Benchmark experiments for the comparison of subglacial hydrological models

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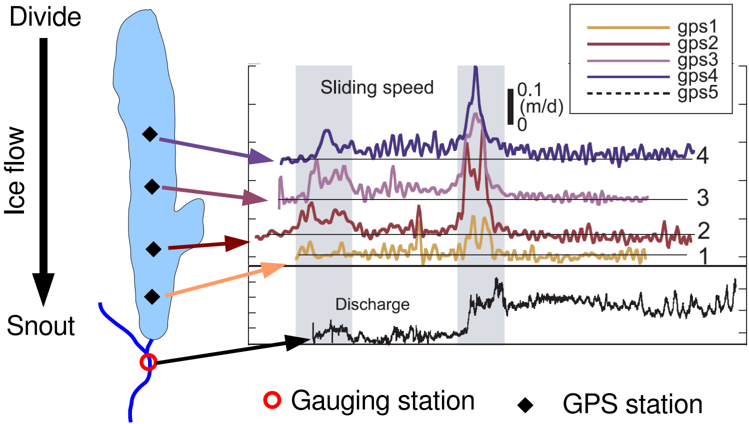
Outlines

1. Overview of Subglacial hydrological modelling
2. Presentation of the comparison set-up
3. Preliminary results
4. Prospective and participation

Water availability is a key to sliding

Water availability impact the velocity of glaciers



Velocity and discharge measurements on Bench glacier (Alaska) adapted from Anderson et al. (2004)

The direct link from water to sliding is the subglacial water pressure.

But water pressure is hard to come by

Borehole measurements gives only local values of a highly spatially variable quantity.
Measurement from 6 boreholes along a 70m line on a Yukon glacier

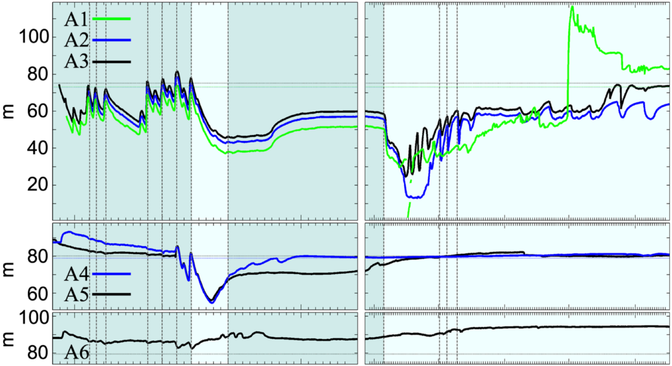


Figure from Schoof et al. (2014)

These data give a good insight on processes but can't be used as a base to describe sliding on a large scale.

Overview of Subglacial hydrological modelling

Founding principles on subglacial hydrology modelling dates back to the 1960's, when the elements of the drainage system where theorized.

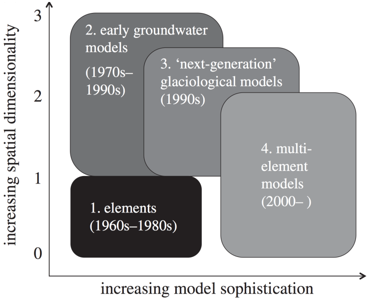


Figure from Flowers (2015)

1. Theory of the drainage elements
2. "Paleologically" interested models
3. Effective pressure is assumed
4. Effective pressure is part of the solution

State of the art in Subglacial hydrology modelling

Flowers (2015) summarized the existing models (around 20) and the methods used two model each component of the drainage system

Inefficient drainage system morphologies

- cavities
- macroporous sheets
- turbulent/laminar sheets
- porous medium / till
- englacial storage

Efficient drainage system morphologies

- 1D R-Channels
- 2D R-Channels
- 1 per cell R-Channels
- water routing scheme
- porous medium

A number of model are used incorporating different physical process which make their results hard to compare.

Necessities for an intercomparison

Recent emergence of a number of models now allows for an intercomparison

- Scarcity of data means that the model validation is problematic
- Different model formulations render the comparisons difficult even on the same experiments

Intercomparison results would help the comunity

- Model choice function of the targeted applications
- Development of future model relying on new approximations

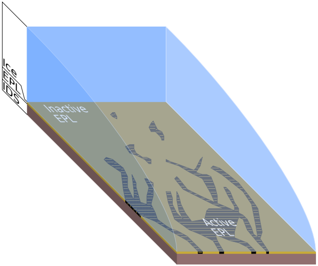
Focus on two different approaches

Double Continuum Approach

de Fleurian et al. (2014)

(DCA)

- Porous layer
  - Darcy equation
- Partly activated porous layer
  - Activation function of N

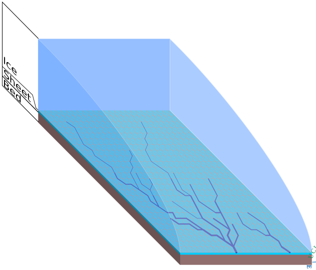


Glacier Drainage System

Werder et al. (2013)

(GLADS)

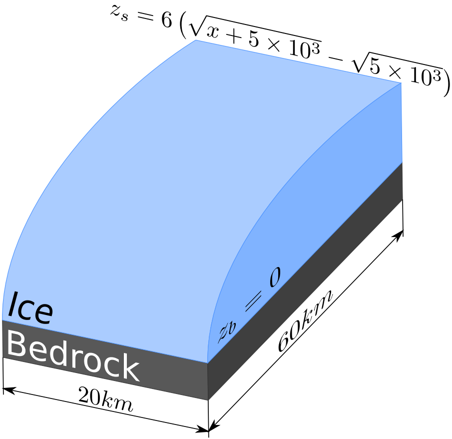
- Water sheet
  - Continuous cavity description
- R-Channel
  - Water exchange with sheet



Intercomparison set up

Synthetic geometry inspired from a Greenland land terminating glacier.

- parabolic ice surface
- flat bed
- 60km long per 20 km wide



Intercomparison set up

Forcing for the model is given as a water input at the ice bedrock interface to avoid the introduction of supra-glacial and intra-glacial drainage models

- So far only uniform input is considered
- A range of value is used from 5mm/year (coherent with a geothermal heat flux source) to 10cm/day (coherent with Greenland runoff peak)

Variable of interest

The variable of interest will be the effective pressure (N)

$$N = p_{ice} - p_{water}$$

- Direct input to sliding models
- Easy way to compare water pressure
- Rules out model with a prescribed effective pressure

Parameters sets and their difference

The use of different model physics lead to the necessity for different parameter sets

Parameters used in the DCA de Fleurian et al. (2014)		Parameters used in GLADS Werder et al. (2013)	
Description	Unit	Description	Unit
Thickness of the IDS	m	Sheet flow exponents	
Conductivity of the IDS	ms^{-1}	Sheet conductivity	$m^{7/4}kg^{-1/2}$
Initial thickness of the EPL	m	Ice flow constant cavities	$Pa^{-n}s^{-1}$
Collapsing thickness of the EPL	m	Basal sliding speed	ms^{-1}
Conductivity of the EPL	ms^{-1}	Cavity spacing	m
Compressibility of the solid	Pa^{-1}	Sheet with below channel	m
density of the porous media	$kg\,m^{-3}$	Bedrock bump height	m
leakage time	s	Channel flow exponents	
porosity of the media		Channel conductivity	$m^{3/2}kg^{-1/2}$
		Ice flow constant channels	$Pa^{-n}s^{-1}$

Description of the simulations

Preliminary simulation have been performed to assess the validity of the set-up

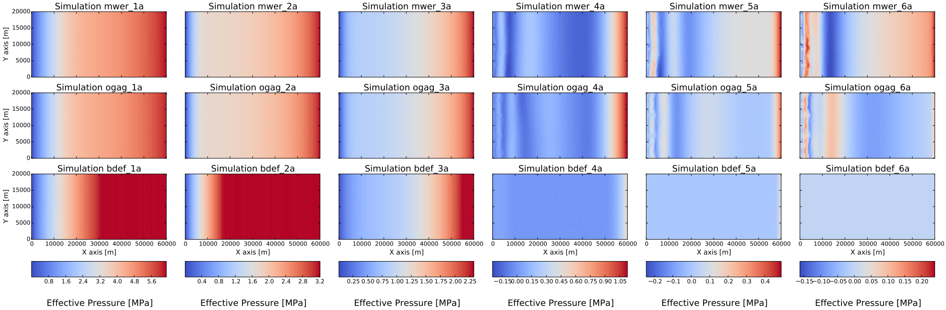
Water input	a Inefficient system	b Two systems
5mm/year	1	1
100mm/year	2	2
1mm/day	3	3
3mm/day	4	4
1cm/day	5	5
10cm/day	6	6

Simulations that are marked in red are used to perform the parameter selection

The target simulations are the one from GLADS (mwer runs), which are “closest to reality”

Initial simulation results

Effective pressure for experiments (*a*) for GLADS (mwer, ogag) and the DCA (bdef).

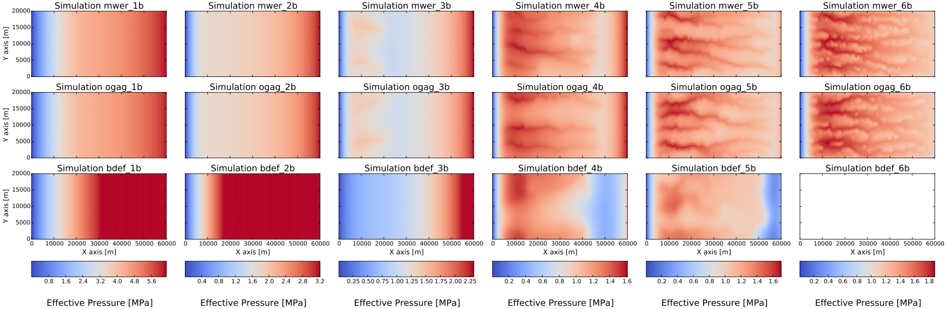


Fixed conductivity of the inefficient drainage system in the DCA leads to negative effective pressure when no efficient drainage system is introduced

GLADS results at high inputs start to shows instability and a wavy pattern

Initial simulation results

Effective pressure for experiments (*b*) for GLADS (mwer, ogag) and the DCA (bdef).

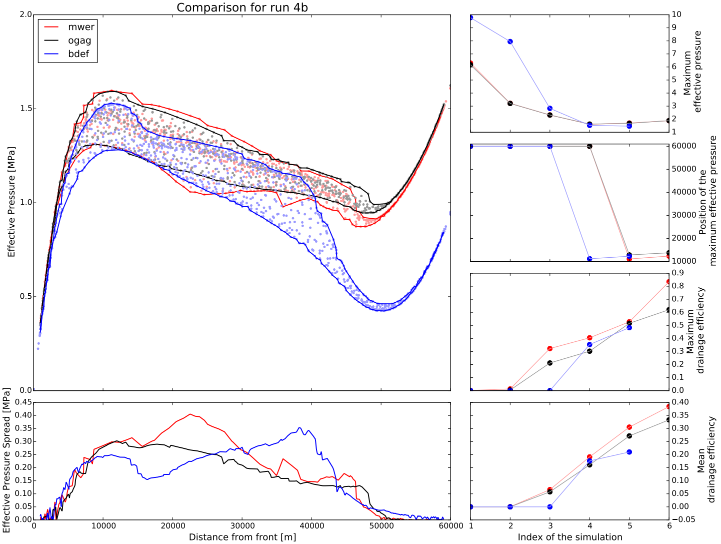


Very high input leads to stability issues with the DCA (experiment 6b)

Results are coherent but difficult to compare under this form

Introducing global variables for comparison

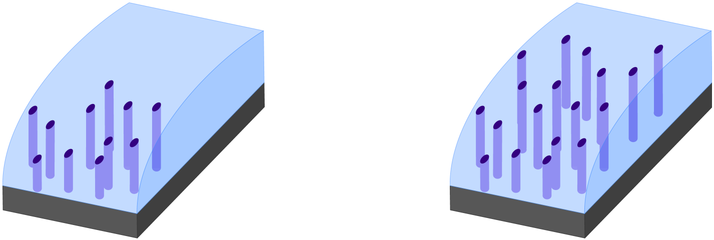
Comparing directly effective pressure maps is hard and limiting



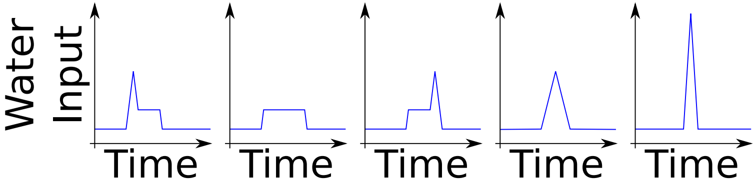
Prospective

Building more complex simulations to investigate specific mechanism

- Effect of localized input and the potential upstream migration of moulins



- Effect of the temporal distribution of the input



Timeline

- Finalization of the set-up during summer
- Preparation of the documents in September
- Launch through Cryolist mid September

Suggestion and/or remarks are welcome during summer

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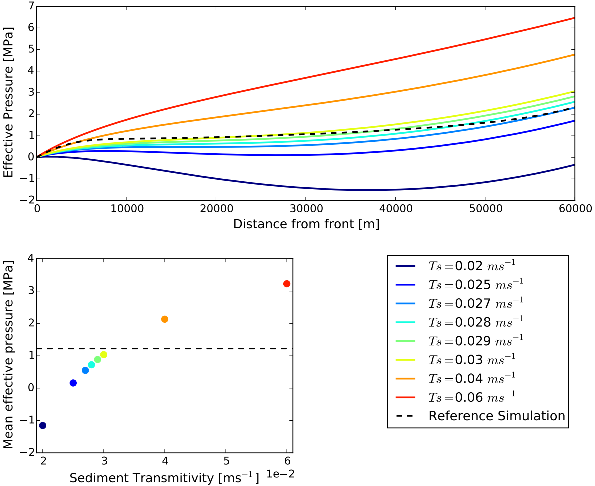
Parameter selection

Defining a parameter space for coherent results in-between models



Simulations 3a and 4b are used to fit the model parameter to a target result given by GLADS.