FEM-modelling of ice dynamics without remeshing

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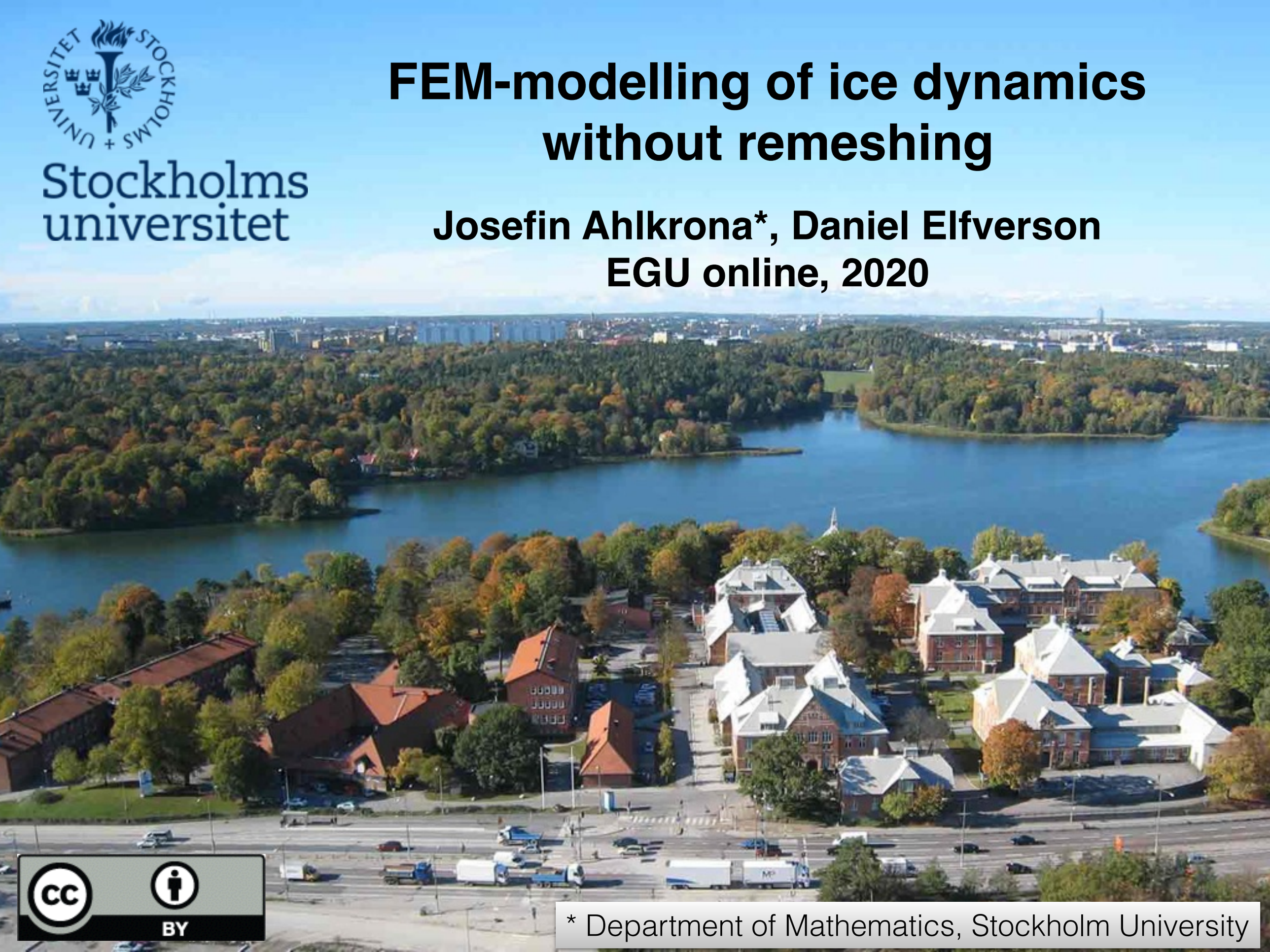

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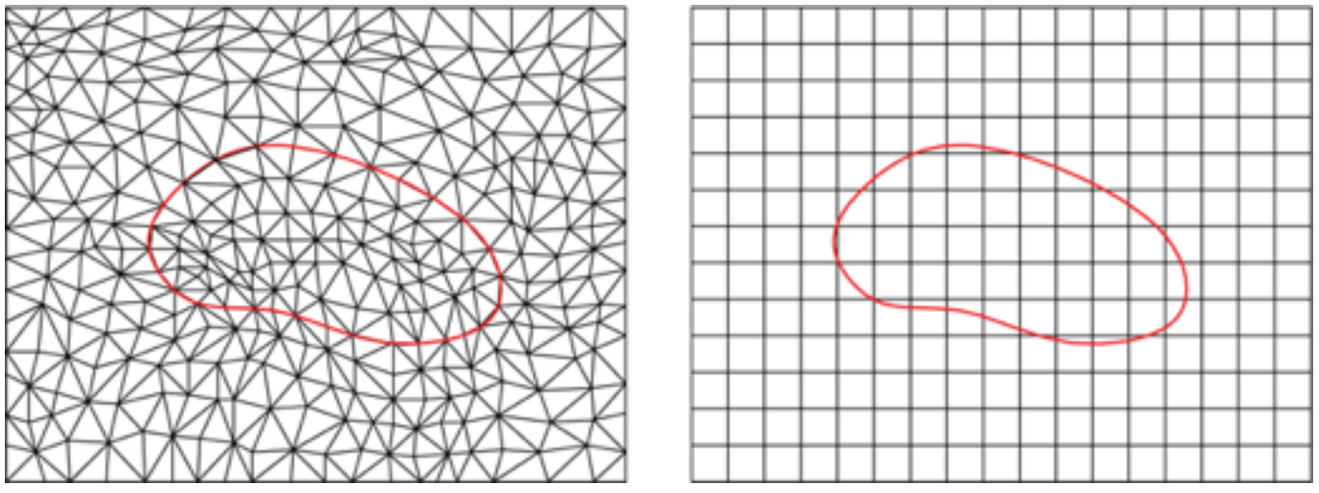
- The ability to handle complex geometries is often mentioned as one of FEM:s strong points

- The capability is however limited by:

  - Expensive remeshing

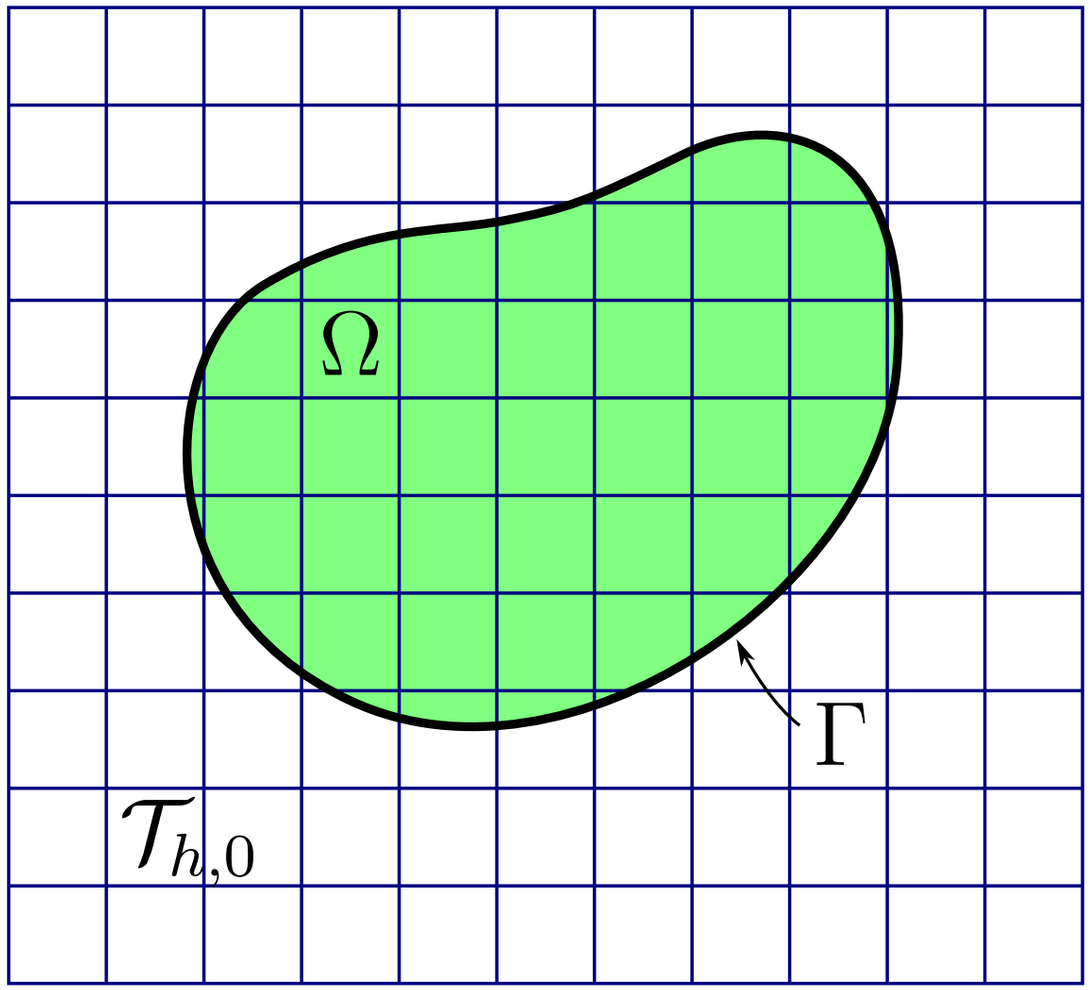
  - Sensitivity to low quality (=distorted) elements

- Therefore, **unfitted methods** such as XFEM and CutFEM are being developed



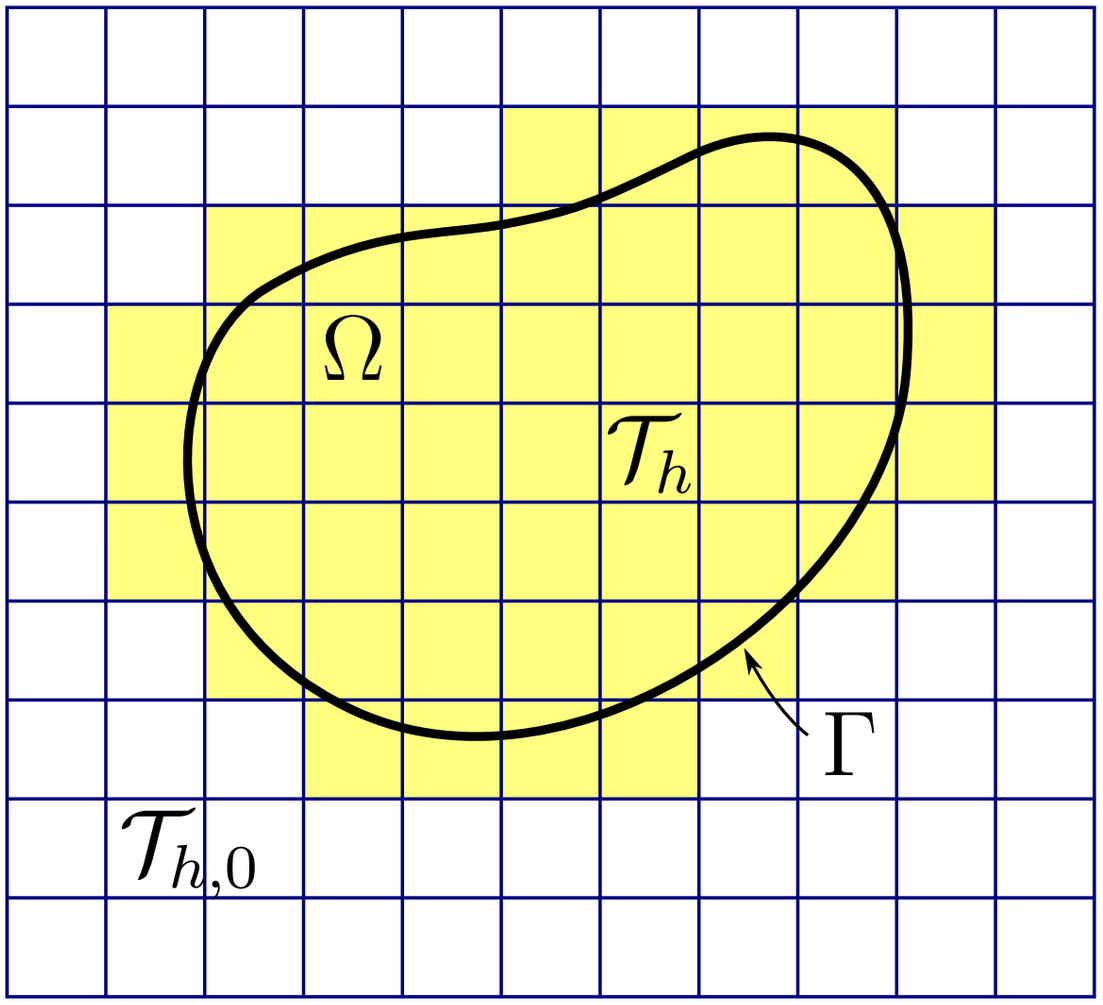
Fitted FEM Unfitted FEM

CutFEM

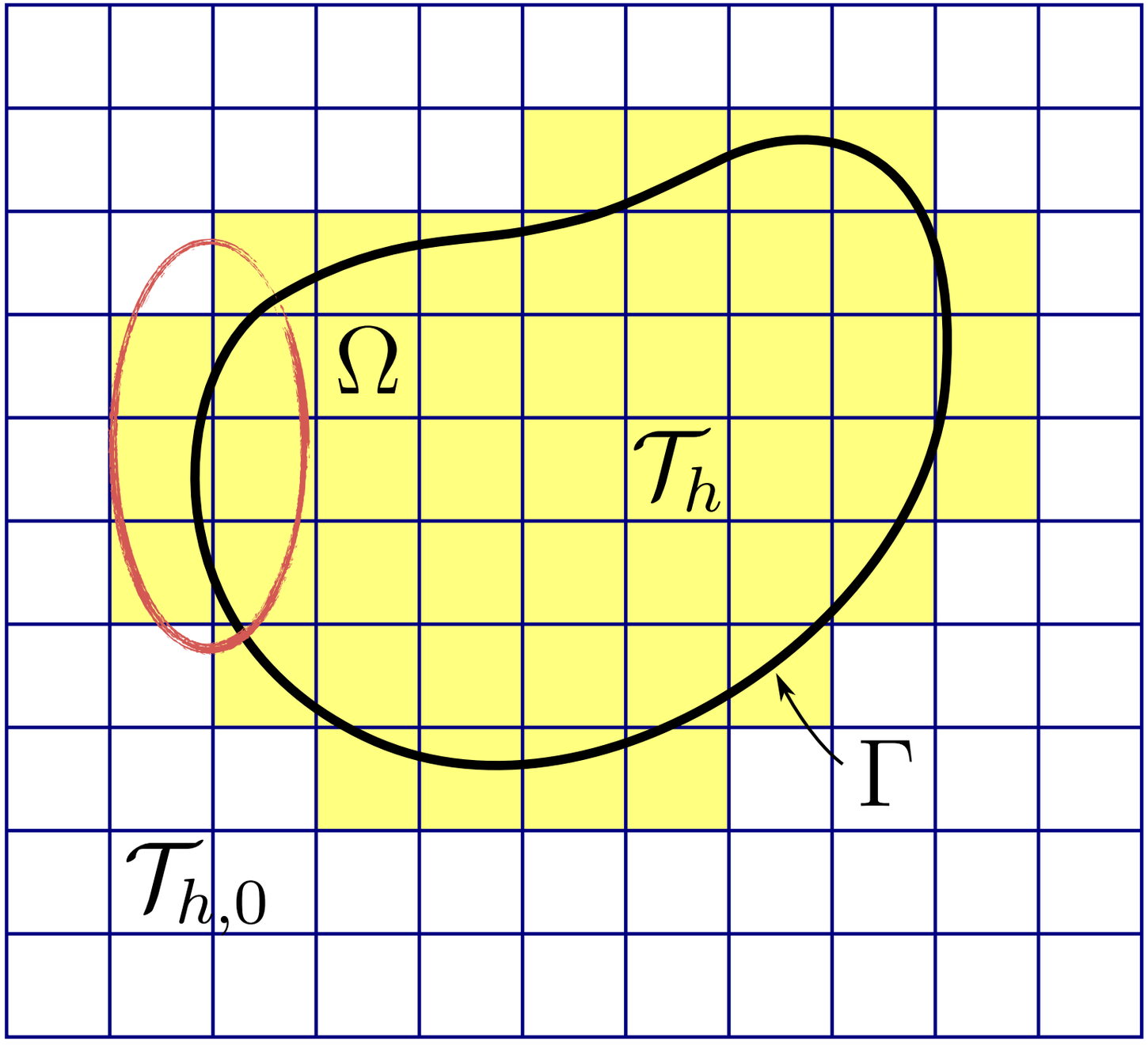


E. Burman, S. Claus, P. Hansbo, M. G. Larson, A. Massing, CutFEM: Discretizing geometry and partial differential equations, International Journal for Numerical Methods in Engineering 104 (2015) 472–501.

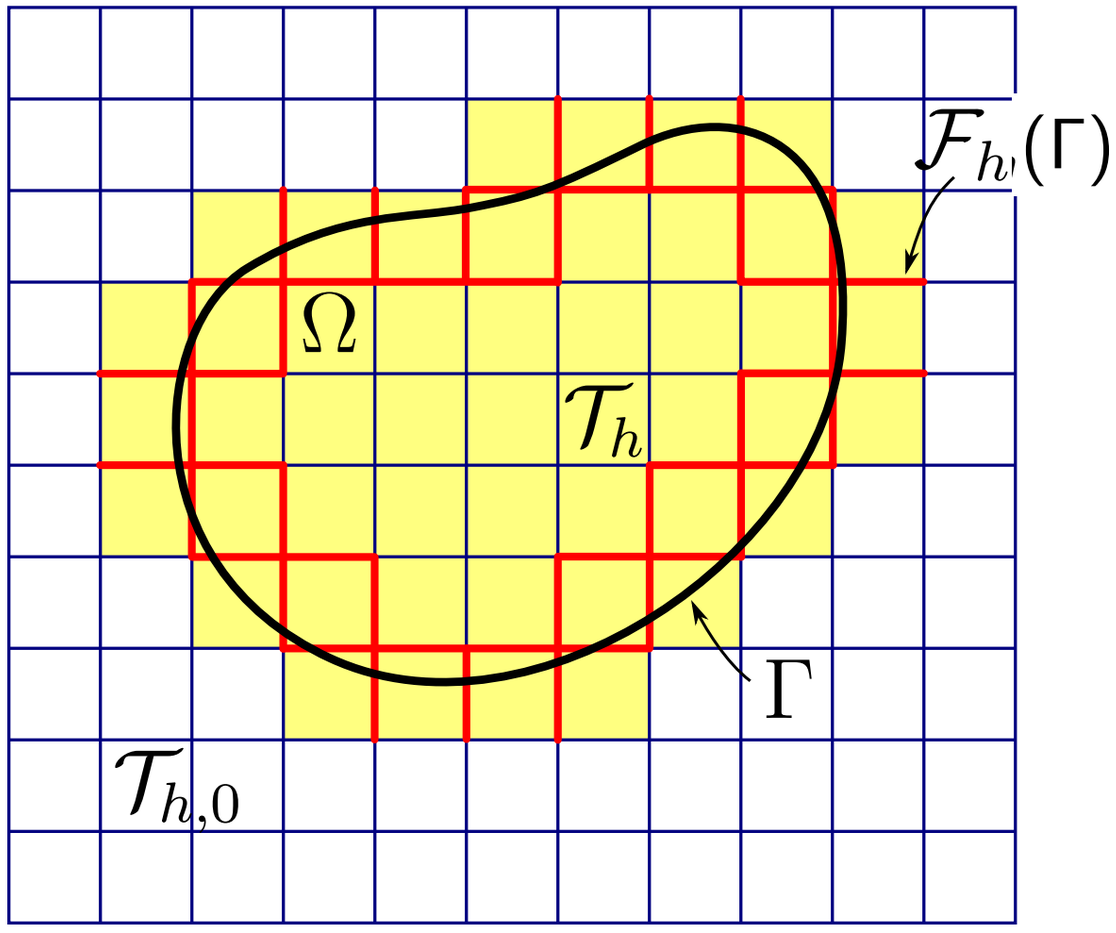
A. Massing, M. G. Larson, A. Logg, and M. E. Rognes. A stabilized nitsche fictitious domain method for the stokes problem. Journal of Scientific Computing, 61(3):604–628, Dec 2014.



- Boundary conditions imposed using Nitsches method
- Integration done only over domain Ω

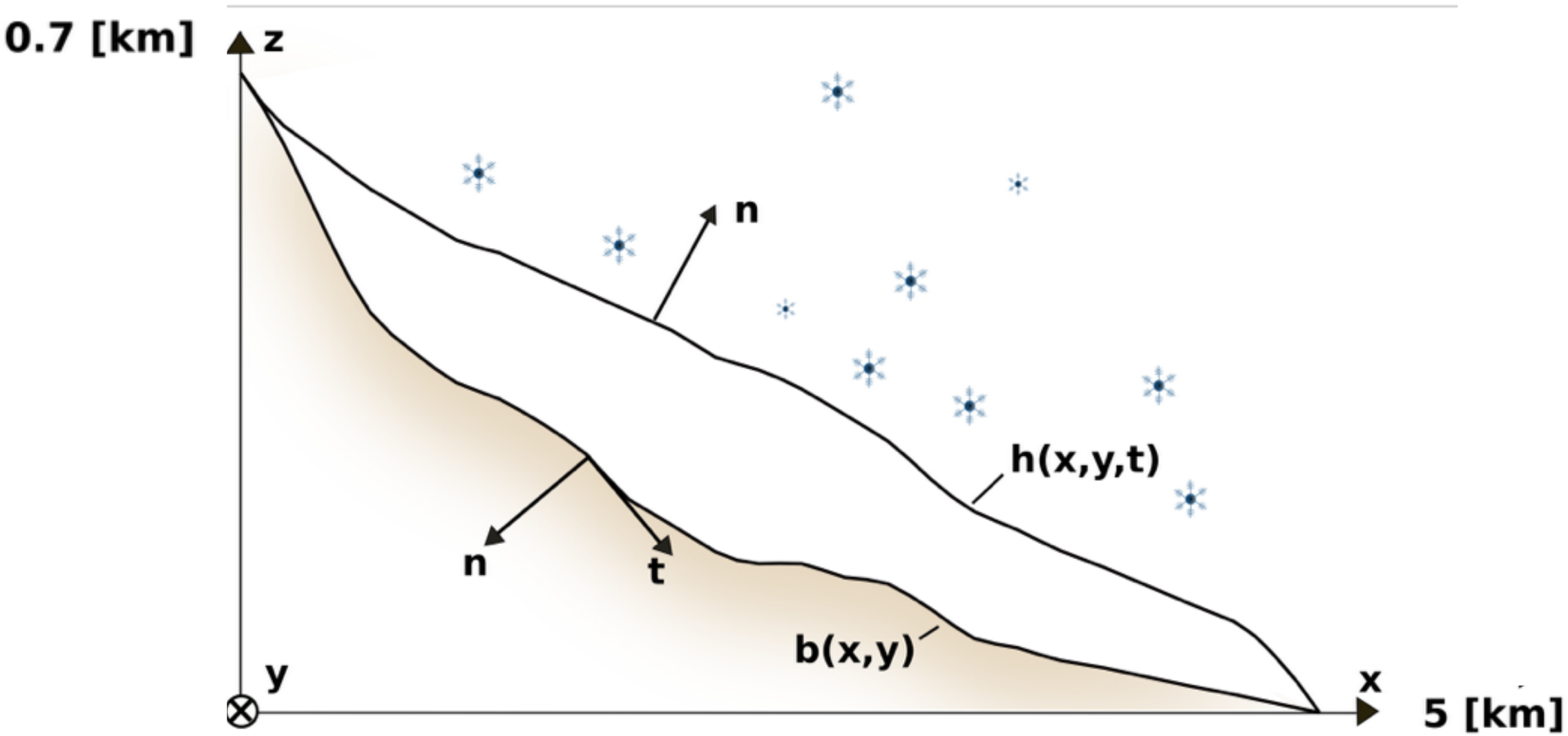


Small element contributions needs special care to avoid bad condition numbers!



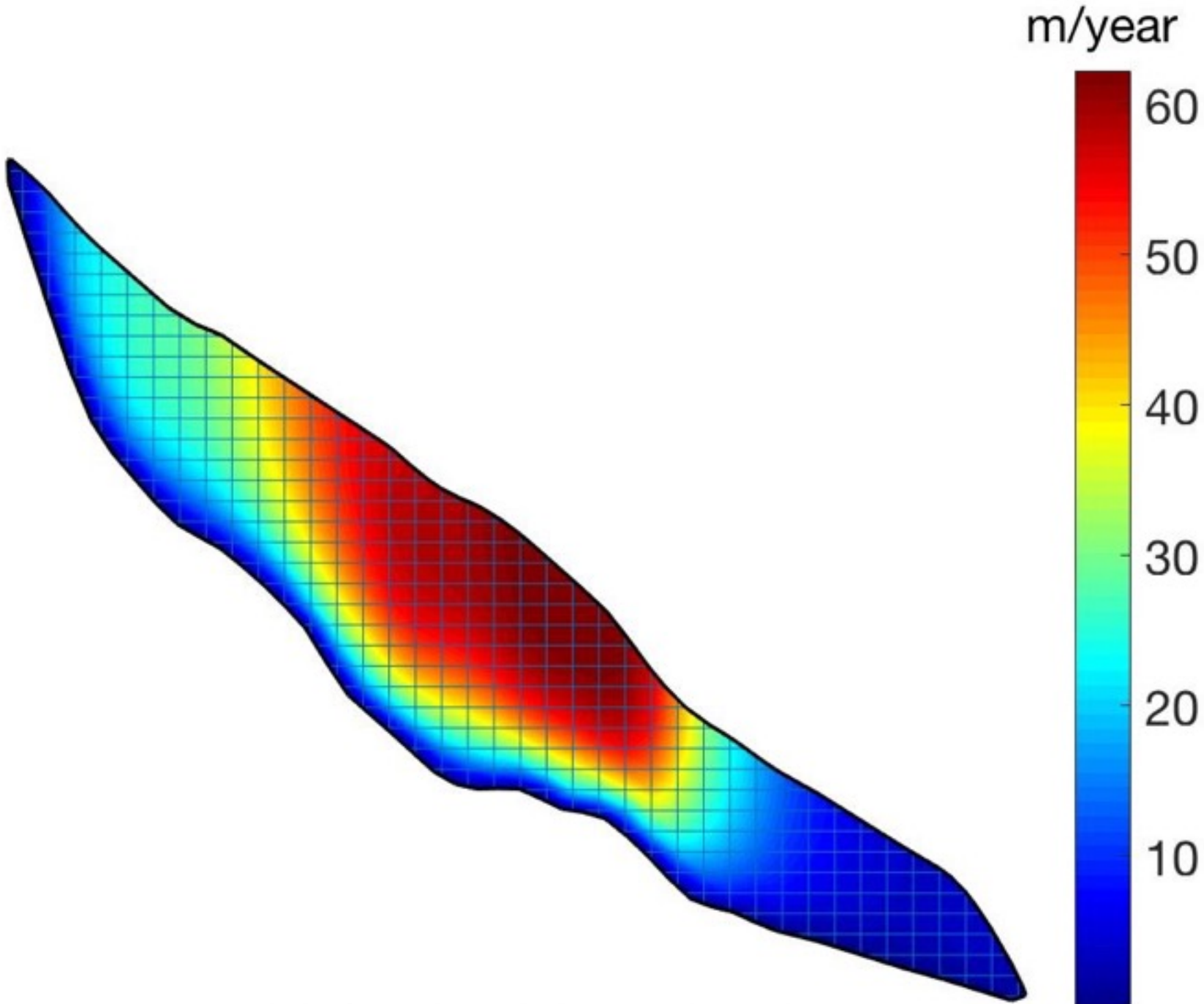
- Boundary conditions imposed using Nitsches method
- Integration done only over domain Ω
- “Ghost penalty” terms to handle small cut element
- No loss in convergence!

Test Problem: The Arolla Glacier



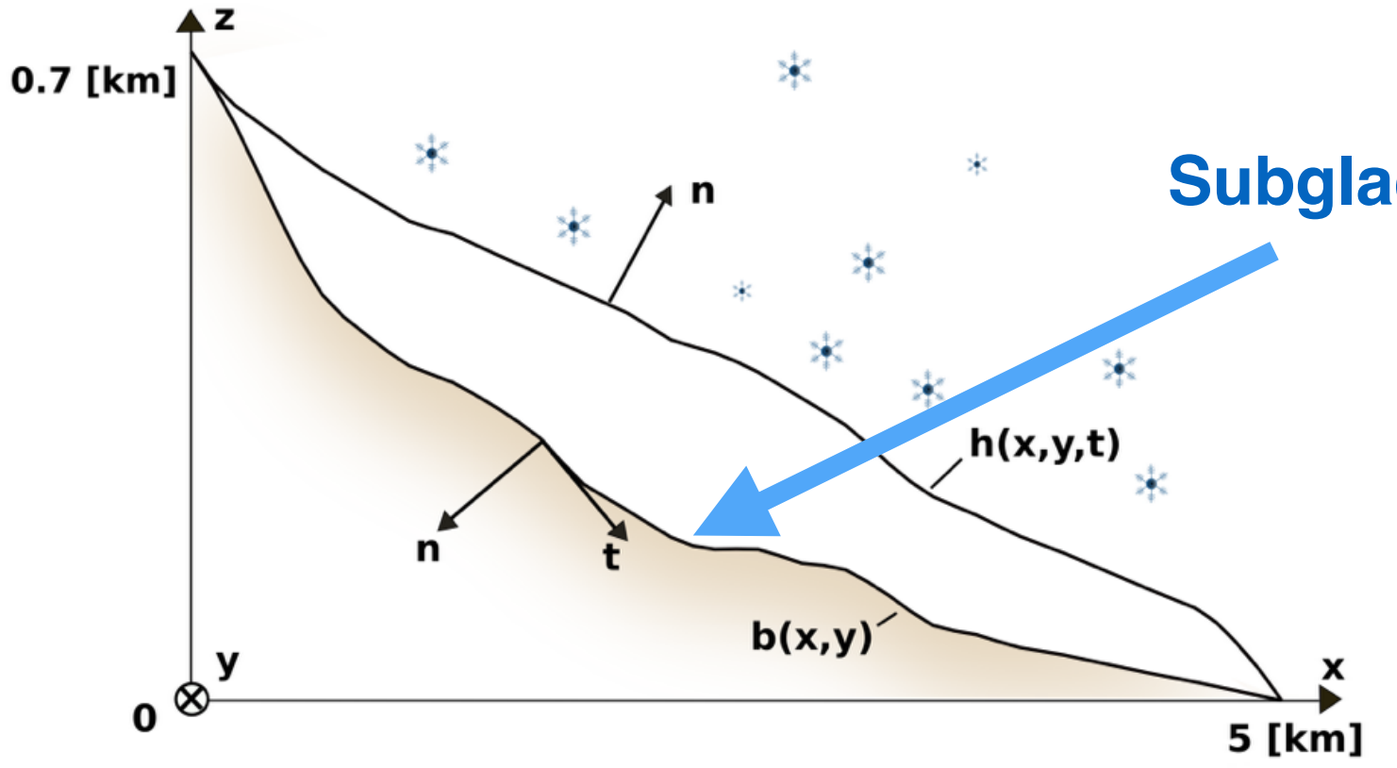
Haut Glacier d'Arolla

CutFEM+full Stokes on Arolla

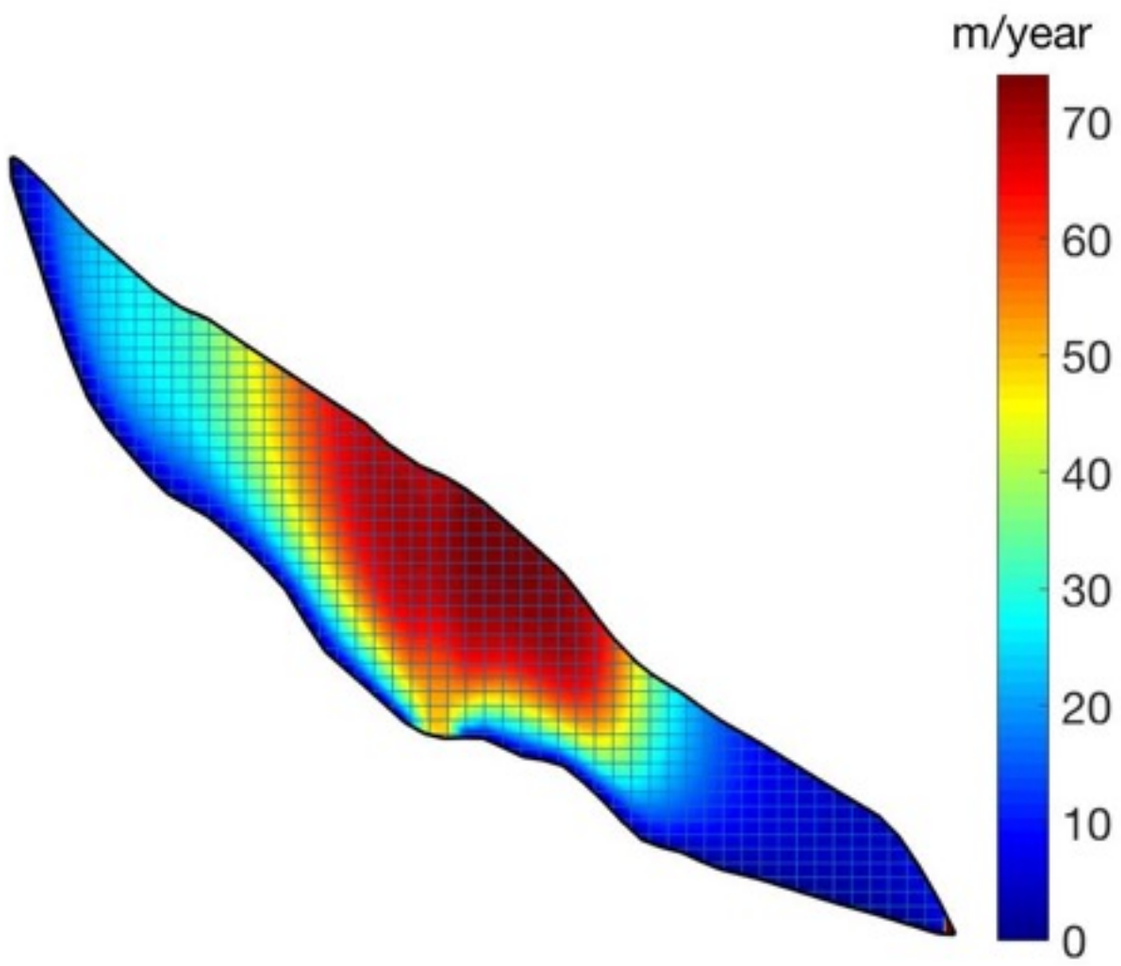


Velocity Magnitude

Slip conditions



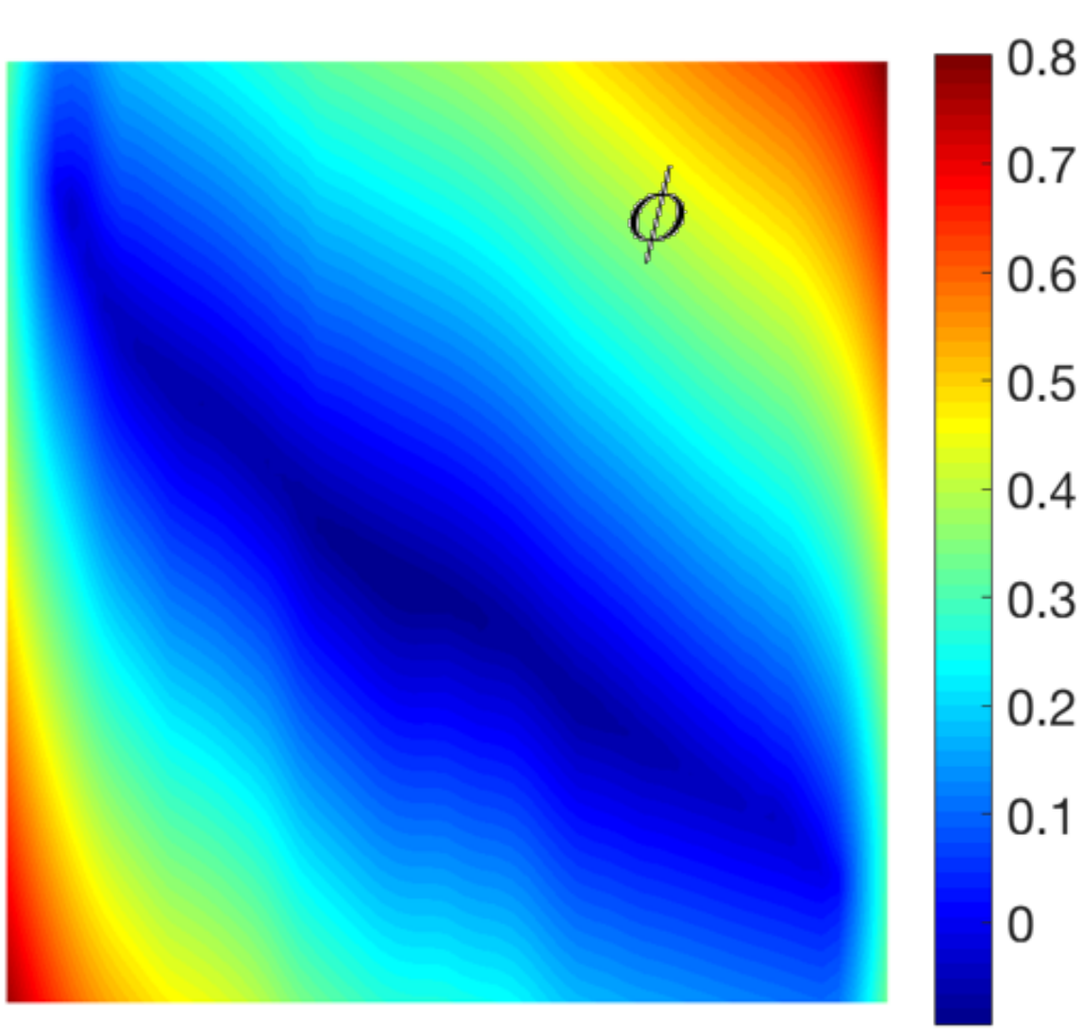
Subglacial lake

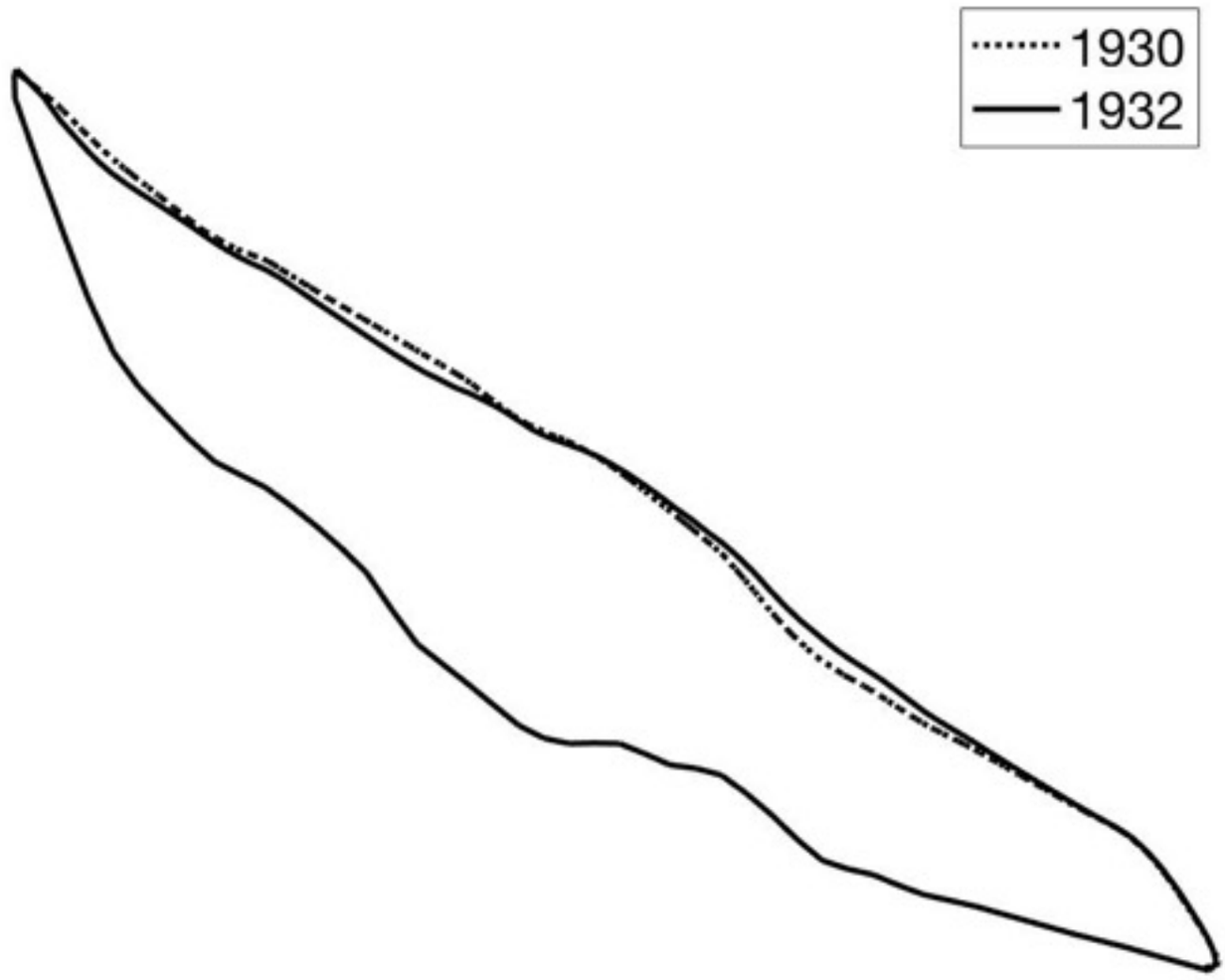


Slip conditions inspired by: *A Nitsche cut finite element method for the Oseen problem with general Navier boundary conditions, M.Winter, B.Schott, A.Massing, W.A.Wall, CMAME (2018)*

Free surface movement using Level-Set

$$\frac{\partial \phi}{\partial t} + \mathbf{u} \cdot \nabla \phi = 0$$





Level-Set Reinitialisation:

A local projection reinitialization procedure or the level set equation on unstructured grids (Parolini, Burman, 2007). Left and right corner of glacier gets rounded off…