

A Hydrologically coupled high-order flow-band model of ice dynamics

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Aims



GLACIODYNAM

A new high-order flow-band model with coupled subglacial hydrology has been developed and will be used to explore the drainage of supraglacially-stored water through englacial fractures and assess the influence of this water on glacier dynamics including at large Arctic outlet glaciers.

Model Description

High-order stress components

- The model incorporates a multilayer longitudinal stress scheme following (Blatter, 1995) and (Pattyn, 2002)
- This provides a good description of glacier flows regimes that include slow and fast sliding (Schoof & Hindmarsh, 2009)
- Longitudinal stretching plays a leading order role when basal sliding and bed topographic variations are considerable

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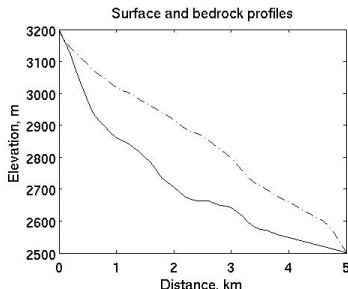
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Model Comparison

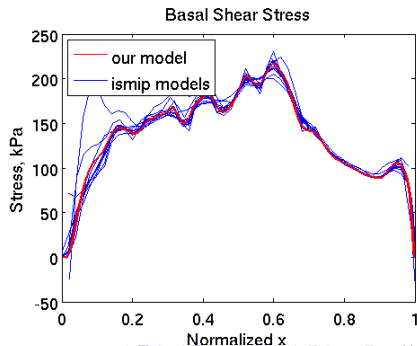
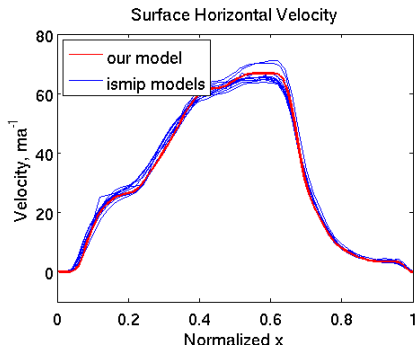
ISMIP-HOM Experiment E: Haut Glacier d'Arolla



- test the velocity/stress solution of the non-linear force-balance equations
- use fixed geometry
- no-slip basal b.c.
- isothermal

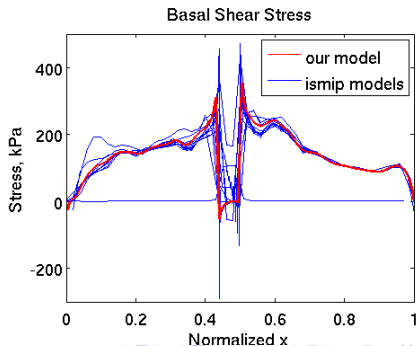
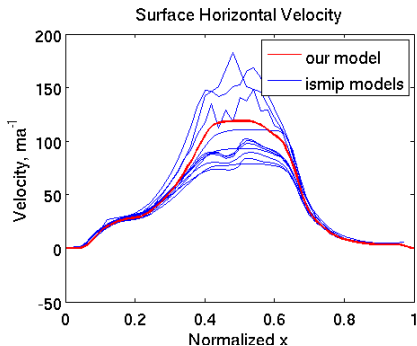
ISMIP-HOM results taken from (Pattyn et al., 2008)

Without Basal Sliding



ISMIP-HOM results taken from (Pattyn et al., 2008)

With Local Basal Sliding



Subglacial hydrology

An interacting “fast” and “slow” subglacial drainage system is implemented (Flowers, 2008)

- **Fast drainage:** Comprises ice-walled conduits, characteristic of summer
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Sliding law

- The hydrology is coupled to the ice mechanics by use of a Coulomb friction law (Schoof, 2005)
- This is a pressure dependent sliding rule utilizing the spatial and temporal variations in basal water pressure from the hydrology sub-model
- Overcomes problems of standard sliding laws which allow arbitrarily large basal shear stresses regardless of effective pressure
- Implemented as a non-linear Robin-type boundary condition which cannot be solved independently but forms part of the solution to the ice-flow problem

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Lateral drag parameterization

- This is a 2-D model, but incorporates the effects of three dimensional geometry
- Vertically resolved lateral shear stress is incorporated into the force-balance equations by use of a new parameterisation
- Lateral shear stress in the model is influenced by:
 - Vertically resolved sliding along the glacier wall which is described by the Coulomb friction law
 - Basin shape

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Additional features

- **Englacial fracture:** Linear elastic fracture mechanics (van der Veen, 2007) used for crevasse propagation
- **Uplift**
 - When large amounts of water impinge on the glacier bed high water pressures are generated and cause flexure of the overlying ice
 - This uplift effect is modelled by treating the glacier as a uniform static beam
- **Surface evolution:** Mass balance equation
- **Thermomechanical coupling:** Advective-Diffusive heat equation

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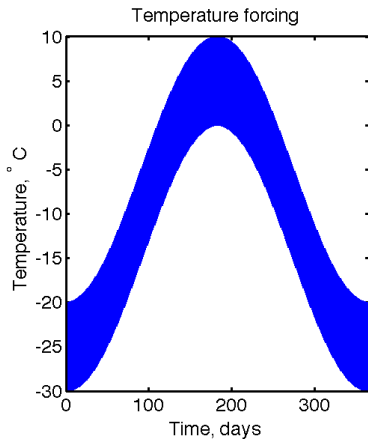
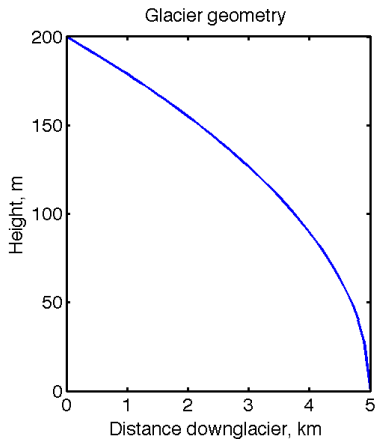
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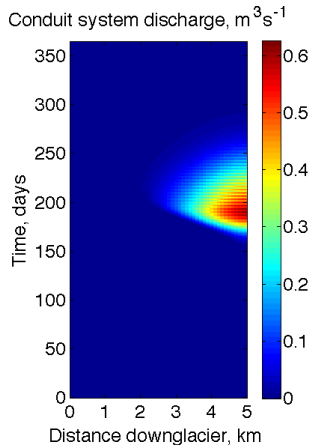
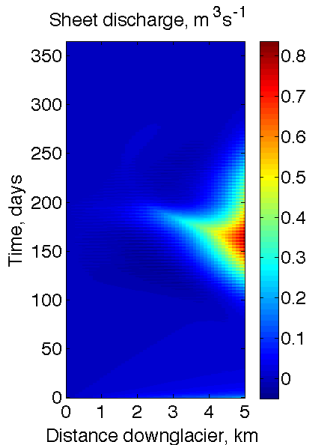
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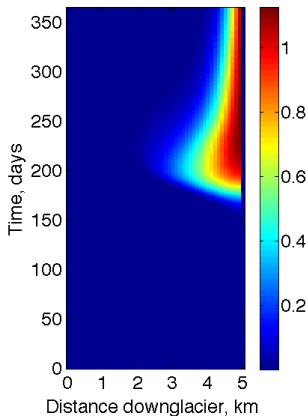
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An idealised test case

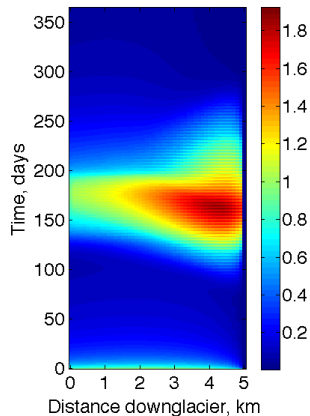


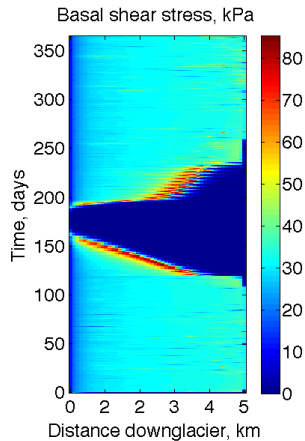
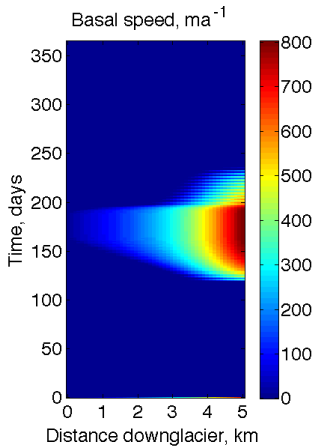


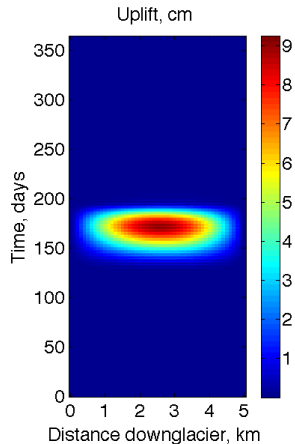
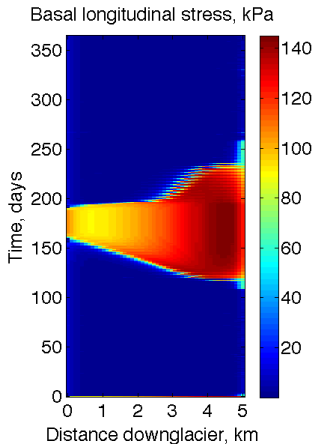
Conduit cross-sectional area, m



Subglacial water pressure, flotation fraction







Current work

- Numerical study of supraglacial lake drainage events e.g. Das et al (2008)
- Application to the Belcher glacier system, Canadian high Arctic
 - A large fast-flowing tidewater outlet glacier
 - Utilizing field observations: surface & bed topography, water inputs, and GPS measurements

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Questions?