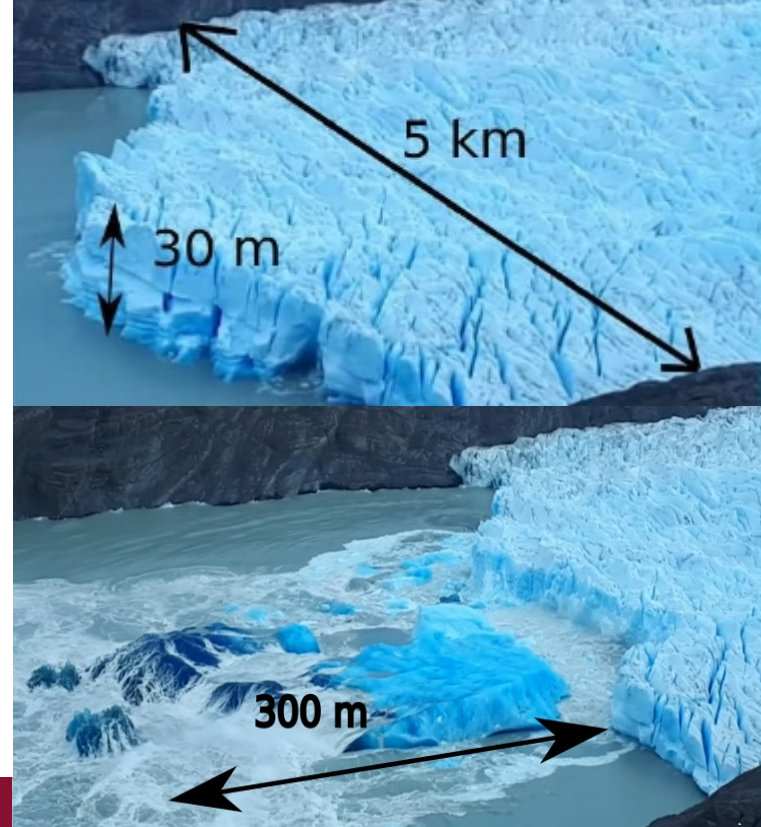
Fuel dams for electricity

Contribute to sea level rise:
15% in Greenland
Half of it from Iceberg calving !

Iceberg Calving & Capsize



<https://www.youtube.com/watch?v=RVwLHX6lgzQ>



How to monitor iceberg calving ?

Time-lapse imaging:

Cameras

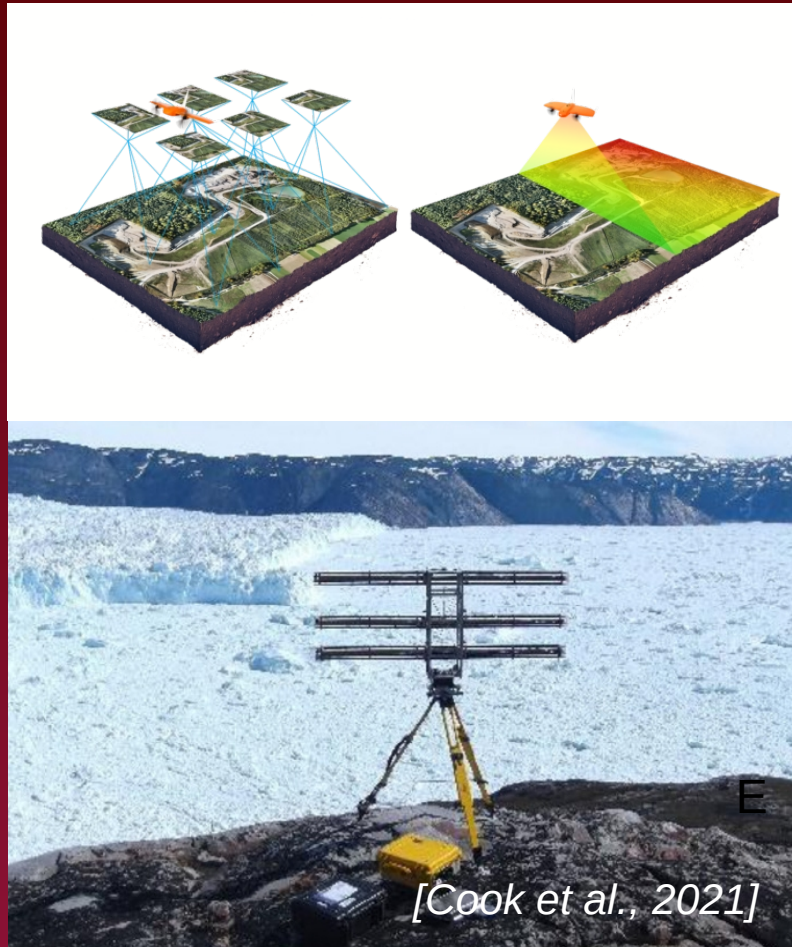
Aerial/space vehicles

Wave-related techniques:

Laser scanning

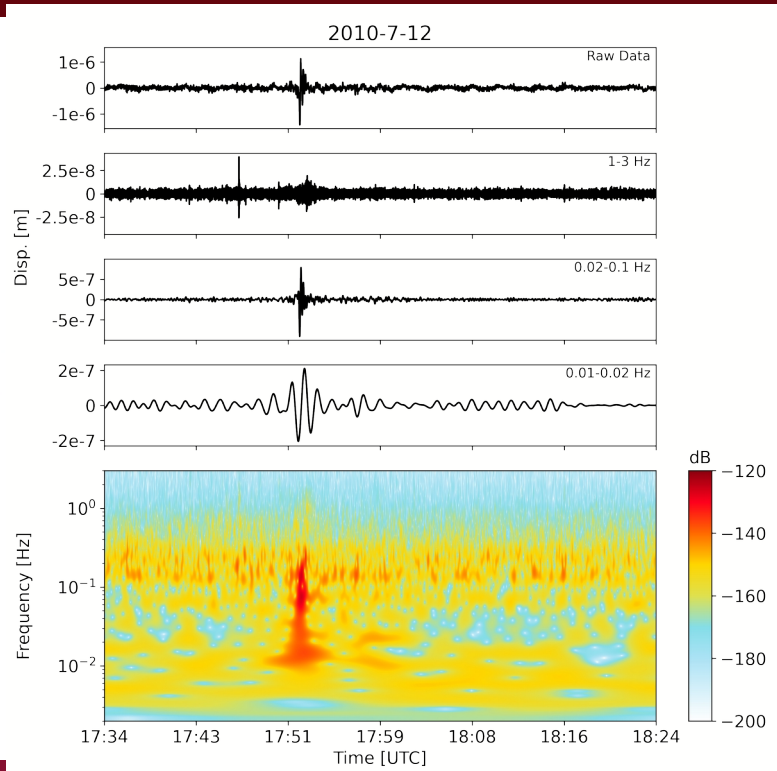
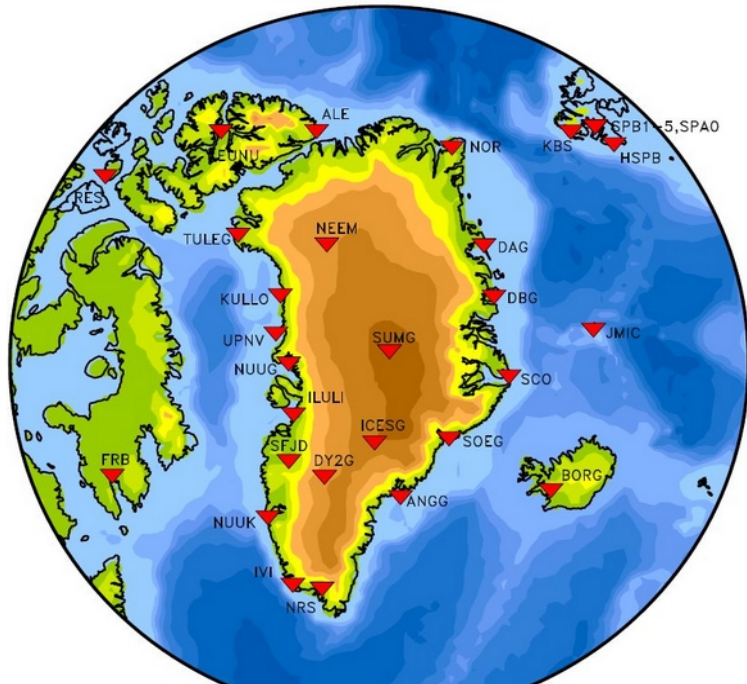
Interferometry

Hydrophones



Seismic signal for calving monitoring

GLISN stations



Work in progress !



Detection & Modeling

A. Sergeant,
P. Bonnet, E. Pirot,
S. Wetter
[Wetter et al.,
EGU2024]

Numerical model for capsizes

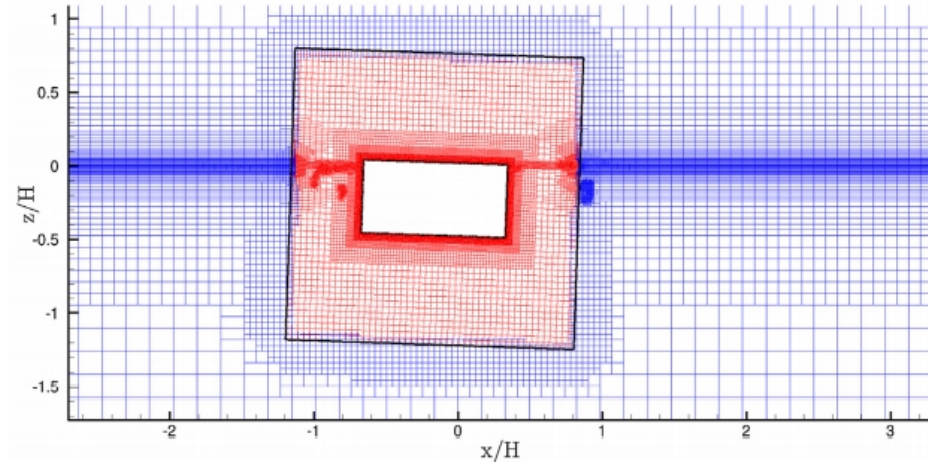
Fine/Marine, developed at EC-Nantes & distributed by Cadence Design
~30 y-old for Naval applications + Fluid-Structure interactions

Reynolds Average Navier-Stokes Equations
Cell centered unstructured **finite-volume** method

Interface capturing method [*Queutey & Visonneau, 2007*]

Arbitrary Lagrangian Eulerian formulation
[*Leroyer et al., 2008*]

Sliding grids [*A.A.B. Basara & D. Belder, 2004*]



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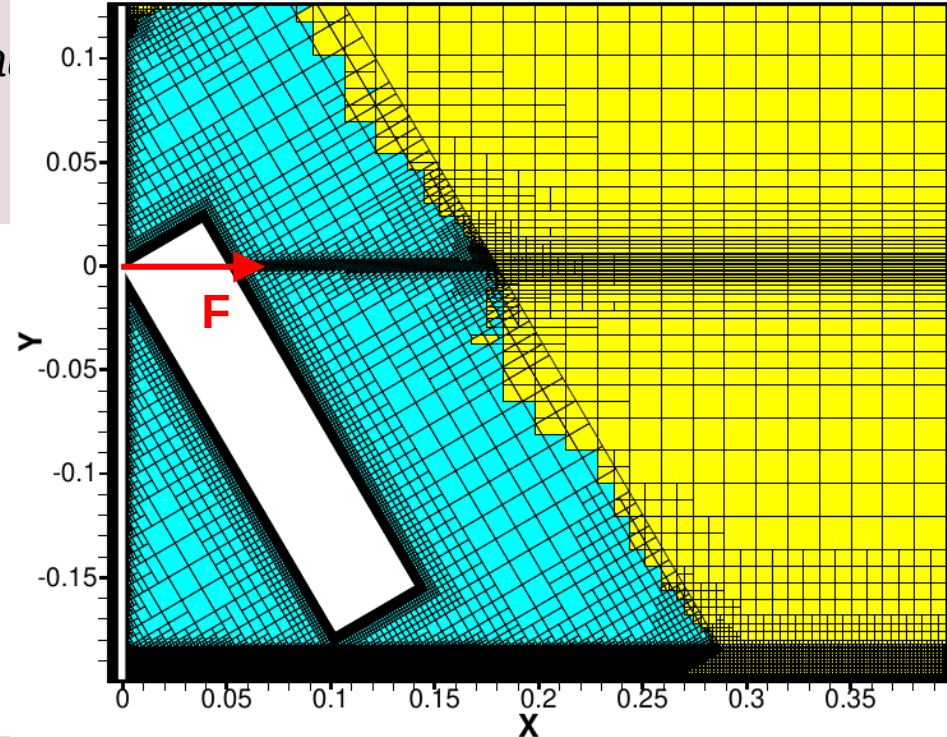
Spring-damper contact model :

$$|\mathbf{F}| = a|x_{\text{ice}} - x_{\text{wall}}|^2 + b|U_x|^2 \text{ for } x_{\text{ice}} < x_{\text{wall}}$$

[*Rengifo et al., 2009, Flores & Lankarani, 2016*]

Volume penalisation method $\propto U/dt^{1.5}$

[*Engels et al., 2015, Hester et al., 2021*]



Experimental database



Validation test cases

Reference lab experiments

Burton et al. 2012

Amundson et al. 2012

Murray et al. 2015

Open Ocean

Floating glacier

Grounded glacier

Iceberg height (H) in cm

10

10

20

Aspect ratio

0.5

0.5

0.22

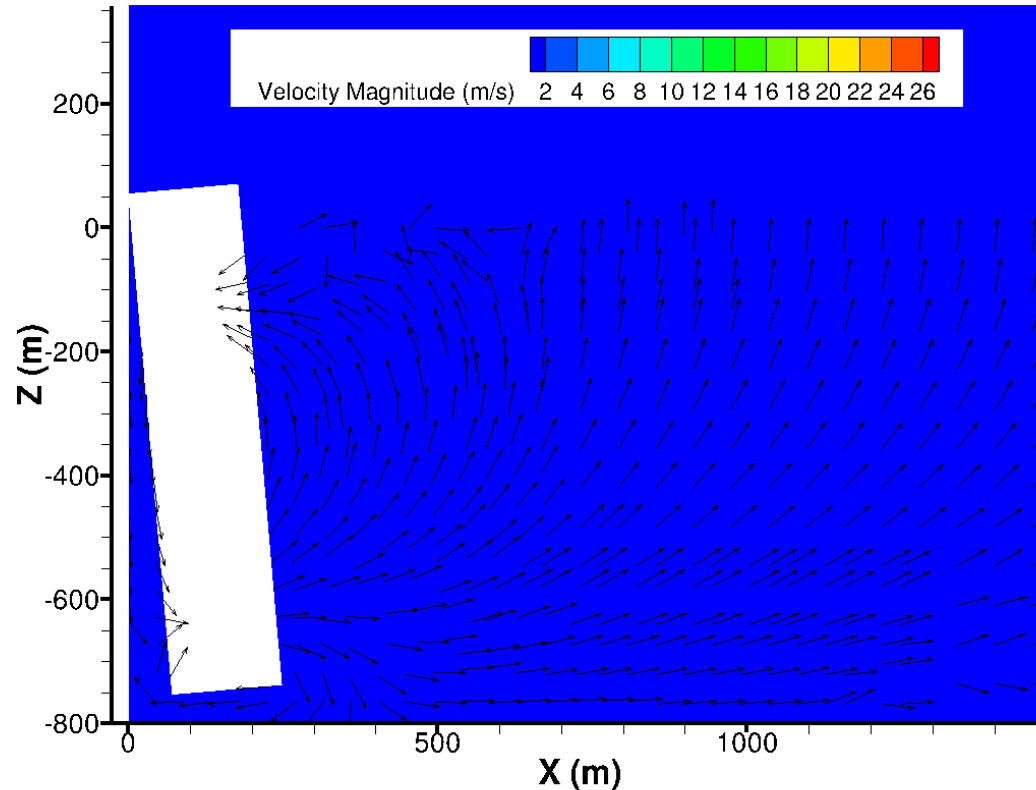
Quasi 2D experiments

Various quantities studied: Positions, velocity, energy, forces, pressure, stability.

Focus on dynamics to validate the model

What does the simulation look like ?

2D Grounded glacier simulation,
Height=800m, aspect ratio=0.22



Some Greenland
Glacier Thicknesses
at terminus :

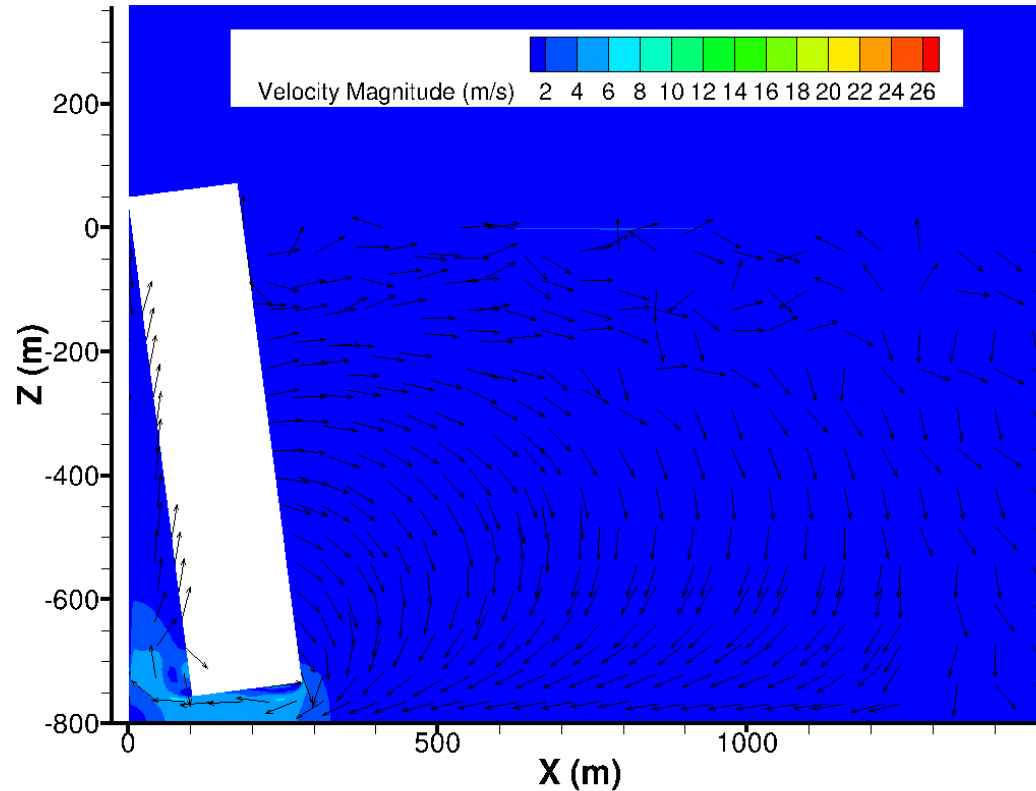
Helheim: 600 m

Jakobshavn: 600 m

Bowdoin: 300 m

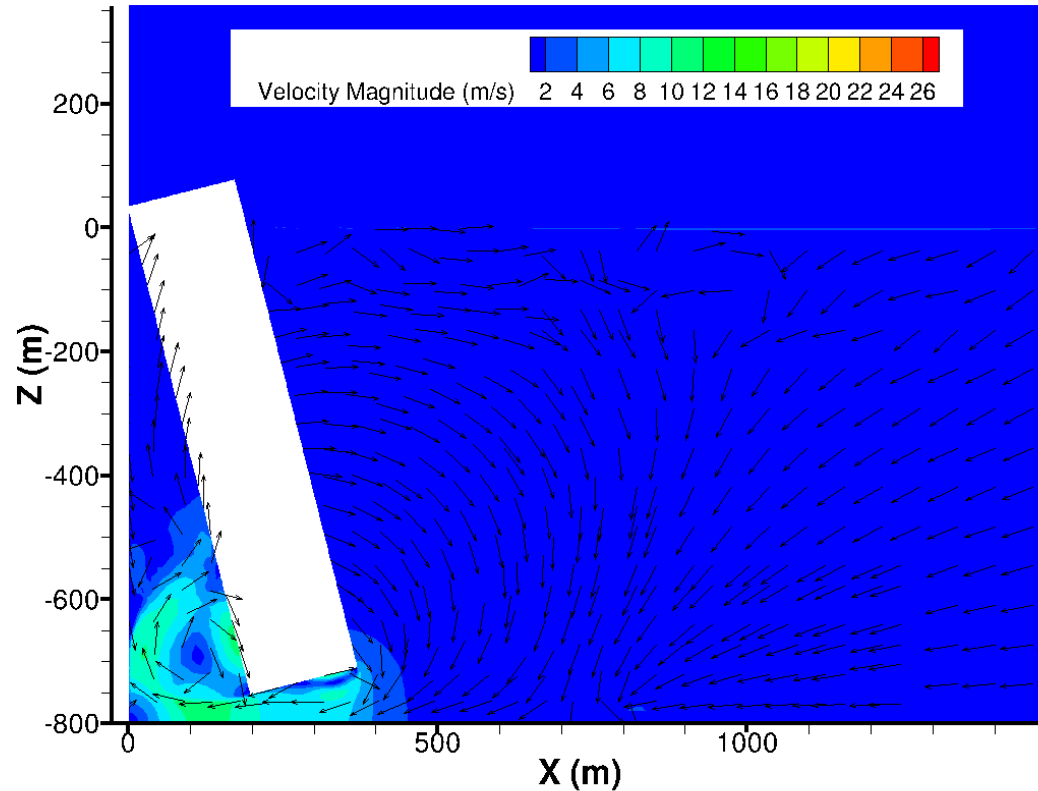
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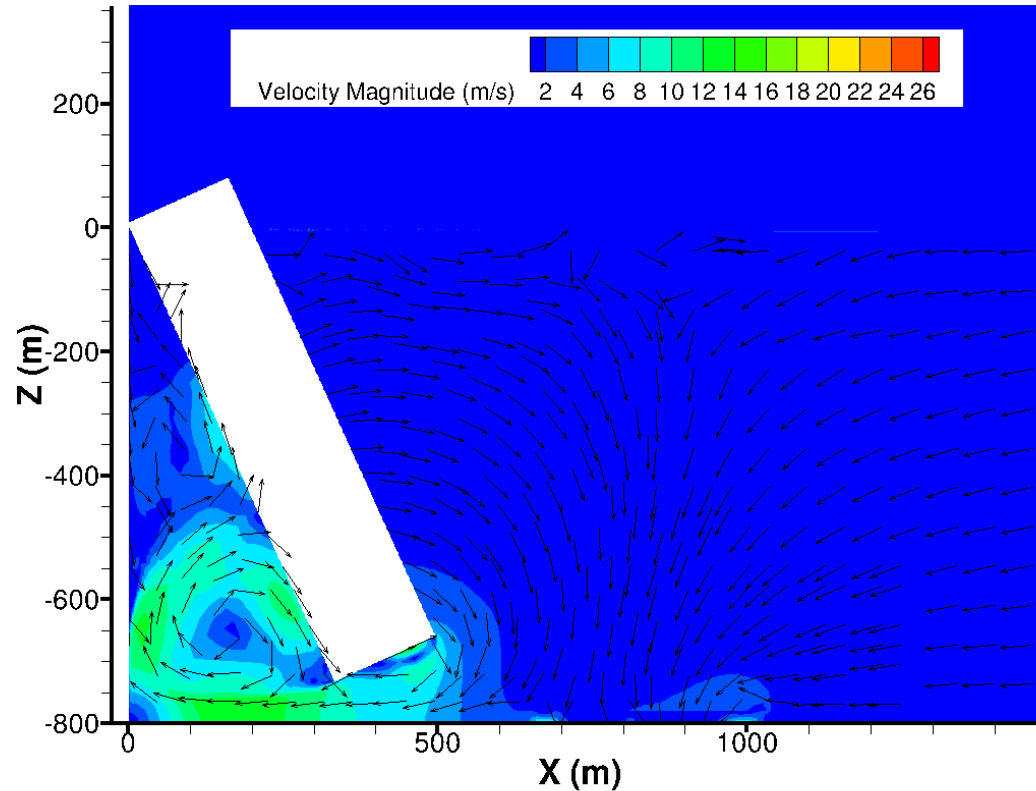
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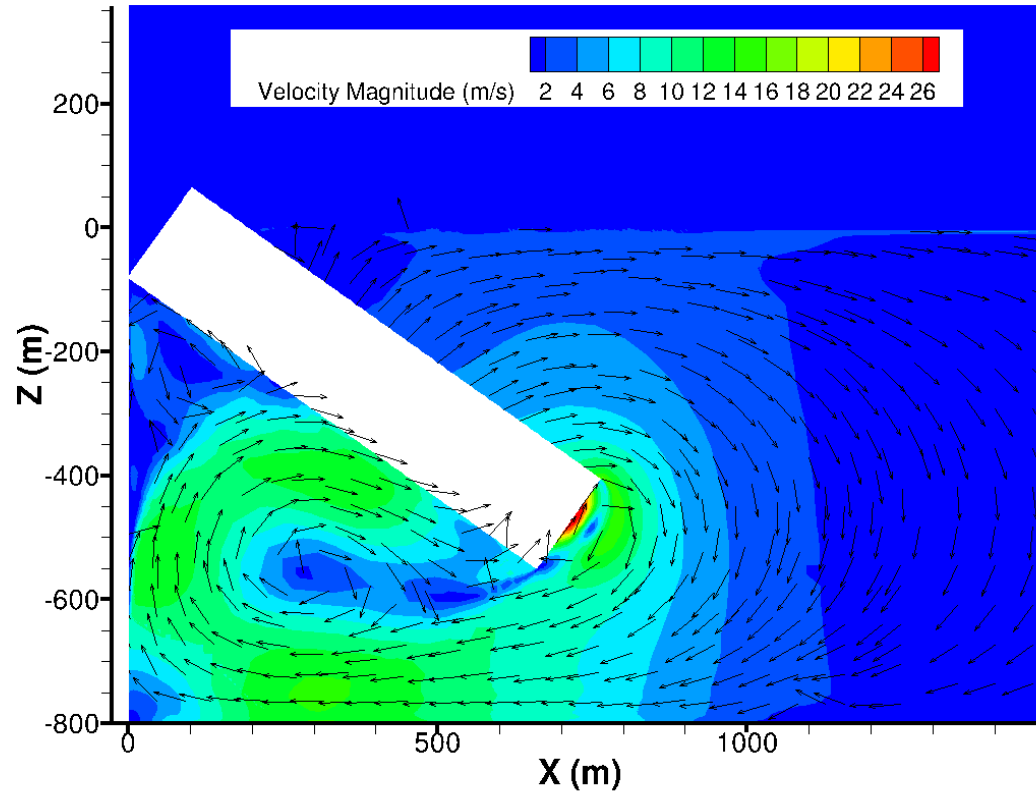
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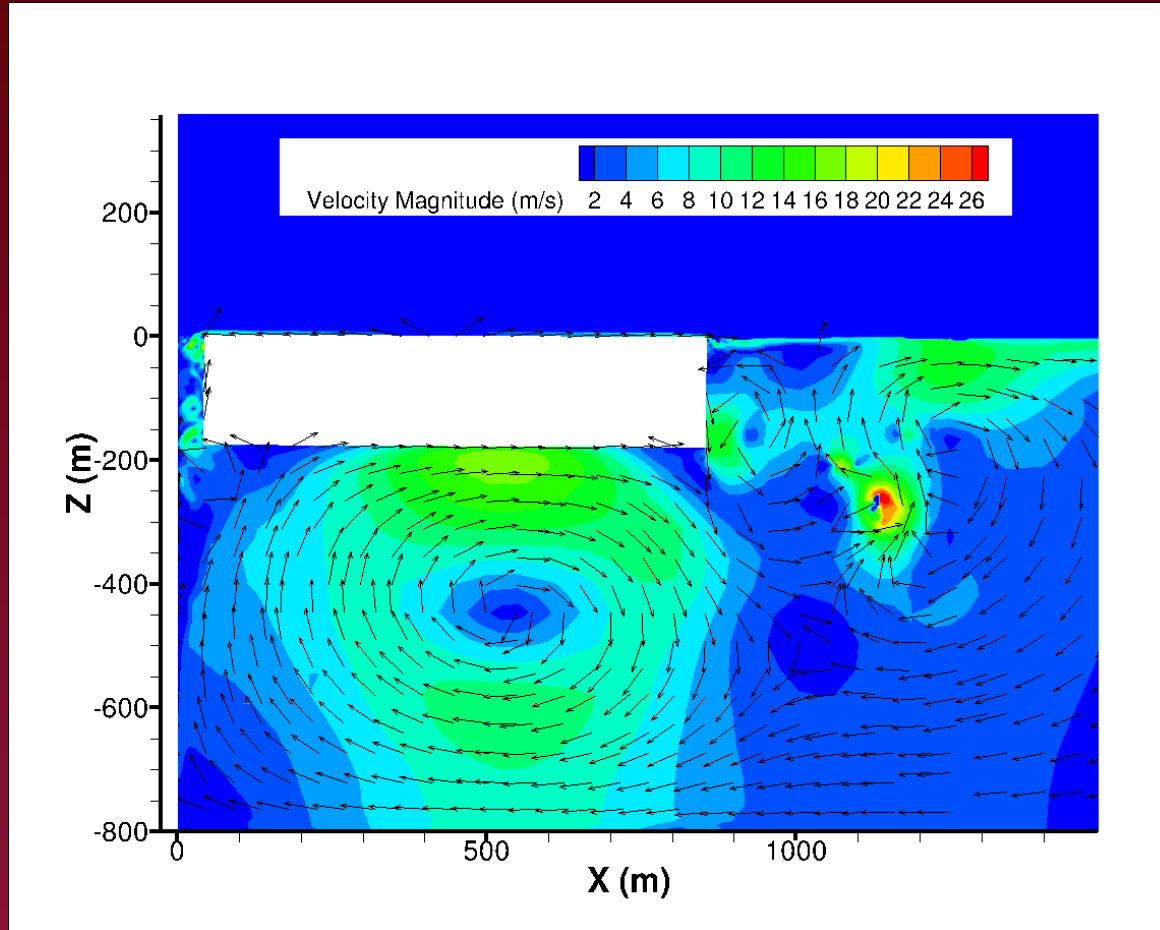
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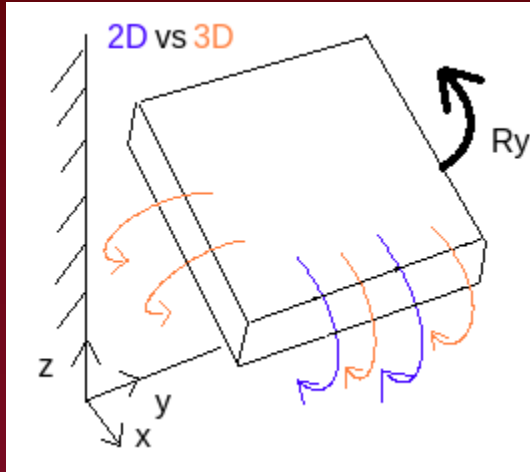


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Results !

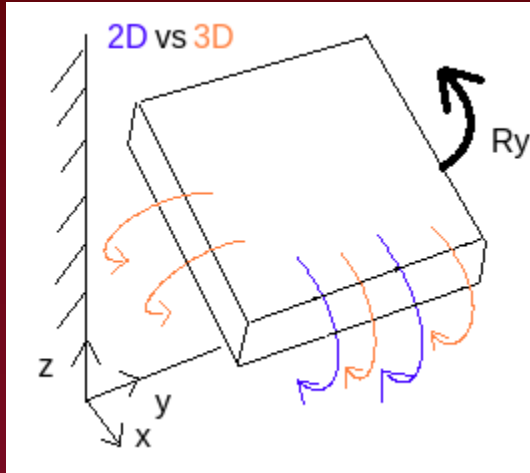


Open Ocean &
Floating Glacier ok

Grounded Glacier 2D ?

3D Effects more
important !

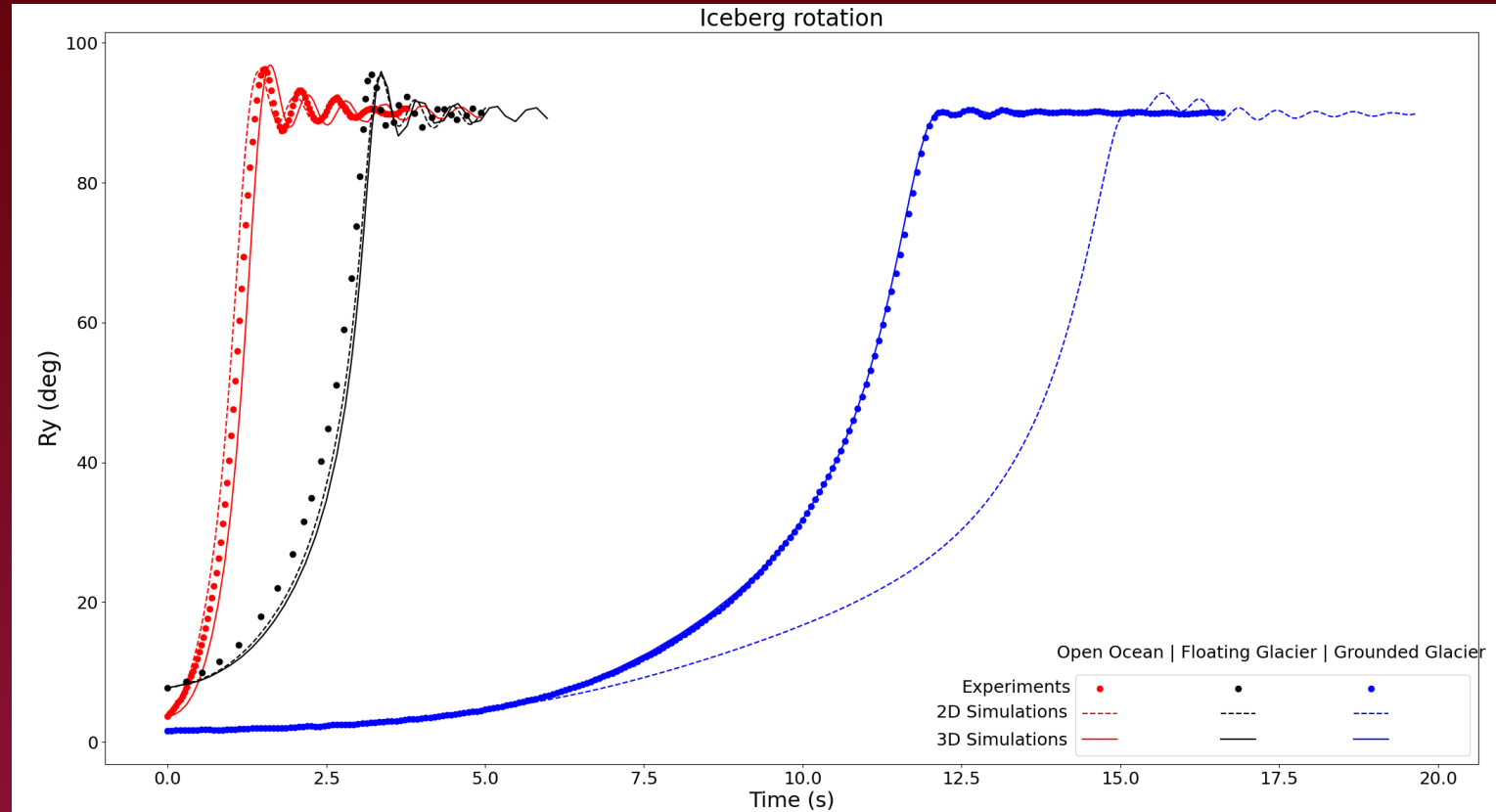
Results !



Open Ocean & Floating Glacier ok

Grounded Glacier 2D ?

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Application in biology



Birds feasting next to a glacier
in Svalbard [*Lydersen et al., 2013*]

Also observed after capsizes, Why ?

Are glaciers and icebergs natural
food dispensers ?

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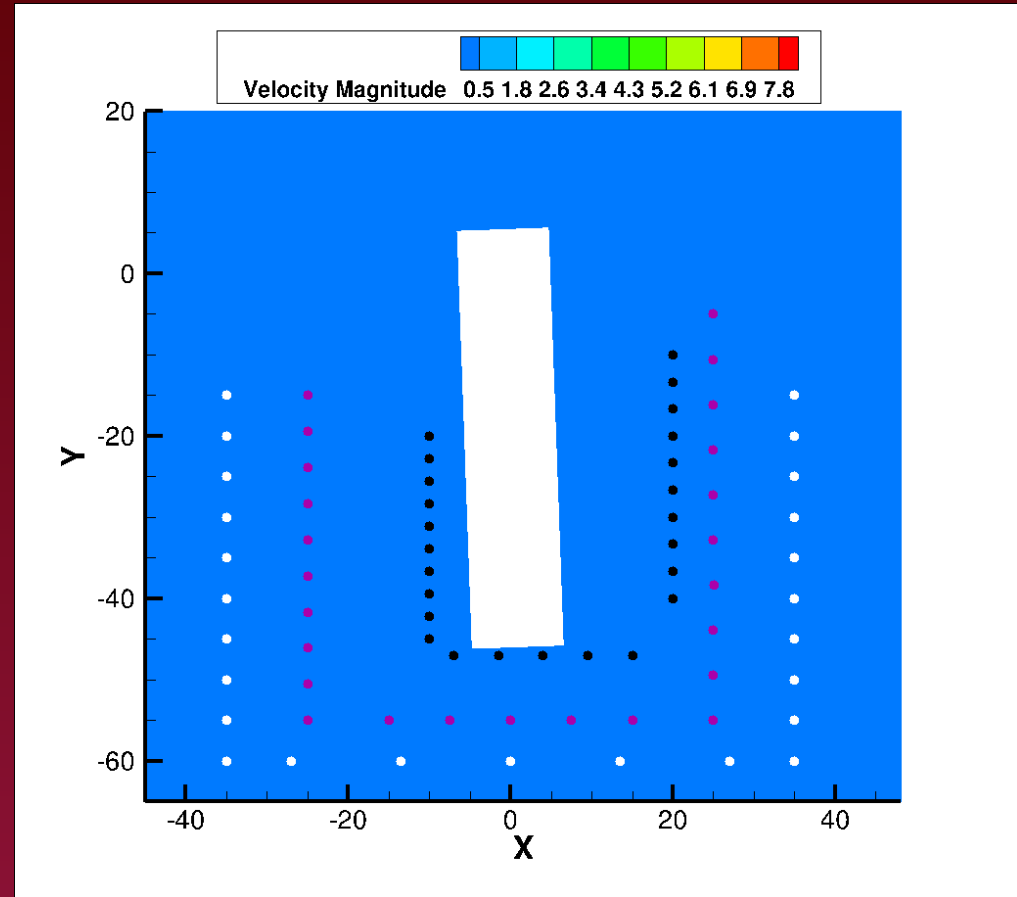
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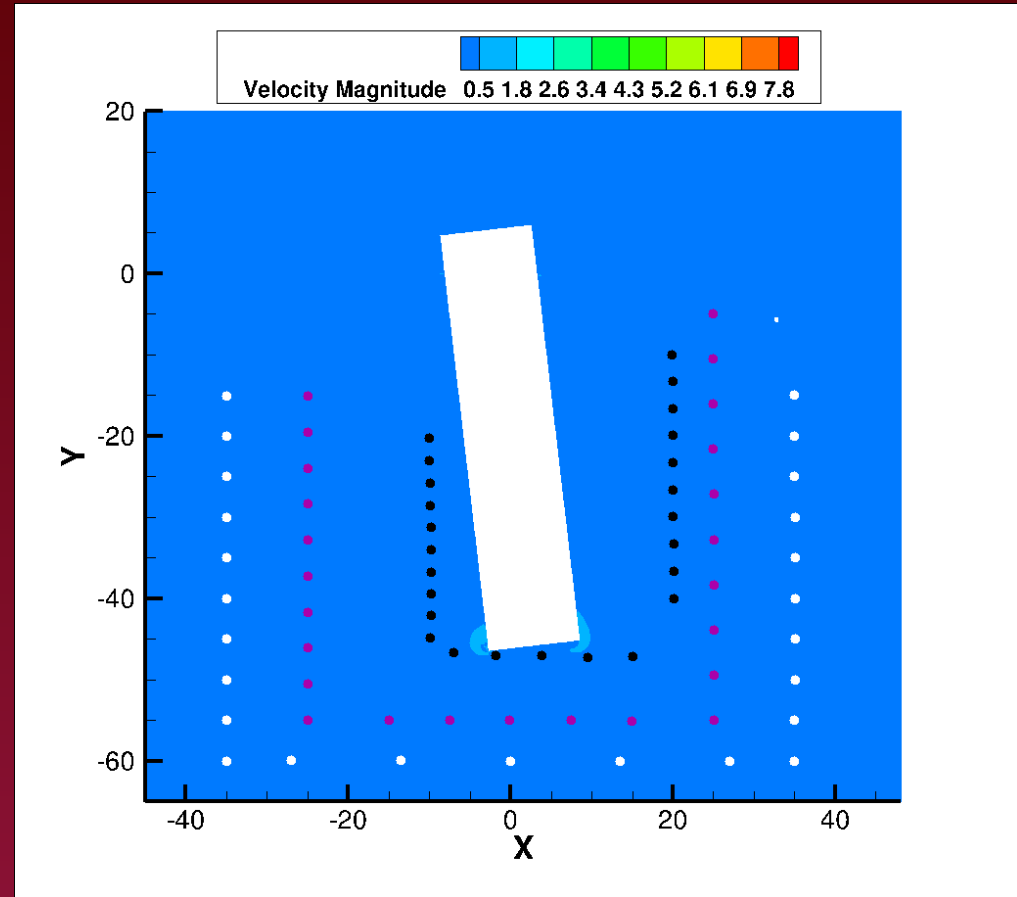
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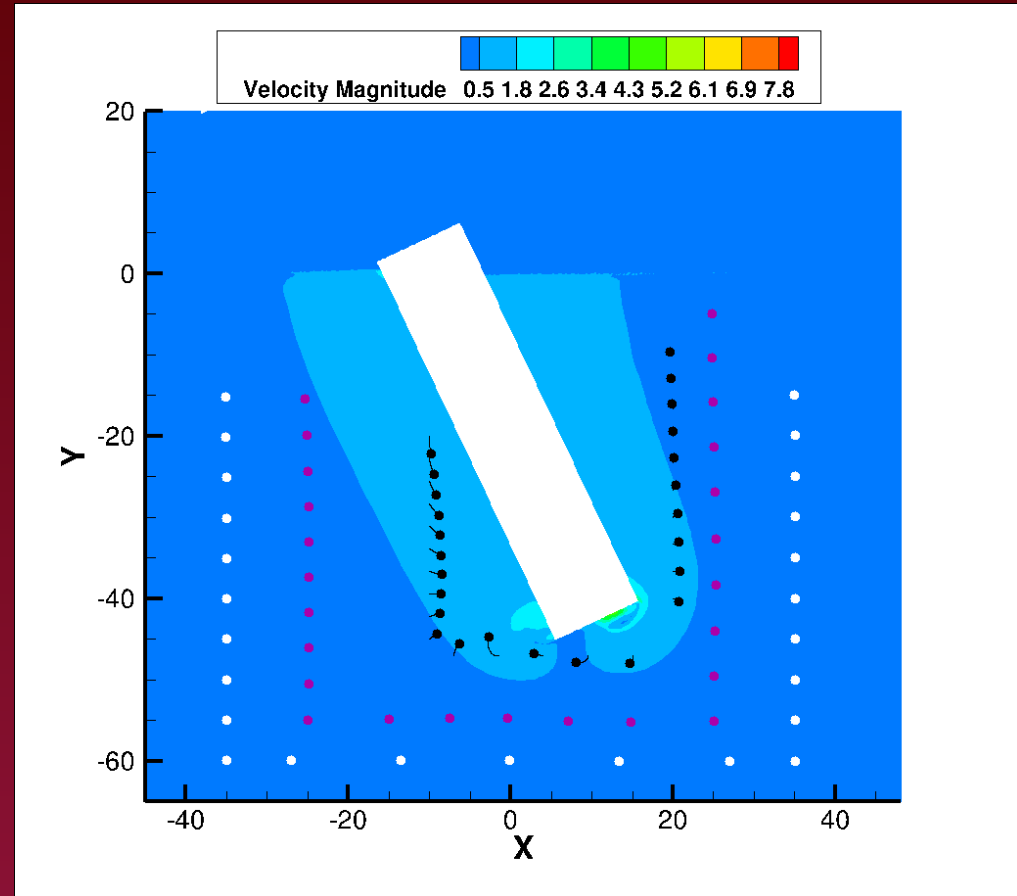
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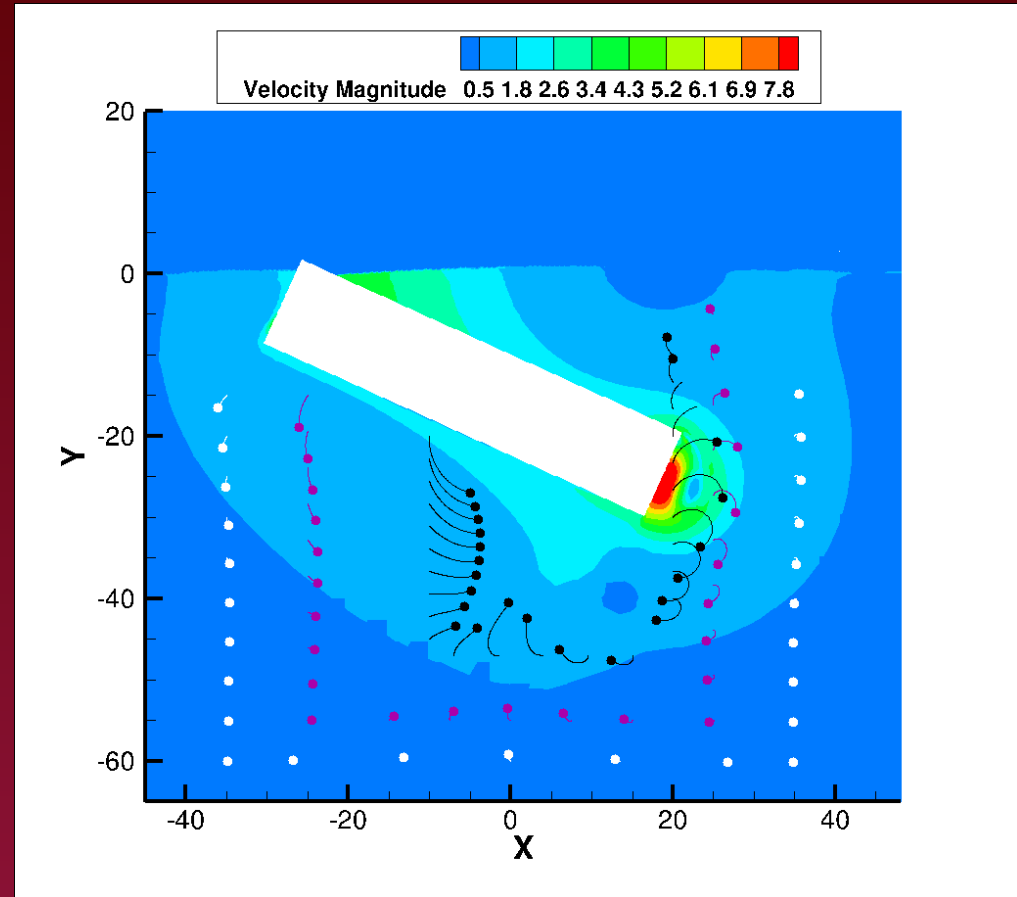
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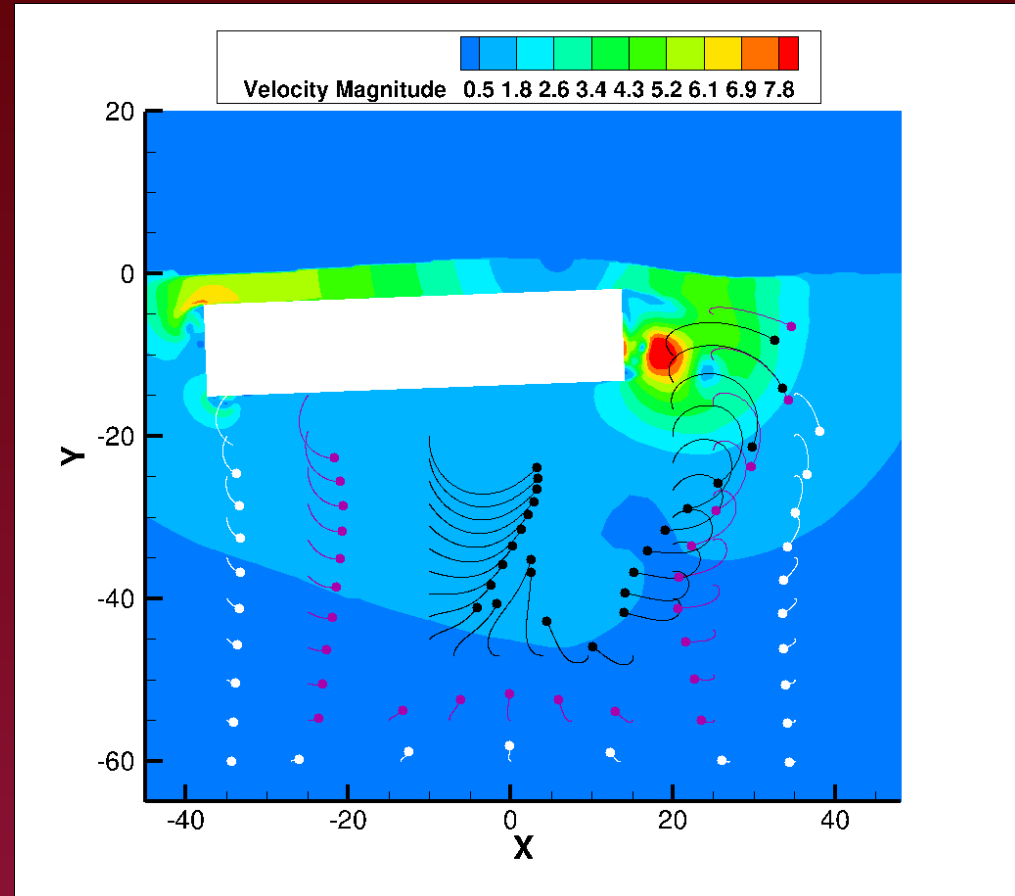
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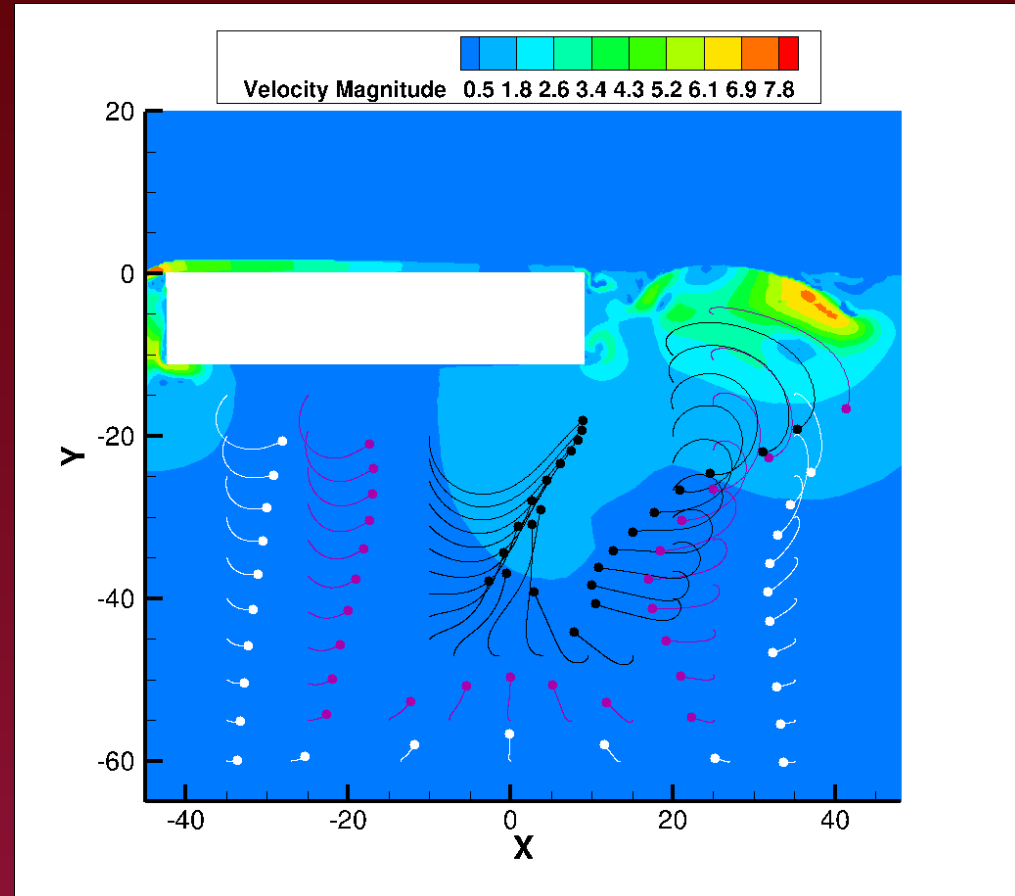
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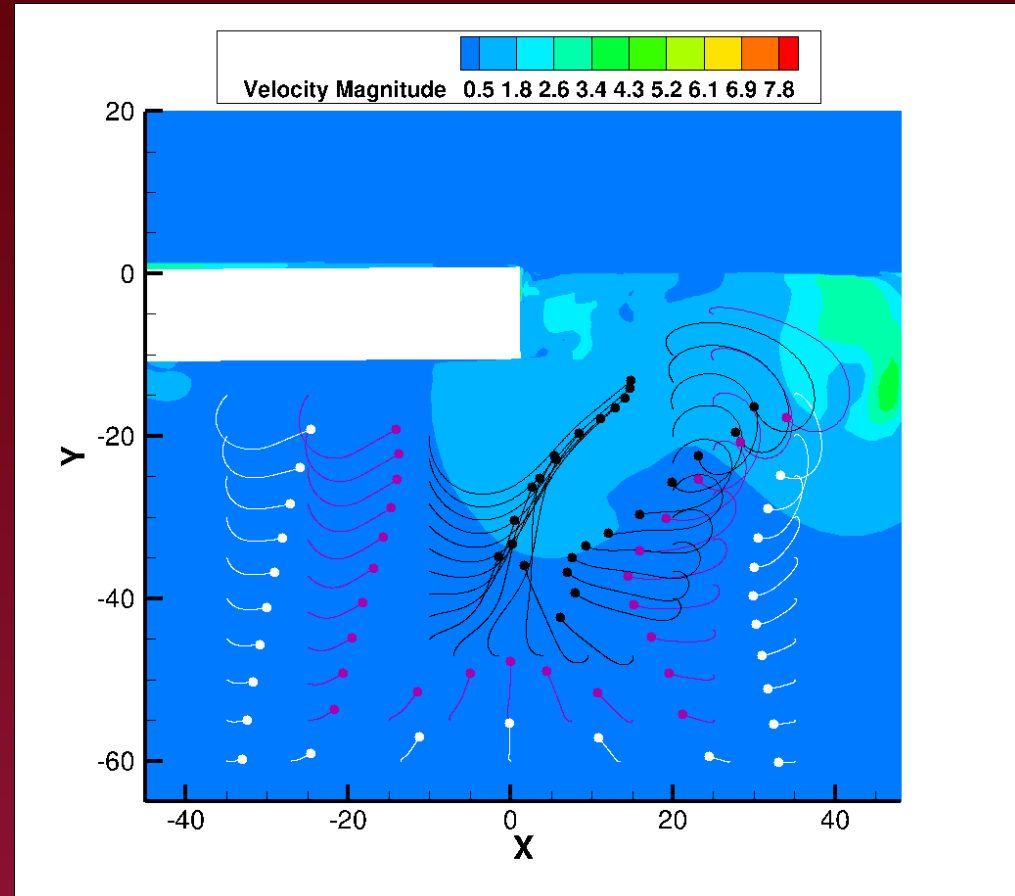
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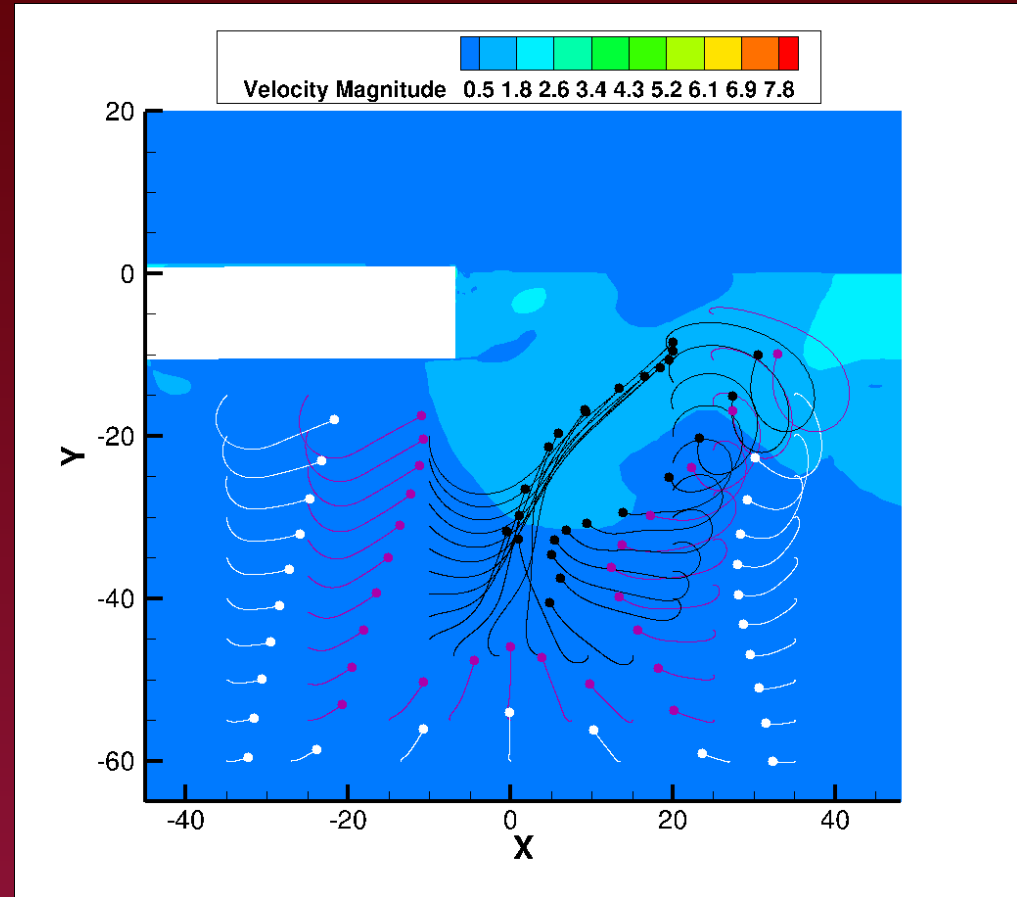
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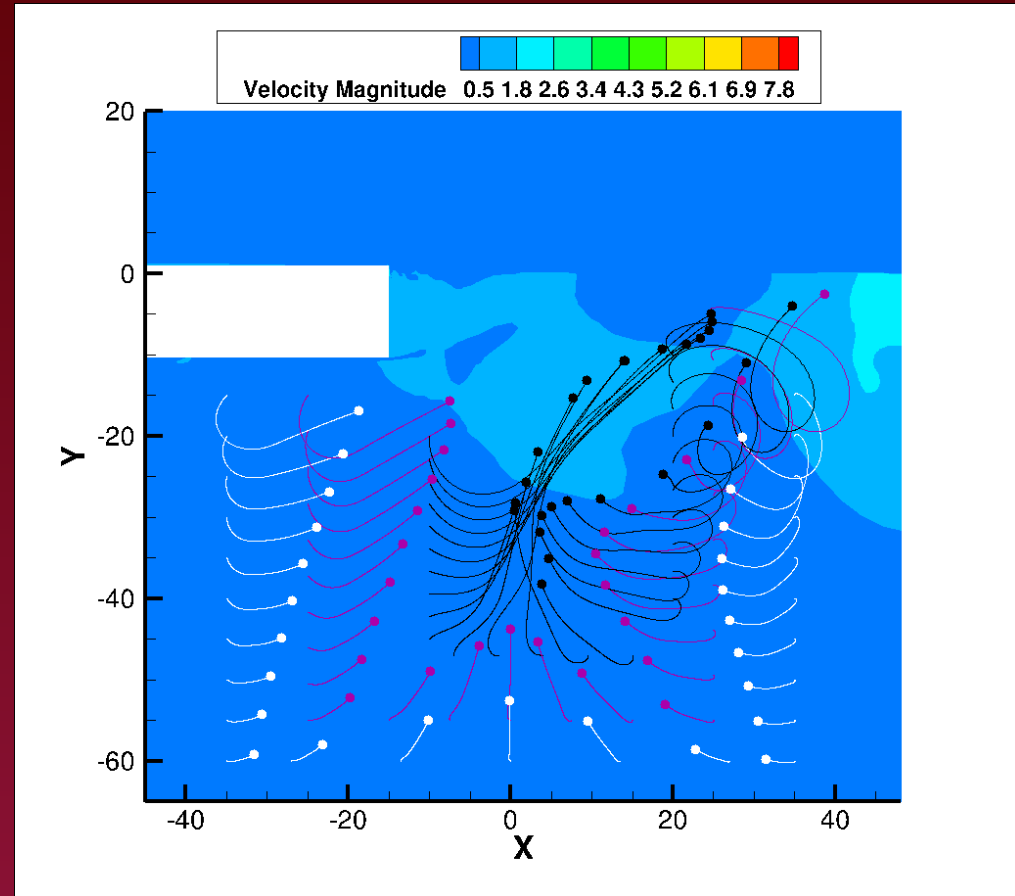
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Take-home message

Successful model calibration
Robust enough to retrieve
experimental data !

Opens applications in many fields
Biology
Cryo-seismology
Glacier mechanics

Next step:
Database to link seismic signal to
calved-iceberg volume

