Basal Melt Beneath Whillans Ice Stream and Ice Streams A and C

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We have used a recently derived map of the velocity of Whillans Ice Stream and Ice Streams A and C to help estimate basal melt. Temperature was modeled with a simple vertical advection-diffusion equation, "tuned" to match borehole temperature profiles. We find that most of the melt occurs beneath the tributaries where larger basal shear stresses and thicker ice favors greater melt (e.g., 10-20 mm/yr). The occurrence of basal freezing is predicted beneath much of the ice plains of Ice Stream C and Whillans Ice Stream. Modeled melt rates for when Ice Stream C was active suggest there was just enough melt water generated in its tributaries to balance basal freezing on its ice plain. Net basal melt for Whillans Ice Stream is positive due to smaller basal temperature gradients. Modeled temperatures on Whillans Ice Stream, however, were constrained by a single temperature profile at UpB. Basal temperature gradients for Whillans B1 and Ice Stream A may have conditions more similar to those beneath Ice Streams C and D, in which case, there may not be sufficient melt to sustain motion. This would be consistent with the steady deceleration of Whillans stream over the last few decades. Additional borehole derived temperature profiles are important as further constraints on the modelled temperature and melt rates.

Decleration of Whillans Ice Stream

Is a reduction in basal melt a factor?

Melt Rate Calculation

$$m_r = \frac{G + \tau_b U_b - k_i \Theta_b}{L_i \rho_{ice}}$$

Geothermal heat flux: G = 70 mW/m^2

Basal shear heating:
> Tributaries: τ_b = 50% τ_d (force balance).
> Ice streams: τ_b = 2 kPa.
> $U_b = U_s$;
> No significant melt where U_b < 25 m/yr.

Basal temperature gradient
> Solve for steady state temperature profiles with no horizontal advection and melted bed.
> An "effective" accumulation rate is used based on fits to borehole temperatures.

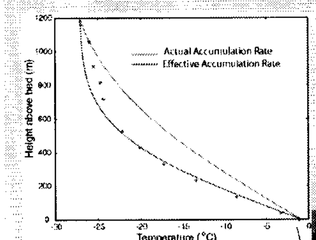
Ice Stream C

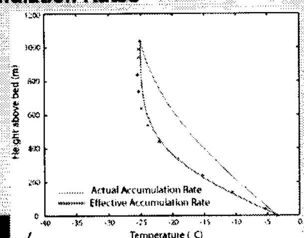
Region	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
Active Region	4.8	4.8	6.5
Ice Plain	[illegible]	[illegible]	[illegible]
Total	1.5	1.1	3.9

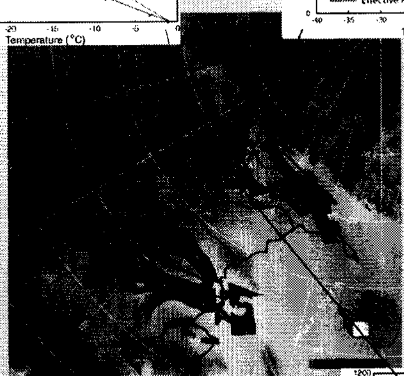
Whillans Ice Stream

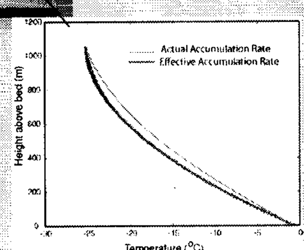
Region	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
Slow Tributary	6.5	6.6	4.1
Fast (Ice Stream)	-2.4	[illegible]	-3.2
Total	3.1	2.6	0.5

Effective Accumulation Rates









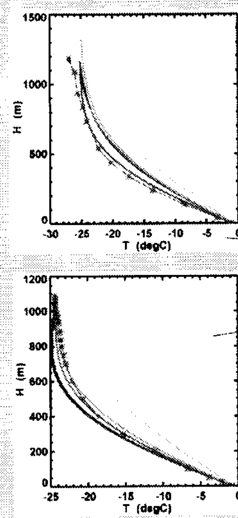
Temperature Profile Ignoring Vertical Advection

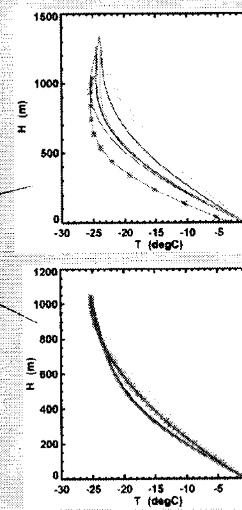
The temperature parameterized by accumulation rate a. Observed accumulation rates yield a poor fit to the measured temperature profile. Much better agreement can be obtained with an effective accumulation rate (see plots).

Horizontal Advection

Along a flow line

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + w\frac{\partial T}{\partial z} = \frac{1}{c}\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)$$





Including horizontal advection provides an improed fit with the measured accumulation rates.

Summary

> Tributaries provide surplus meltwater, while ice streams of undergo basal freeze-on.
> By rapidly draining ice from the interior, tributaries push the basal temperature gradient toward significantly less melt.
> Additional borehole temperatures need to provide model validation/contraints and to for areas of nonsteady flow (e.g., Ice Stream C and Whilans Ice Stream).