Ocean-Driven Melting near and within Ice Shelf Basal Channels and Crevasses

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Research Overview

- Goal is to investigate how different conditions and forcings within ice shelf cavities impact the near-boundary dynamics and thermodynamics, which drive disparate magnitudes and spatial patterns of melt.
- Use Large Eddy Simulations of circulation within ice shelf cavities to simulate a parameter regime including: (1) channel width, magnitude of (2) far-field temperature, (3) salinity, and (4) velocity, and (5) orientation of far-field velocity.

Motivation

- Ice shelves in West Antarctica and Northern Greenland have lost a significant amount of mass, thinned, and retreated over the past two decades.
- **Gap in understanding: (1) How does 3D circulation within basal channels/crevasses influence melting and evolution of these morphologies? (2) Do basal geometries stabilize or destabilize ice shelves?**

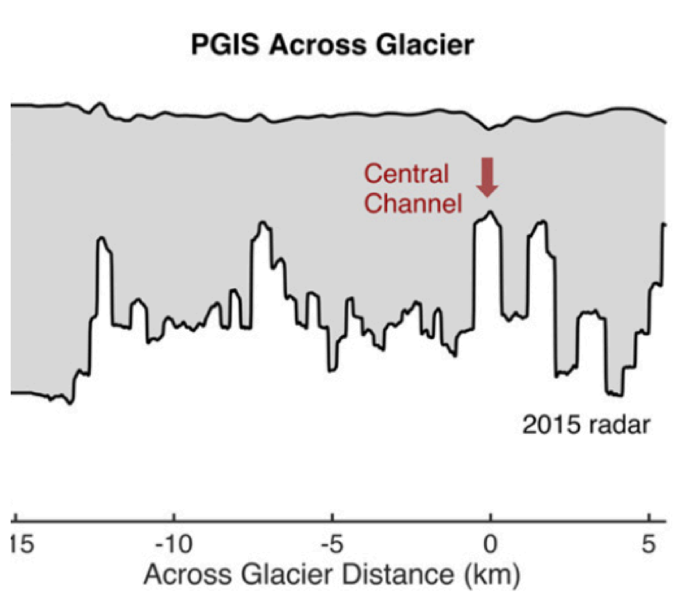

Figure 1: Radar profile across the Petermann Gletscher in Northwest Greenland. Credit: Washam et al (2018).

Model Configuration

- Large Eddy Simulations of ocean circulation within basal geometries were developed using MITGCM with 3D Smagorinsky viscosity
- **Sensitivities of melt to each control parameter can be predicted by using 3-eq. ice-ocean boundary layer parameterization.**

$$m = C_{eddy} V (T - T_f) \tag{1}$$

Definitions: T is the ambient temperature, T_f is the local freezing temperature at the ambient salinity S (which can be calculated using the liquidus condition). C_{eddy} is the turbulent transfer of heat by small-scale ocean boundary layer eddies.

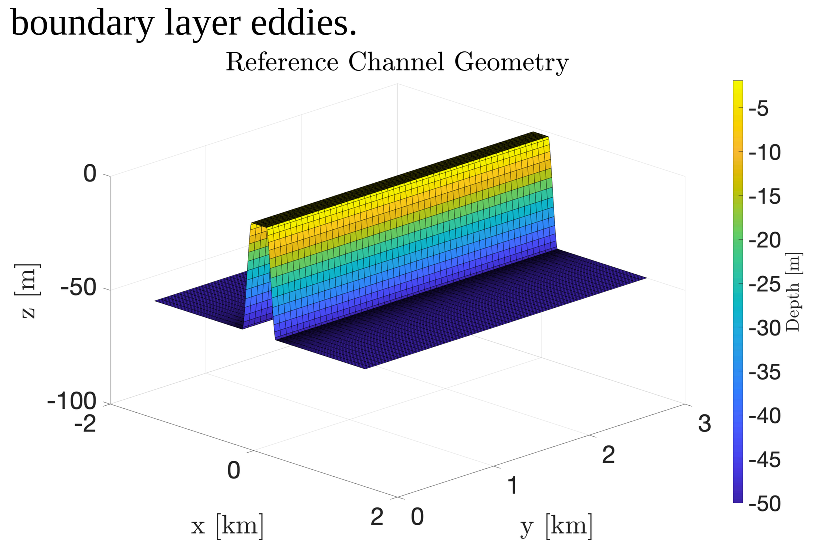

Figure 2: Channel geometry of reference case, with a height of 50m and width of 500m.

Channel width [m]	70, 125, **500**
T_∞ [°C]	-1.8, -1.2, **-0.25**
S_∞ [psu]	29, **34.15**, 34.6
V_∞ [m/s]	0.05, **0.1**, 0.2
θ	**0**, 45, 90

Table 1: Parameter regime chosen to represent a range of Greenlandic and Antarctic conditions. **Reference case values in bold.**

Reference Case Dynamics & Thermodynamics

- **Western boundary upwelling/Coriolis-favored circulation**

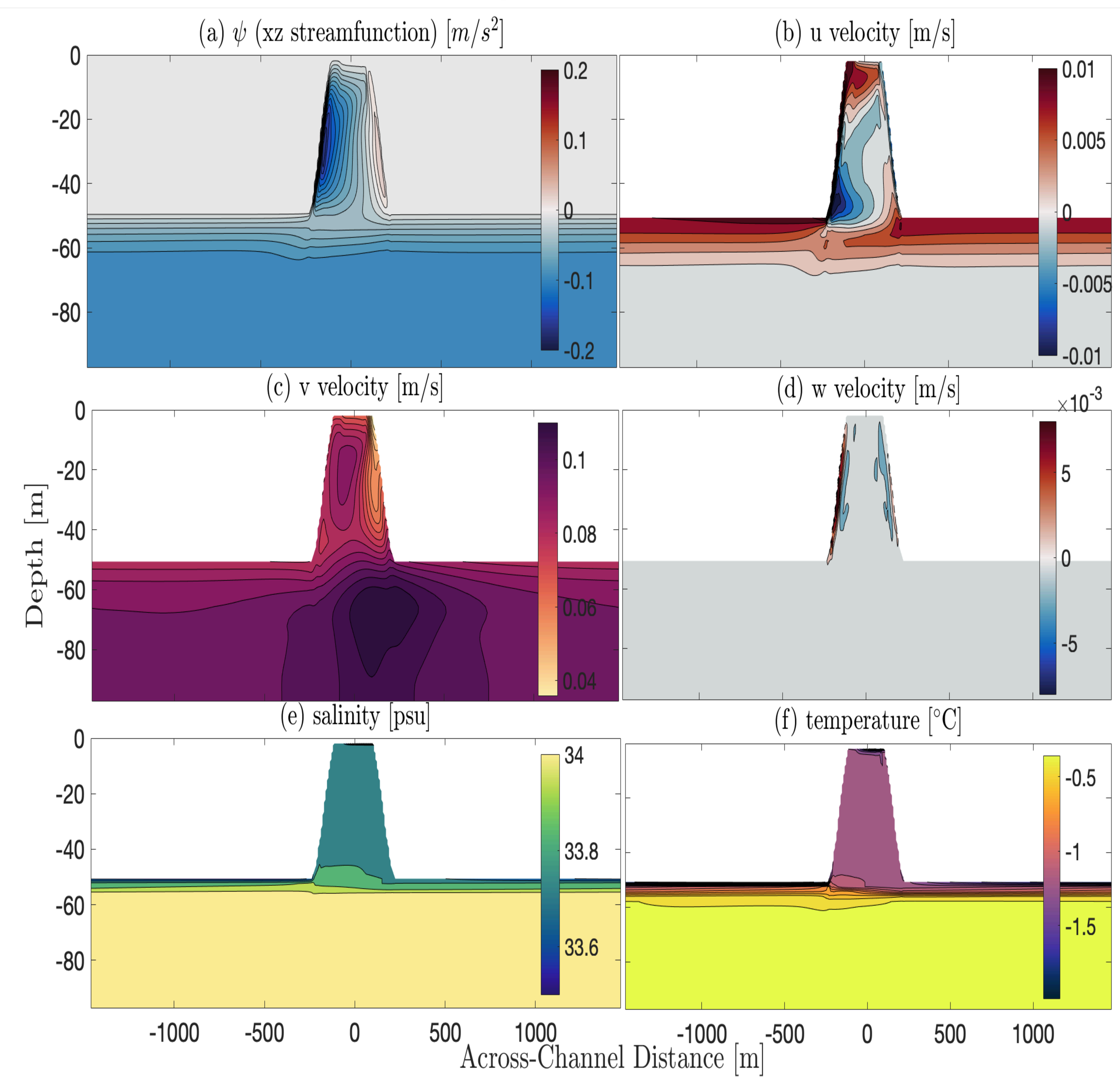

Figure 3: Y-averaged profile of (a) xz streamfunction, (b) u velocity, (c) v velocity, (d) w velocity, (e) temperature, and (f) salinity at day 10 of simulation. Oriented facing the outflowing boundary to the North.

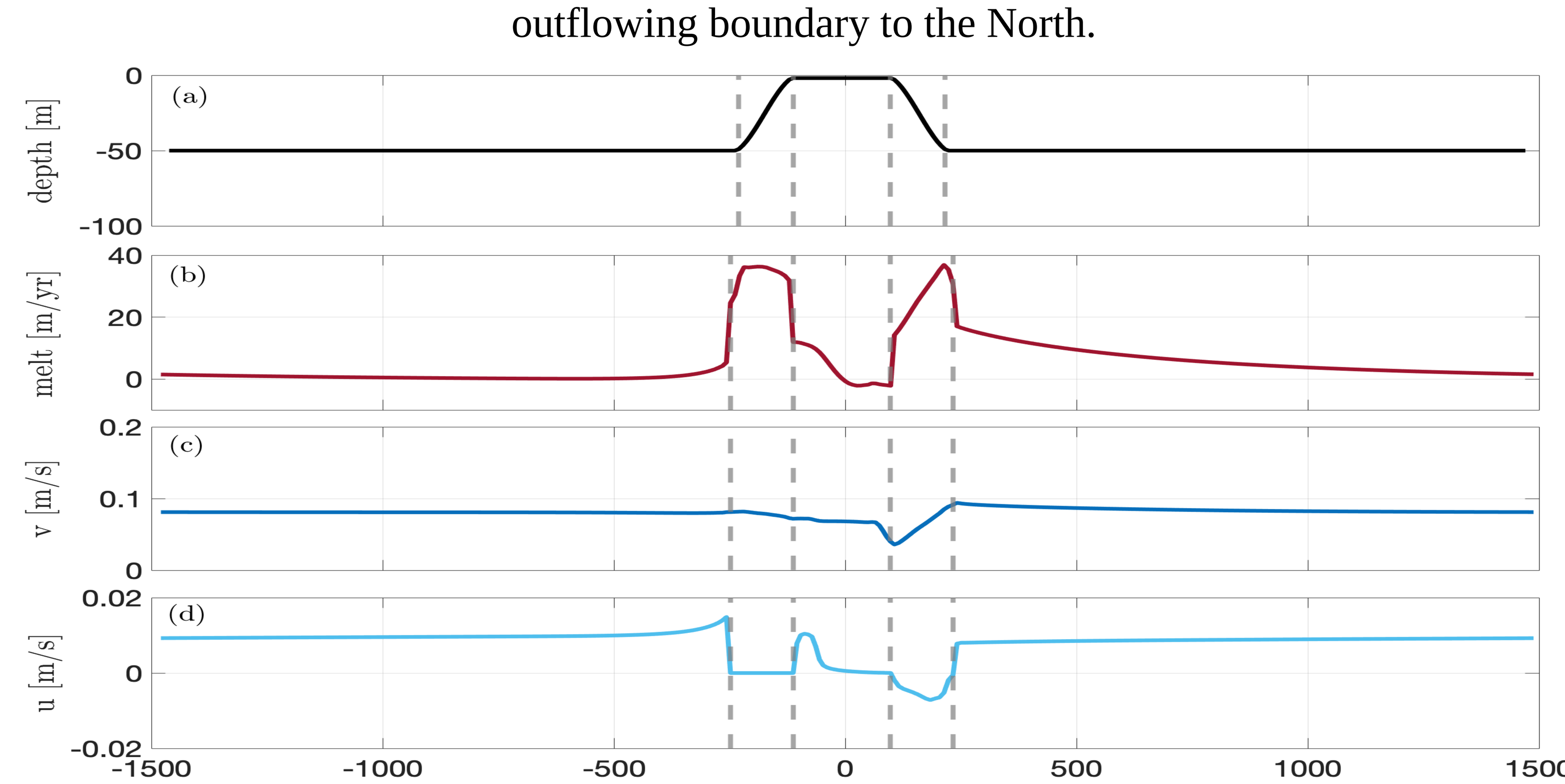

Figure 4: (a) Across-channel depth. Y-averaged profile of (b) melt (c) v velocity, and (d) u velocity at day 10 of simulation. Grey lines mark the sides and top of the channel.

Preliminary Melt Theory

- Melt rates can be predicted within and near various geometries by analyzing nondimensionalized momentum $\hat{V}$ and thermal forcing channel permeability $\Delta\hat{T}$, where

$$\hat{V} = \frac{V_{\text{min}}}{V_\infty} \tag{2}$$

$$\Delta\hat{T} = \frac{T_{\text{min}} - T_f}{T_\infty - T_f} \tag{3}$$

Definitions: V_∞ is the far-field velocity, and V_{min} is the velocity at the top of the channel. T_∞ is the far-field temperature, T_{min} is the temperature at the top of the channel, and T_f is the local freezing temperature at the ambient salinity S (which can be calculated using the liquidus condition).

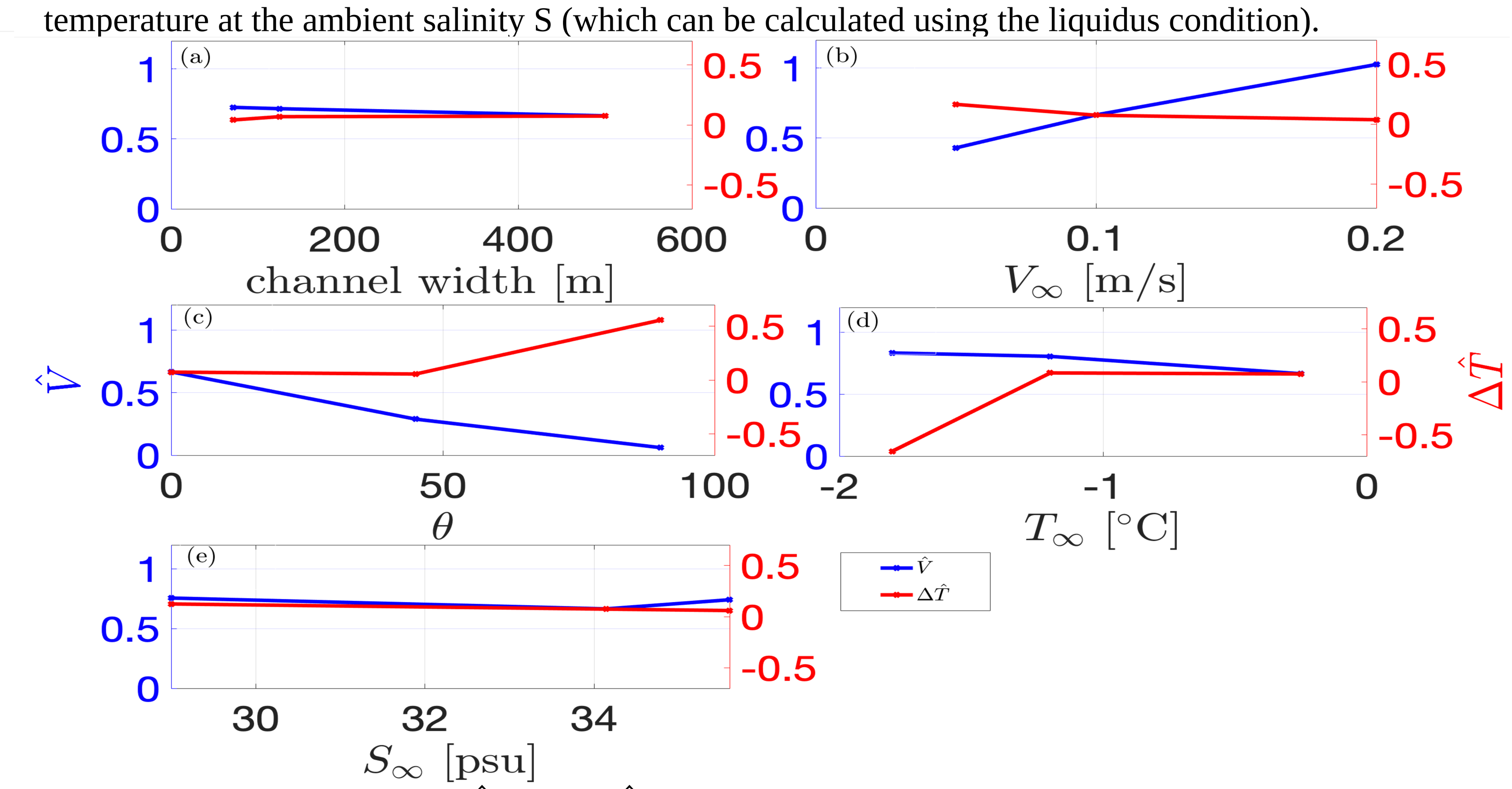

Figure 5: $\hat{V}$ and $\Delta\hat{T}$ as a function of control parameters.

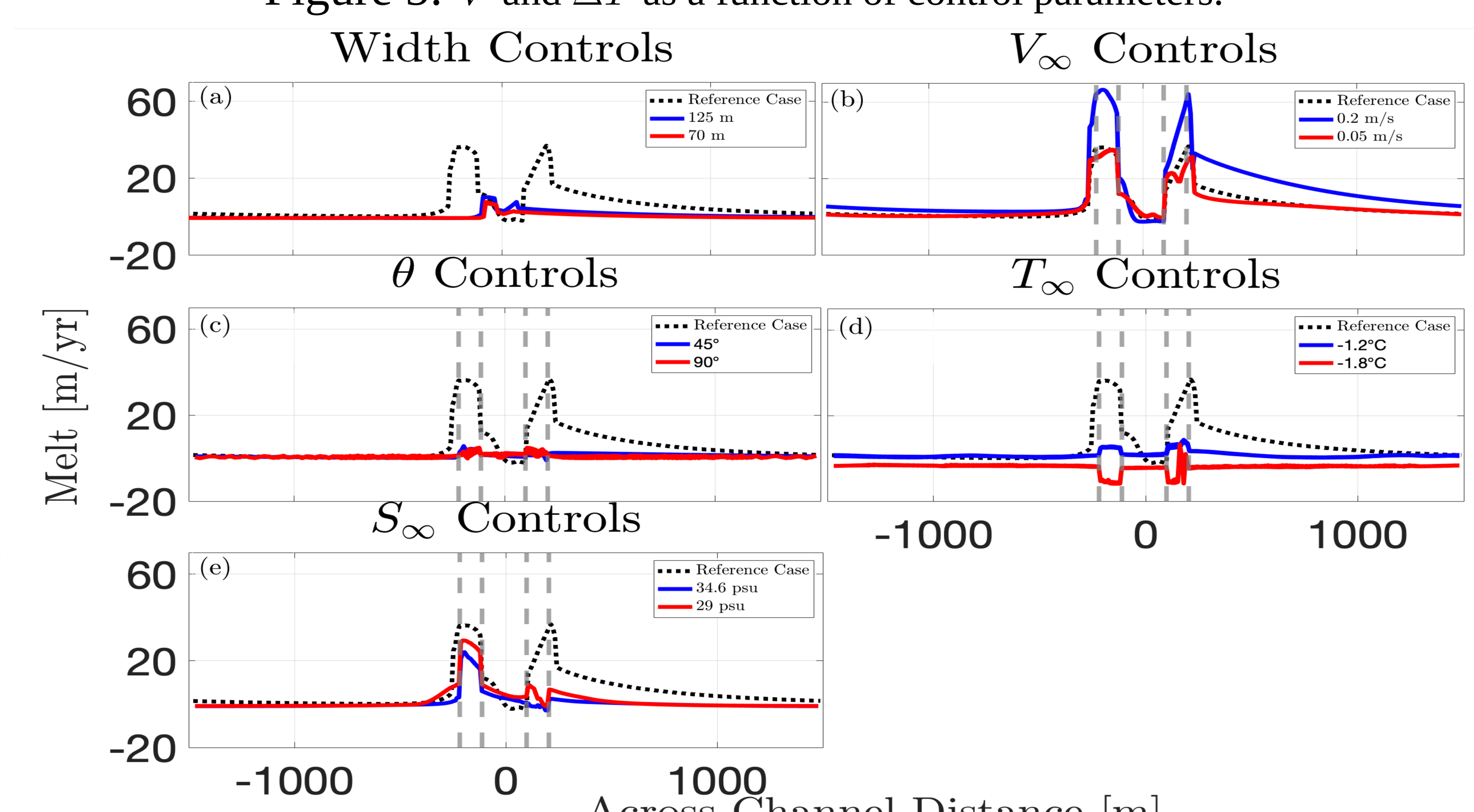

Figure 6: Sensitivities of annual melt rate to (a) channel width, (b) V_∞, (c) θ, (d) T_∞, and (e) S_∞.

Summary and Future Work

- Higher melt rates are found on channel walls compared to the top of channels.
- Melt rate is most sensitive to increasing V_∞ and T_∞.
- Use $\hat{V}$ and $\Delta\hat{T}$ to predict melt rates within and outside basal geometries

$$m \propto \left(\frac{V_\infty + V_{\text{min}}}{2}\right)\left(\frac{T_\infty + T_f}{2}\right)$$