Modelling of surface to basal hydrology across the Russell Glacier Catchment

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Sam Pimentel and Alun Hubbard
Centre for Glaciology
Institute of Geography and Earth Sciences
Aberystwyth University, UK
Ice-flow Model (Pimentel et al., *JGR*, 2010)

- **Higher-order stresses:** 1st-order approximation of the Stokes equation (Blatter, 1995; Pattyn, 2002), includes longitudinal stress gradients
- **Flow-band:** 2-D flowline model with flow-unit width parameter
- **Coulomb friction law:** basal sliding rule (Schoof, 2005)
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A mixed subglacial drainage network which includes dynamic switching between drainage components (Flowers, 2008)

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  - low capacity and efficiency
  - characteristic of winter

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  - ice-walled conduits
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Subglacial Hydrology Model

Distributed System

- macroporous water sheet
- low capacity
- low efficiency
- typical of winter

Channelized System

- ice-walled conduit
- high capacity
- high efficiency
- typical of summer

Image taken from Creyts & Clarke, J. Geophys. Res., 2010
Illustrative Example: Drainage switching

\[ Q \uparrow \Rightarrow N \downarrow \Rightarrow u_b \uparrow \quad Q > Q^* \quad Q \uparrow \Rightarrow N \uparrow \Rightarrow u_b \downarrow \]

Model Setup

- Observed surface velocity at GPS site s10a (~1885m elevation) (from Sam Doyle, Aber. Uni.) is used as an upper boundary condition.

- No seasonal variability is found at this location.

- We use vertically averaged modelled ice temperatures along the flowline taken from the sub-project B study (Brinkerhoff et al, 2011).
Flowline with surface and bed topography (from Rickard Pettersson, Uppsala Uni.) uses DTU lines and Bamber DEM
Model parameters are tuned to determine modelled flowline velocities (black line) that match 2009 TerraSAR-X observations (blue lines) (from Andy Fitzpatrick, Aber. Uni.)
Meltwater timeseries along the flowline (Dirk van As, GEUS) injected directly into the modelled subglacial system
Subglacial Discharge

Meltwater discharge through the inefficient (left) and efficient (right) drainage systems

2009
Modelled subglacial water pressure as a fraction of flotation
Modelled subglacial water pressures are currently slightly lower than those measured at this borehole location, ice thickness $\sim 600\,\text{m}$ (Paul Smeets, UMAU, ice2sea)
Modelled Seasonal Velocities

2009 seasonal envelope of modelled flowline surface speeds
Immediate Plans

- Refine model parameters using the available observational data
- A comparison of the 2009 and 2010 meltseasons
- More realistic meltwater input timeseries based on supraglacial lake/moulin locations, volumes and drainage times
- Perturbation experiments to assess impact of lake drainage events on glacier dynamics
- Coupling a groundwater component to the hydrology model
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Future Plans

2D Planform Subglacial Network Model (Schoof, *Nature*, 2010)

A unified treatment of linked cavities and channels

Switching between drainage components within a spatially extended drainage catchment

\[
\frac{\partial S_{ij}}{\partial t} = c_1 Q_{ij} \psi_{ij} + u_b h - c_2 N^n_{ij} S_{ij}
\]

- $S$: conduit cross-sectional area
- $Q$: water discharge
- $N$: effective pressure
- $\psi$: hydraulic gradient
- $u_b$: basal sliding speed
- $h$: bedrock bump
- $c_1, c_2, c_3, \alpha$: constants
Coupled Hydrology Components

- **Supraglacial** hydrology
- **Englacial** storage and transport
- **Groundwater** flow