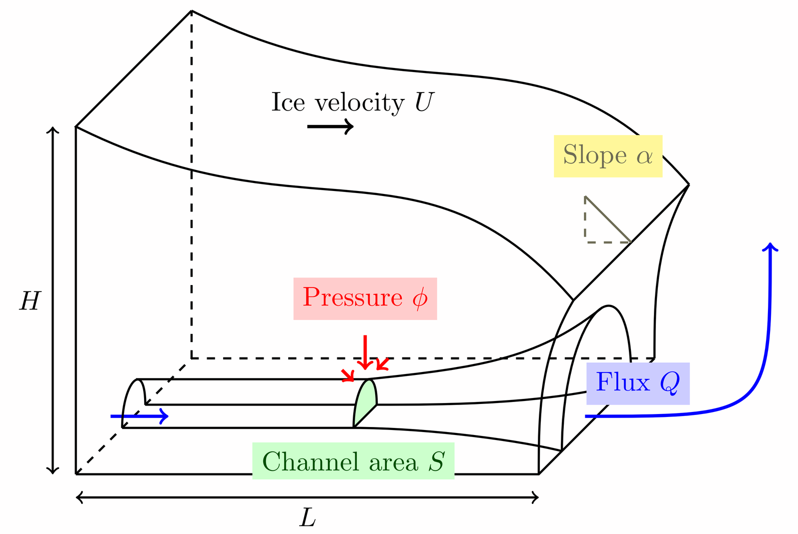
AGU 2013

Behaviour of subglacial drainage systems near the ice-ocean boundary

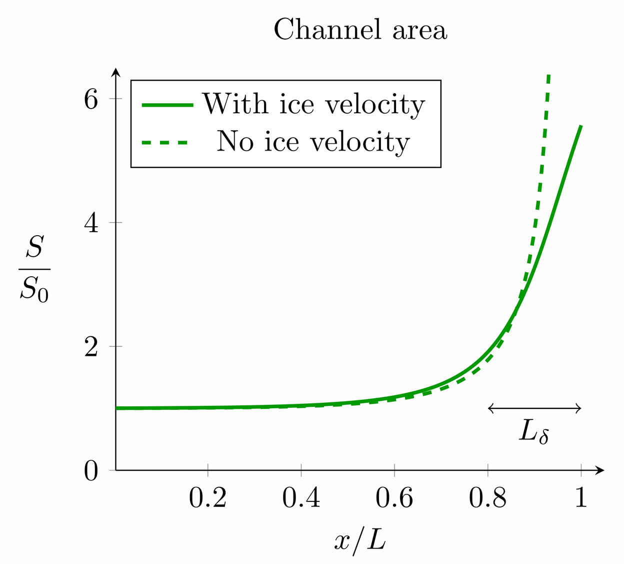
MICHAEL DALLASTON (dallaston@maths.ox.ac.uk), IAN HEWITT (hewitt@maths.ox.ac.uk), UNIVERSITY OF OXFORD

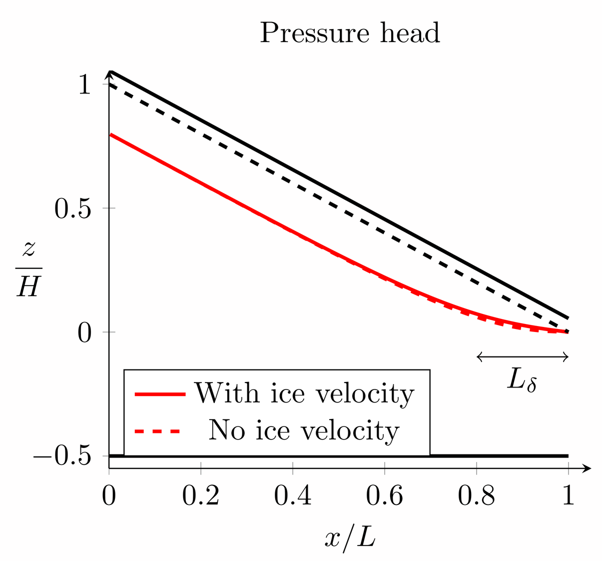
- ▷ Meltwater discharge from beneath glacier margins exerts a strong control on plume dynamics and melting rates at the ice front (Jenkins 2011, Gladish et al 2012, Sciascia et al 2013).
- ▷ We model how subglacial conduits behave as they approach the margin to explore the nature of this meltwater discharge.

SINGLE CONDUIT APPROACHING THE MARGIN



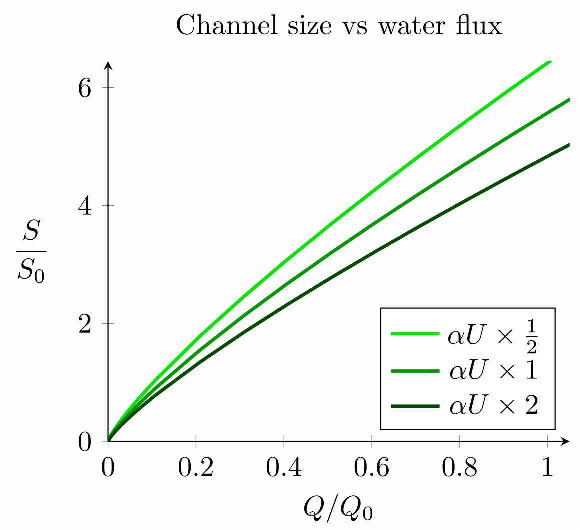
Creep closure of conduits reduces near the margin. Cross-sectional area become very large and water velocity is reduced.





Conduits are advected with rapid ice flow. Formula for cross-sectional area at margin

$$S = C(\alpha U)^{-9/44} Q^{9/11}, \quad C \approx 0.3\,\mathrm{m}^{-1/4}\mathrm{s}^{27/44}$$



Representative values

	Q ($\mathrm{m^3\,s^{-1}}$)	S ($\mathrm{m^2}$)	Q/S ($\mathrm{m\,s^{-1}}$)
HELHEIM	1	4	0.2
$\alpha = 0.01$	10	27	0.4
$U = 8\mathrm{km\,yr^{-1}}$	100	179	0.6
JAKOBSHAVN	1	3	0.3
$\alpha = 0.02$	10	22	0.5
$U = 11\mathrm{km\,yr^{-1}}$	100	146	0.7

CONDUIT MODEL

Advection Melting Sliding Creep closure

$$\frac{\partial S}{\partial t} + U_b \frac{\partial S}{\partial x} = \frac{\rho_w}{\rho_i} M + U_b h_r - A S N^n$$

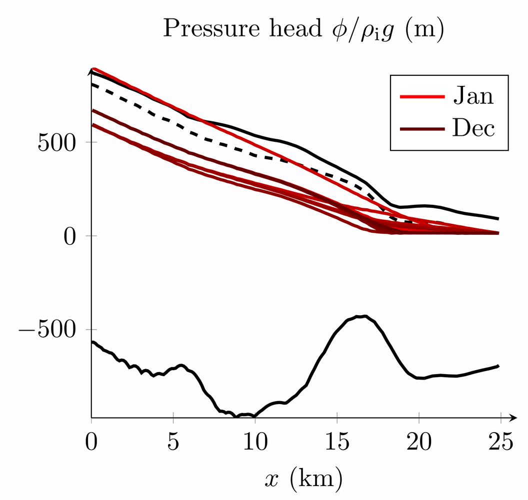
Water conservation $\frac{\partial S}{\partial t} + \frac{\partial Q}{\partial x} = M$

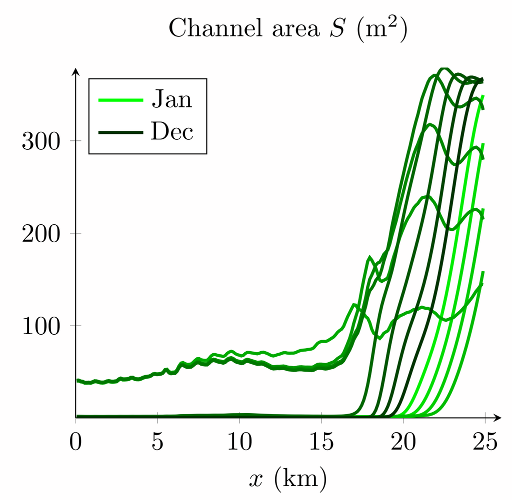
Turbulent flow $Q = K_c S^{4/3} \left|\frac{\partial \phi}{\partial x}\right|^{1/2}$

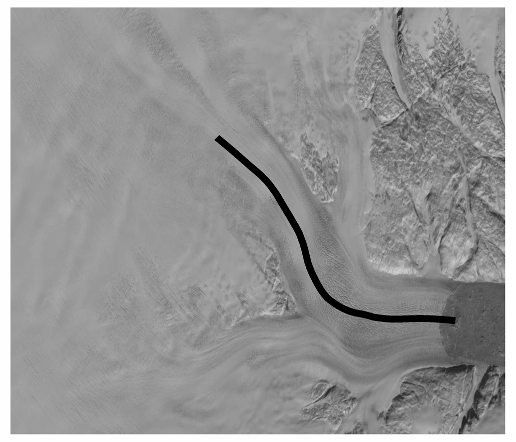
Melting $M = \frac{1}{\rho_w L}\left|Q \frac{\partial \phi}{\partial x}\right|$

Effective pressure $N = \rho_i g Z_s - \phi$

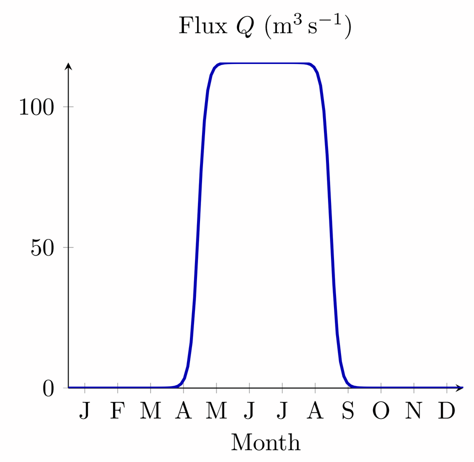
SEASONAL CYCLE

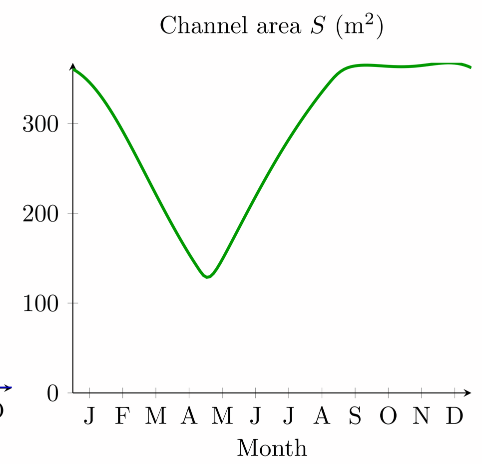


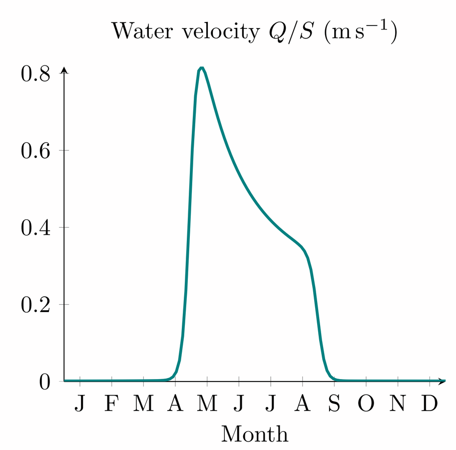




Flow line along Helheim Glacier, single conduit forced by seasonal discharge.



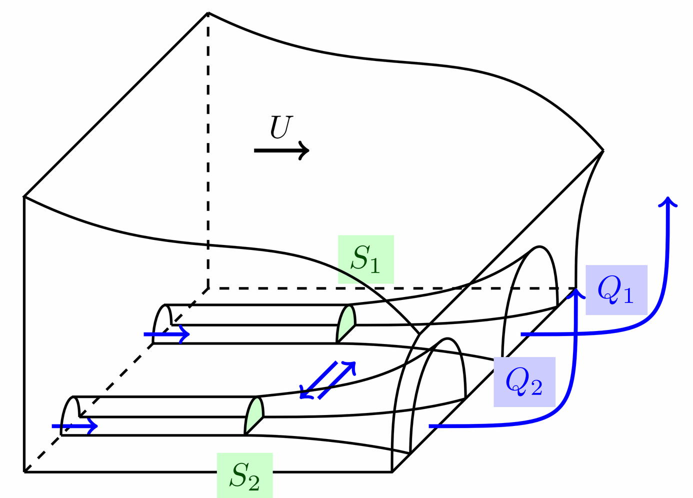




Conduit grows at the margin throughout summer. Closes primarily by advection during winter.

MULTIPLE CONDUITS

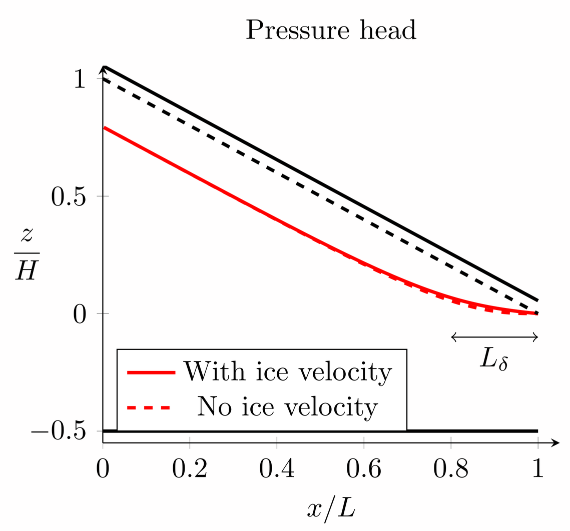
2D models suggest water may spread laterally from a conduit close to the margin.

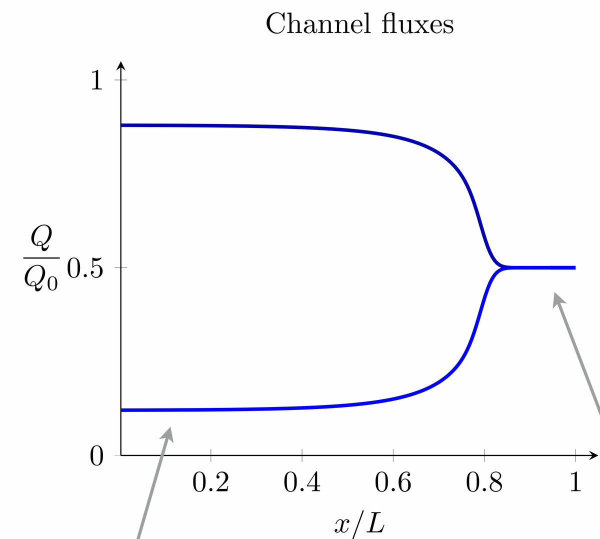


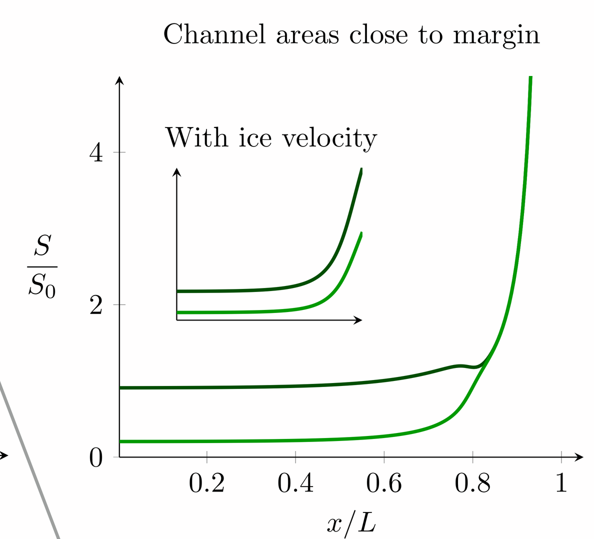
$$Q_1 + Q_2 = Q$$

$$\phi_1 = \phi_2$$

Consider two conduits in parallel with efficient transverse connection.



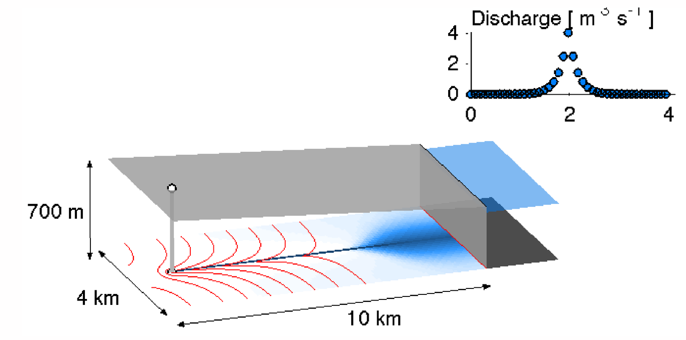




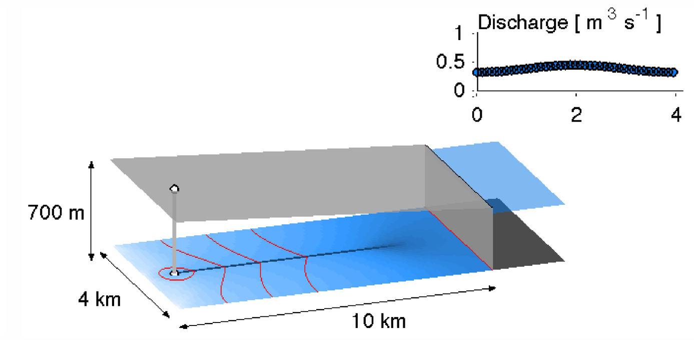
Channelisation due to dissipative heating. One conduit carries most of discharge.

Dissipative heating reduced. Conduits become the same size and share the discharge.

TWO-DIMENSIONAL MODELS



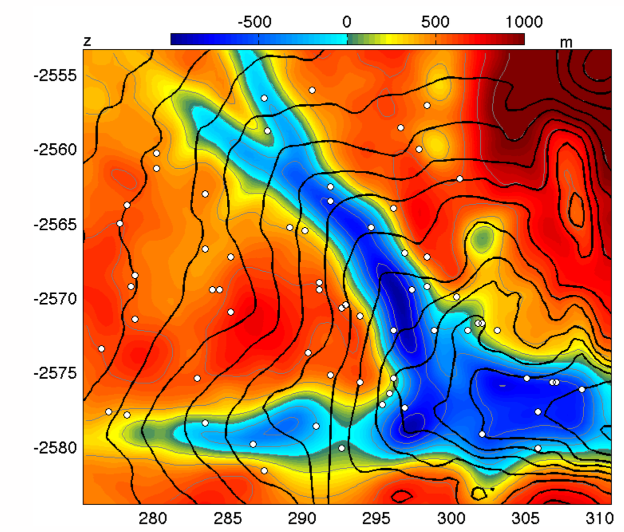
Slower sliding



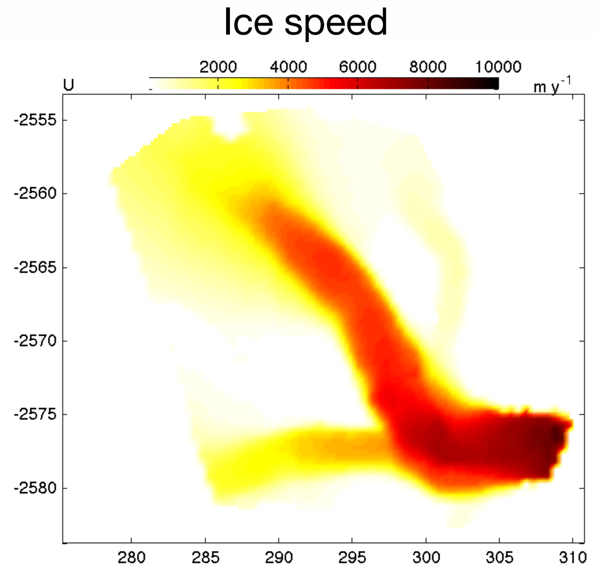
Faster sliding

Model includes a network of potential conduits (Hewitt 2013).

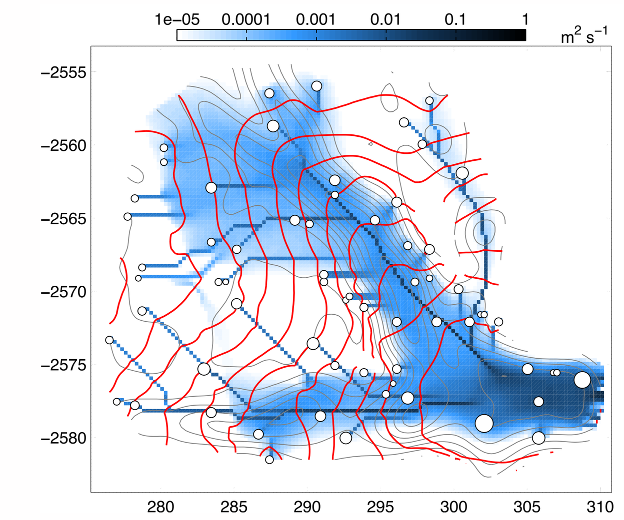
Bed & surface elevation



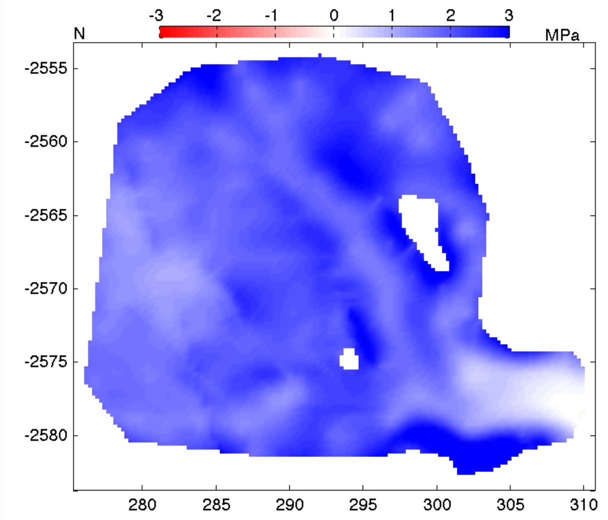
Ice speed



Discharge



Effective pressure



Model applied to Helheim with imposed ice topography and velocity.

- ▷ Conduits tend to grow near the margin due to low effective pressure.
- ▷ Ice advection is important in controlling conduit size at margin.
- ▷ Water may spread laterally in a delta-like fashion.
- ▷ Rapid sliding may preclude significant channelisation.

References

Gladish, C.V. et al 2012 Ice-shelf basal channels in a coupled ice/ocean model. J. Glaciol.
Hewitt, I.J. 2013 Seasonal changes in ice sheet motion due to melt water lubrication. Earth Plan. Sci. Lett.
Jenkins, A. 2011 Convection-Driven Melting near the Grounding Lines of Ice Shelves and Tidewater Glaciers. J. Phys. Ocean.
Joughin, I. et al 2010 Greenland Flow Variability from Ice-Sheet-Wide Velocity Mapping. *J. Glciol.*
Mernild, S.H. & Liston, G.E. 2012 Greenland Freshwater Runoff. Part II: Distribution and Trends, 1960–2010. *J. Clim.*
Sciascia, R. et al 2013 Seasonal variability of submarine melt rate and circulation in an East Greenland fjord. J. Geophys. Res.

Acknowledgements

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Gogineni, P. 2012. CReSIS Radar Depth Sounder Data, Lawrence, Kansas, USA.
Joughin, I. et al. 2011, updated 2013. MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR. Boulder, Colorado USA: National Snow and Ice Data Center.