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erc-responder.eu

Calving, Hydrology and Plumes in Elmer/Ice

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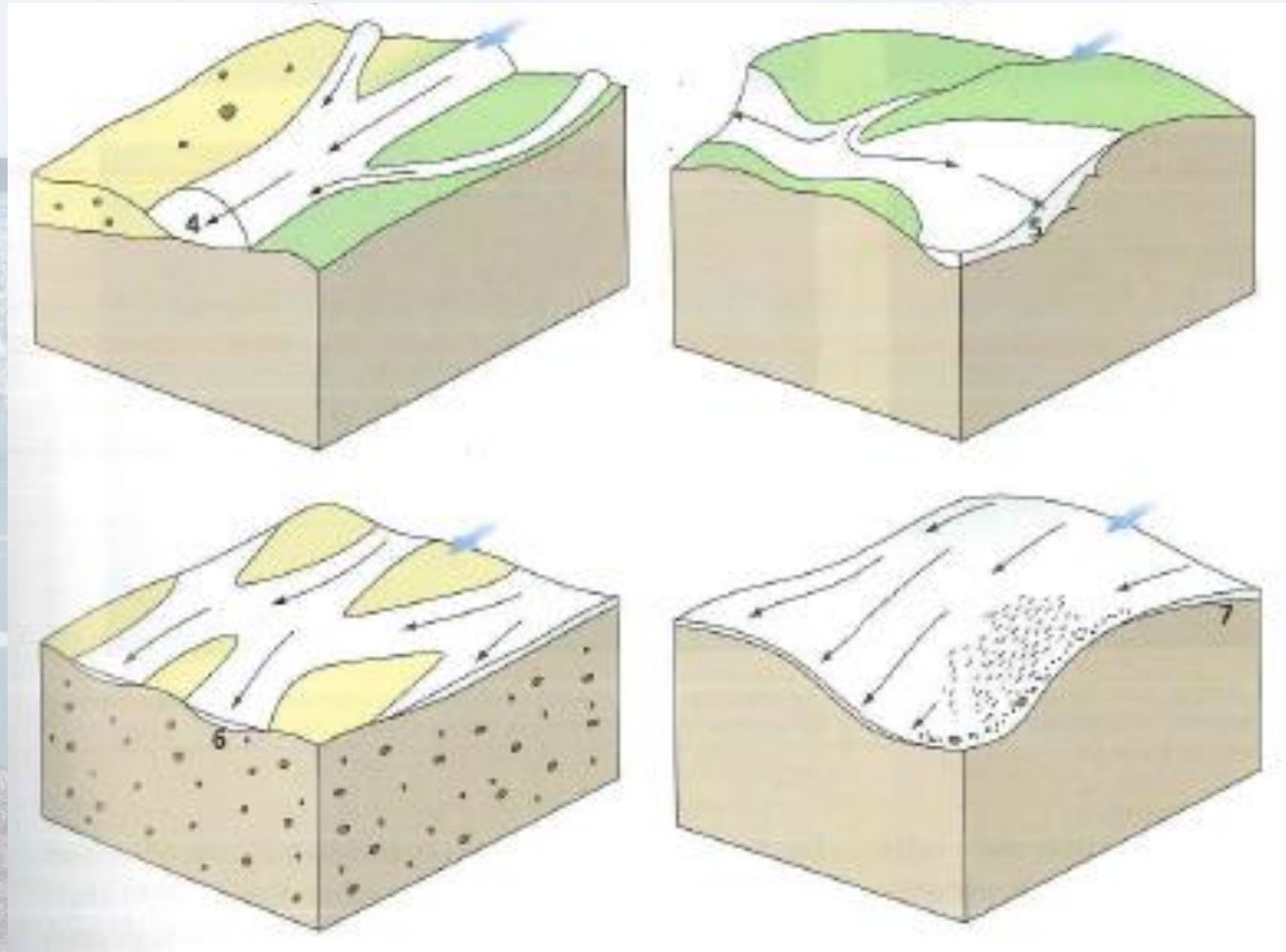
NERC SCIENCE OF THE ENVIRONMENT

RESPONDER

Subglacial Hydrology

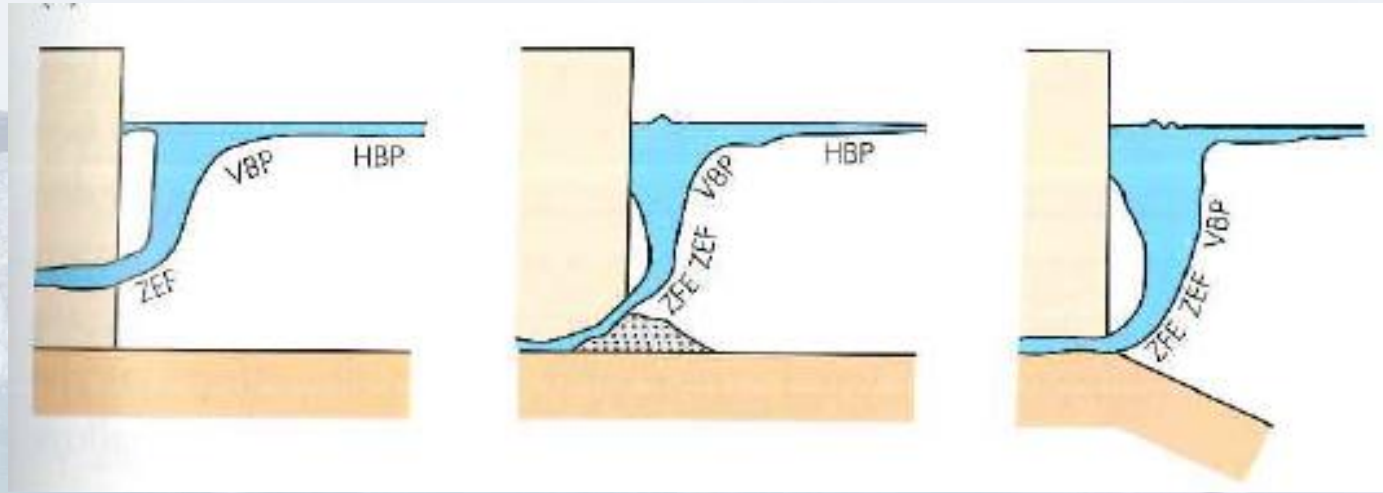
- Effective Pressure (N)
- Inefficient versus efficient drainage systems
  - Opposite effects on N
- Seasonal variation
  - Idea of ‘Spring Event’
  - How far is this applicable to Greenland?



Adapted from Benn and Evans (2010)

Tidewater Glacier Hydrology

- Meltwater plumes
  - Effects on melting
  - Effects on calving
- Also fjord circulation



Adapted from Benn and Evans (2010)

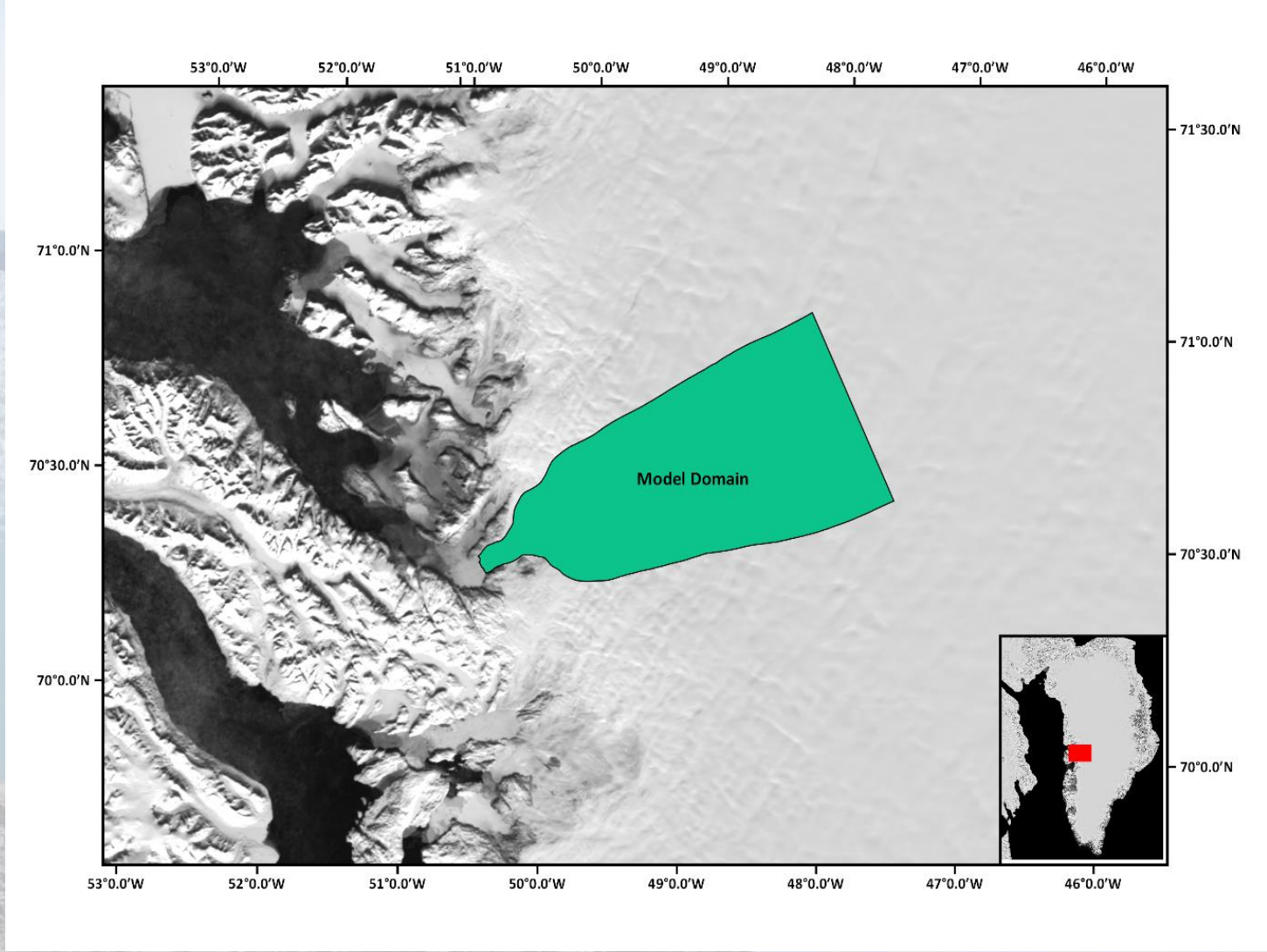
Photo Credit: The Author

Aim

- Produce a 3D, fully-coupled model of a tidewater glacier, incorporating ice flow, calving, subglacial hydrology and proglacial plumes
- And validate it
- Without going mad in the process

Study Site

- Store Glacier
- Large, tidewater glacier
- Stable
- Domain about 110 x 40 km



Work on Store So Far

- SAFIRE and RESPONDER projects

- Modelling work on calving
  - Todd and Christoffersen (2014)
  - Morlighem et al. (2016)
  - Todd et al. (2018)

- Plume observations and modelling
  - Xu et al. (2013)

- Variety of fieldwork undertaken – lots of validation data!

Problems

- Make GlaDS work in 3D with an internally extruded mesh – 1st year
- Make calving and GlaDS play ball when it comes to meshes – 2nd year
  - Calving relies on interpolating variables between pre- and post-calve meshes; GlaDS channel variables defined on edges of mesh, so can't easily be interpolated….
- Then get both calving and GlaDS code to interface correctly with some sort of plume model – July onwards

Solutions – GlaDS in 3D

- This all implemented in source code now
- Mainly a case of making sure MeshUtils.F90 creates edges properly, and then defining everything correctly in the SIF
- Also set up a USF to calculate source input to GlaDS from a provided surface raster and internal melt from temp residual
- And written a solver to calculate ice normal stress properly

Solutions – GlaDS and Calving

- Strategy: have GlaDS and ice flow/calving operating on two separate meshes
  - Allows ice mesh to be deformed and messed around with by calving without affecting hydrology
  - Requires interpolation of variables between meshes at coupling points and a moving frontal boundary on the hydrology mesh
- Elmer contains functionality for loading solver-specific meshes, so used this as a starting point

Solutions – GlaDS and Calving

- Put in a calving Boolean in SIF to specify when should use new code
- Extensive modification to GlaDS source code to keep all references within solver
  - Meshes
  - Variables
- Minor modifications to CalvingRemesh.F90 to stop it trying to add the hydrology solvers and variables to the post-calving mesh

Solutions – GlaDS and Calving

- Also required source code changes related to interpolation and restarting simulations, as well as mesh loading
  - Interpolation: InterpVarToVar.F90 – perm allocations, looks at all elements
  - Restarting: ModelDescription.F90, ElmerSolver.F90 – will now restart correctly from multiple-mesh hydro-calving simulations, subject to a new solver
  - Meshes: MeshUtils.F90 – now correctly applies edges to a solver mesh even when solver variable not defined on them, based on a SIF keyword
- Written a new solver to manage interpolation between two meshes, as well as basic error correction, and a new restart solver

Solutions – GlaDS and Calving

- Need to be careful on resolution of meshes
  - Interpolating from a much finer mesh to a much coarser one creates artefacts
  - Ice mesh needs high resolution near calving front/grounding line, but can be coarser upstream
  - The finer the better for GlaDS, resolution-wise, but should try to match ice mesh
  - Interpolation solver has some very basic routines to remove problematic artefacts, mainly in normal stress and grounded mask, but best to avoid creating any in first place

Solutions – GlaDS and Calving

- How to treat hydrology in ungrounded areas?
  - At the moment, ungrounded areas that connect to the frontal boundary have all hydrology set to 0 – they're essentially part of the fjord
  - Isolated ungrounded patches are ignored, because GlaDS can't handle water transfer through them, so they become unphysical sinks if treated in the same way
- Moving frontal boundary
  - Fixed hydro mesh needs a larger footprint than dynamic ice mesh down-fjord to deal with moving calving front
  - On the hydro mesh, the moving frontal boundary of the ice mesh is replicated with boundary conditions in the Body Force section of the SIF that are only applied based on certain variable values

Solutions – GlaDS and Calving

- Coupling
  - Using Olivier's Coulomb sliding law to couple hydrology and ice flow
  - Coupling other way assured by normal stress solver and interpolation of velocity field
  - Written solver to calculate sliding coefficient required by sliding law from temperature field, though I haven't got beyond checking it compiles yet….
  - Water pressure at base also used in calculating basal crevassing
  - Need to work out best parameters for sliding law – at moment, modelled ice only going about 60% of actual velocity

Solutions – Plume Model

- Adapted Tom Cowton's MITgcm implementation of Donald Slater's plume model – uses ODEPack library (compiled with it)
- Written new dynamic plume solver, based on Joe's fixed version
- Takes channel flux from GlaDS at each point on GL, models the plume at that point as a linear plume and applies the resulting melt rate to the terminus
- Means, hopefully, that get a continuous linear plume with varying melt rates along whole calving front

Solutions – Plume Model

- Current implementation avoids need to specify plume locations or magnitudes, and allows them to dynamically evolve as drainage system changes

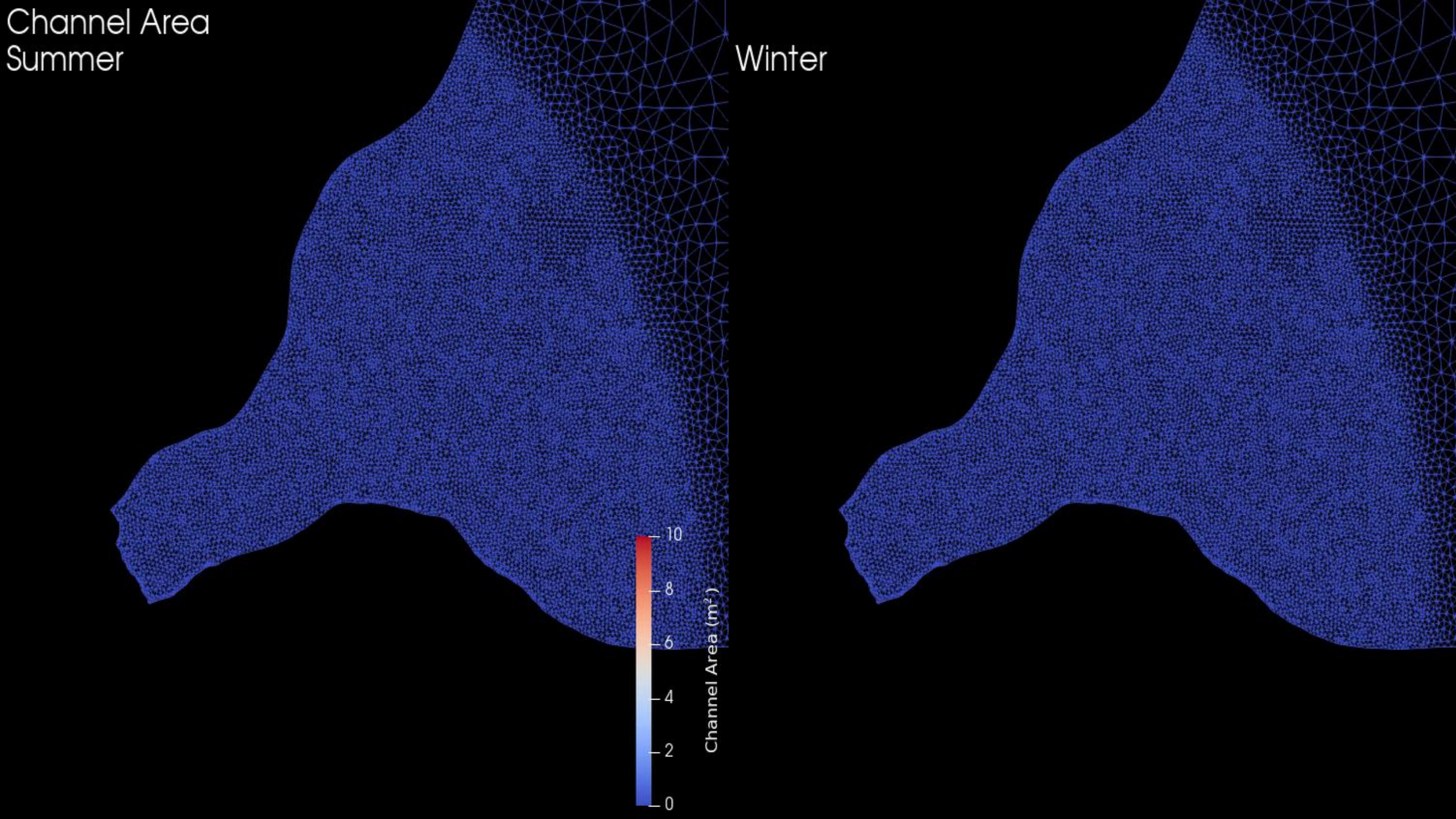
- Required some modifications to GroundedSolver.F90 to force the GL to be defined along the base of the frontal boundary in grounded areas (as plumes sited at GL)
  - Also added SIF keyword that allows you to force GroundedSolver to treat whole domain as grounded (for restart purposes)

Problems – Plume Model

- Currently, have a 10x ‘tuning factor’ on the channel flux from GlaDS to replicate plumes of roughly right size
  - Problem with runoff input?
  - Problem with GlaDS?
  - Problem with plume model? – ambient conditions?
- Also some sort of bug on applying melt rates on some timesteps – fixed?
- But, it all runs and only randomly crashes ~10% of the time!

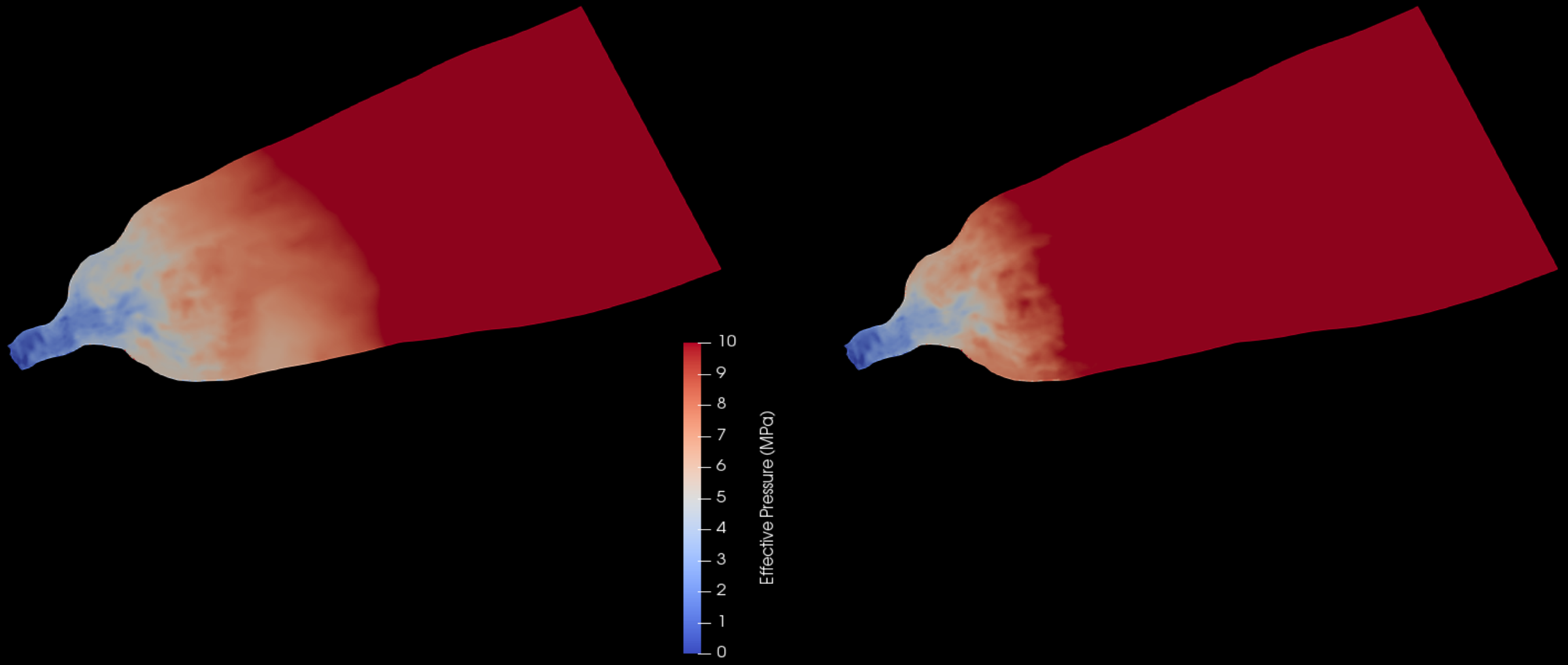
Results

- Not quite at that point yet….
- Based purely on running GlaDS in 3D, without calving or plumes, seems to show N under Store drops in summer, which is counter to expectations
  - But is this due to how I’m routing water to bed?


Channel Area
Summer
Winter
10
8
6
4
2
0
Channel Area (m²)

Effective Pressure
Summer

Winter

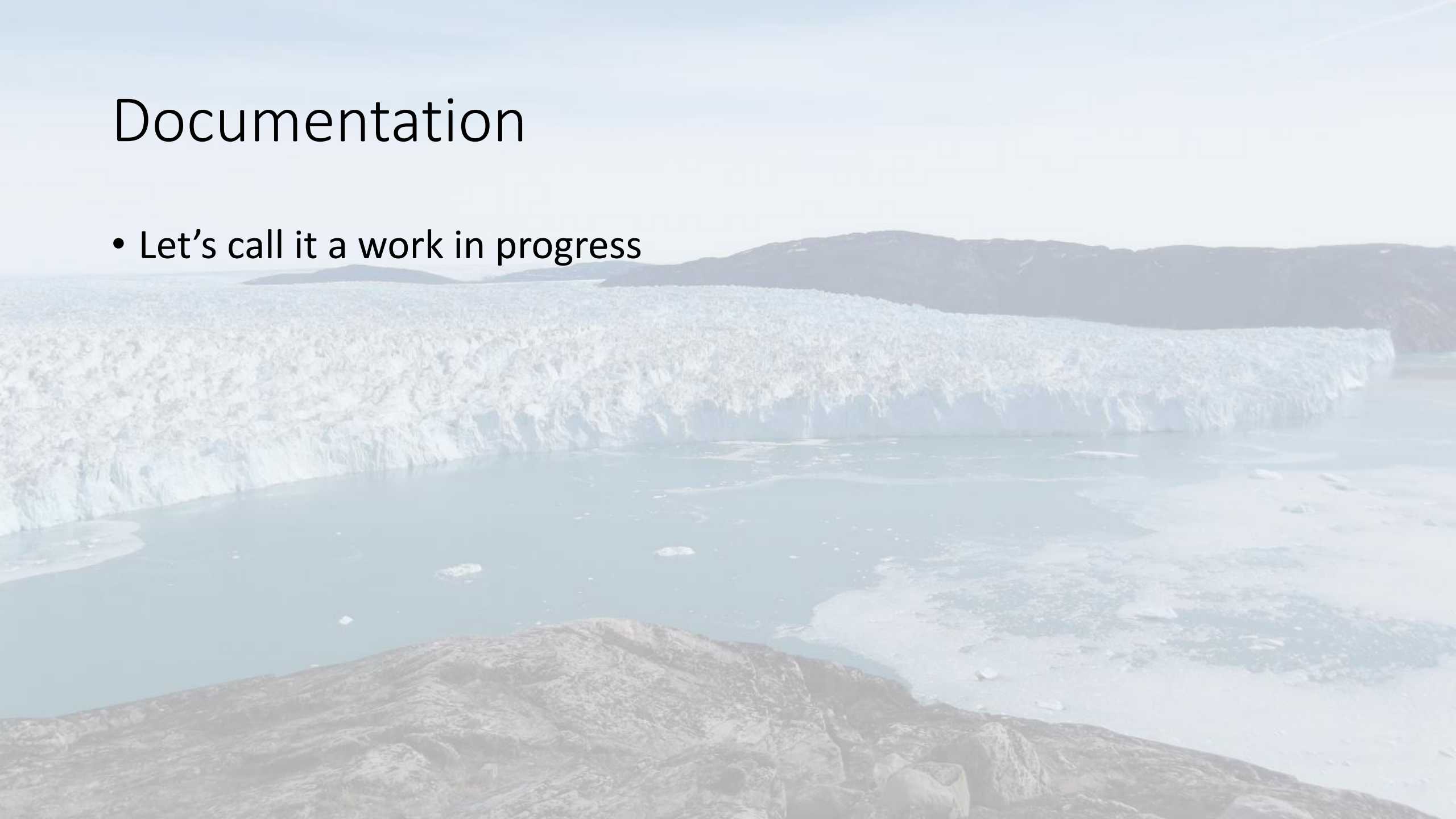


Testing

- Er….
- It doesn’t obviously break anything….

Documentation

- Let’s call it a work in progress



Any Questions?

Thanks for listening