Simulation of Sub-marine Melting with ECCO2

Yun Xu

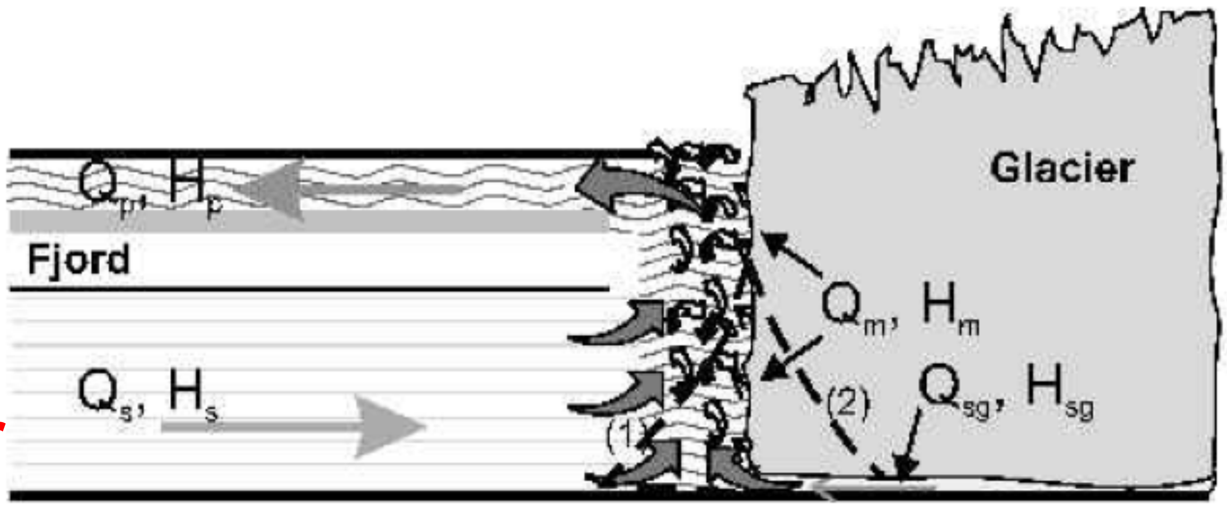
Earth System Science

Univerisity of California, Irvine

Motivation

- Glacier front retreat could reduce the basal and lateral drag, and therefore accelerate glacier velocity
- Sub-marine melting is one reason for glacier retreat. It is fast [m/day] at the front of some Greenland tidewater glaciers
- What are the reason and the result of sub-marine melting at the front?

(Motyka, et al., 2003)



Warm water

Sub-glacial runoff

T=0 ℃; S=0

→ upwelling

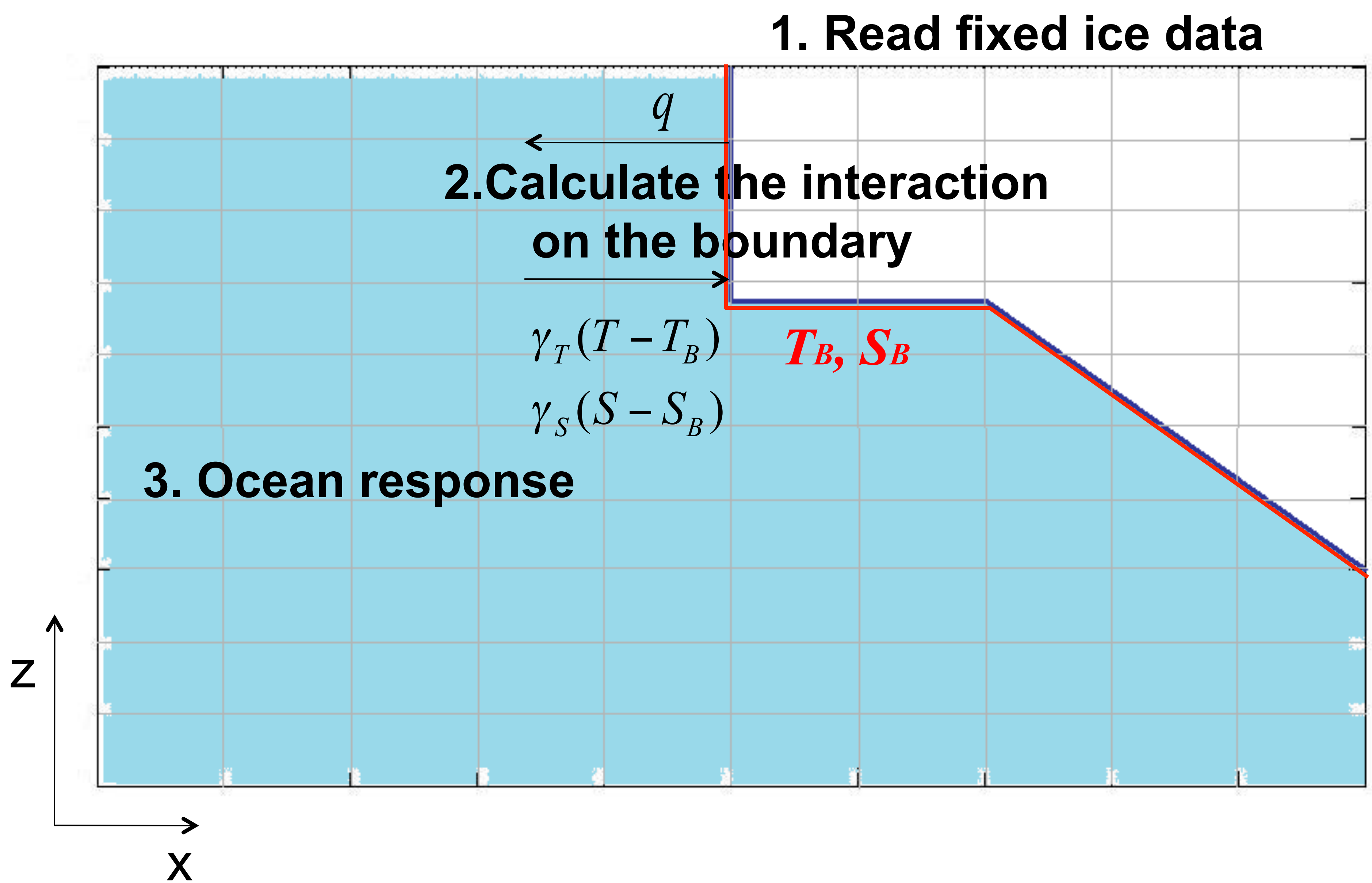
Goals

- Use ECCO2 (and ISSM) to study the sub-marine melting
  - What processes affect melting rate? (ocean warming, sub-glacier runoff)
  - What's the melting rate?
  - What is the consequent front retreat and glacier acceleration?

ECCO2

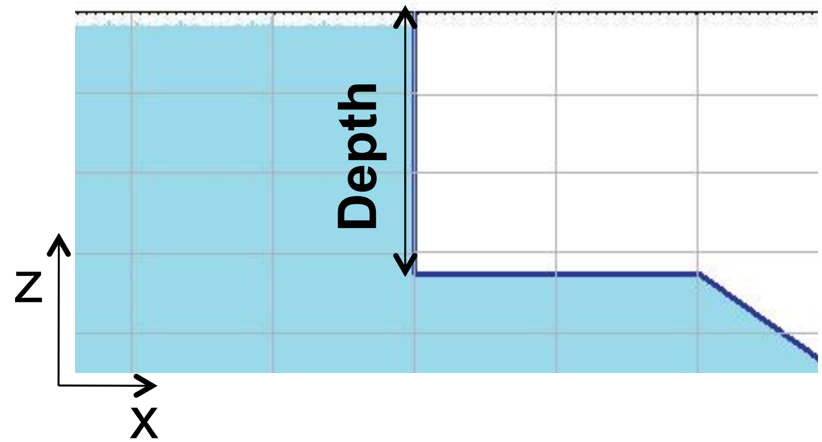
- 3-D ocean model
- It has ice shelf basal melting, but no melting on the vertical face.
- Fixed ice shelf topography
- **I add a package (called icefront) to calculate the melting on the vertical face**
  - Ice topography is still fixed. Hydrostatic balance and Boussinesq approximation will be assumed.

Basic physics



1. Read fixed ice data

- **Depth (2-D file)**



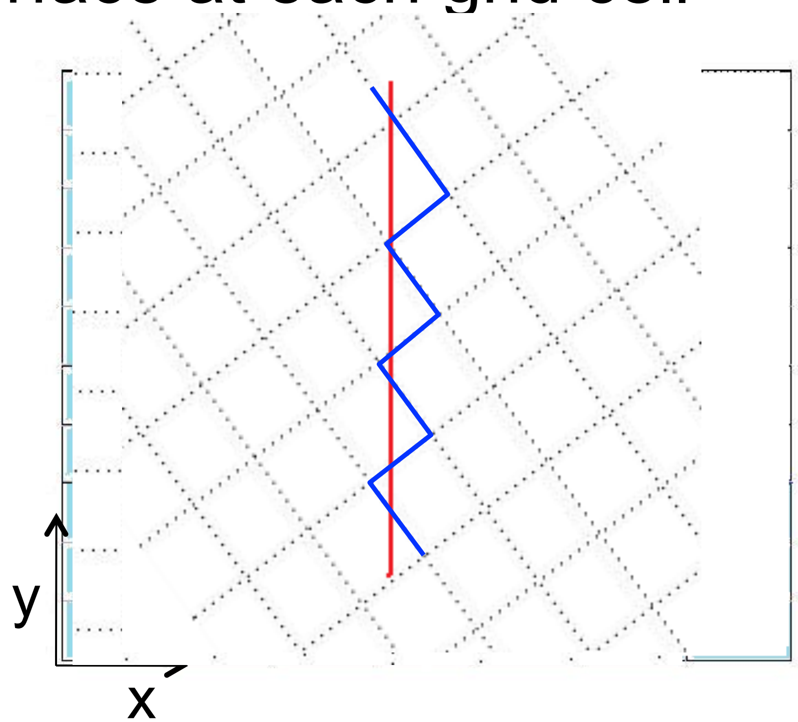
- **Length** of ice-ocean interface at each grid cell

  Tells the location of interface

  Doesn't care position of ice

  Keep consistence between different projections

  Make calculation easy



2. Interactions at the boundary

Three constraints:

a. Temperature must be at the local freezing points;

b&c. conservation of heat & salinity

(Walker & Holland, 2007)

$$T_B = aS_B + b + cp_B$$

$$c_{pI}(-q)(T_{ice} - T_B) + c_{pW}\rho\gamma_T(T - T_B) = -qL_f$$

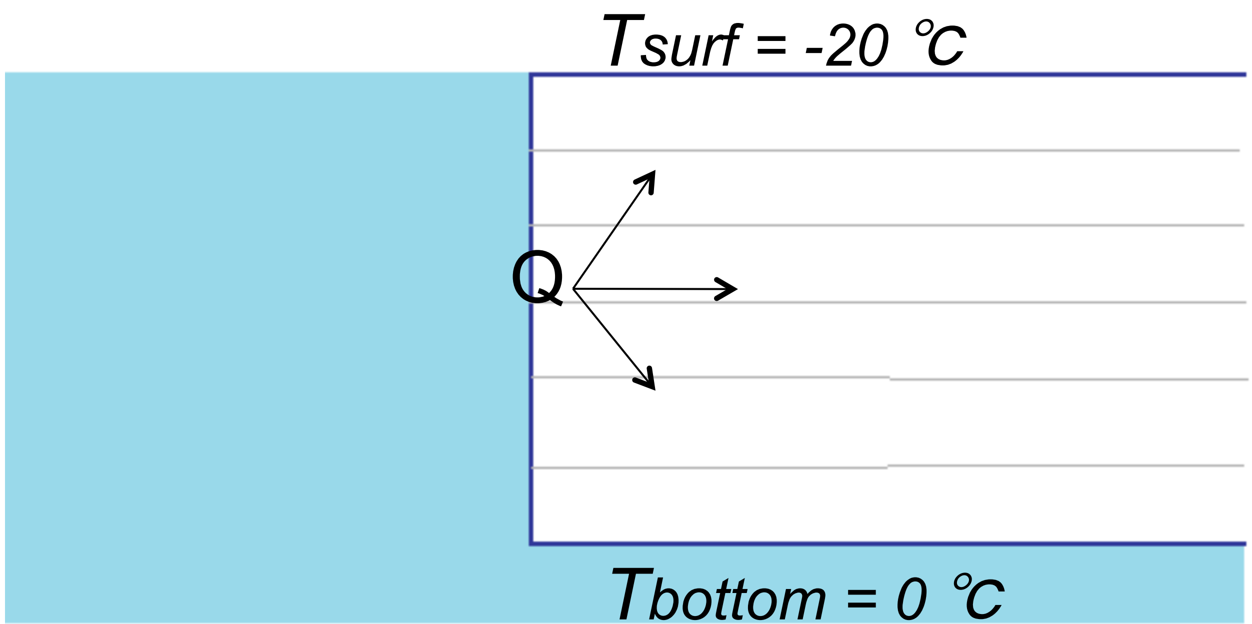
$$\rho\gamma_S(S - S_B) = -q(S_B - S_{ice})$$

$$\rho_I c_{pI} \kappa \left. \frac{\partial T_{ice}}{\partial x} \right|_B$$

$$\rightarrow T_B, S_B, q$$

T_ice

Constant temperature at each horizontal layer



$$\rho_I c_{pI} \kappa \left. \frac{\partial T_{ice}}{\partial x} \right|_B \leq c_{pI} (-q)(T_{ice} - T_B)$$

$$\rho_I \cancel{c_{pI}} \kappa \cancel{\frac{\partial T_{ice}}{\partial x}}\bigg|_B \leq \cancel{c_{pI}} (-q)(\cancel{T_{ice} - T_B})$$

$$\frac{-q}{\rho_I} \geq \frac{\kappa}{\Delta x} = \frac{1.5\times 10^{-6}\,\mathrm{m}^2/\mathrm{s}}{\Delta x}$$

If Δx = 100 m, melting needs to be > 1.3 mm/day

How big is the error?

$$\underline{\underline{c_{pI}(-q)(T_{ice}-T_B)}}+c_{pW}\rho\gamma_T(T-T_B)=\underline{\underline{-qL_f}}$$

$$c_{pI}(\cancel{-q})(T_{ice}-T_B):\cancel{-q}L_f$$

$$2000\times(-20):334000$$

$$1:10$$

Therefore, the error of the first term is pretty small compare to the latent heat term, and is not quit harmful to the whole balance.

In addition, if the heat conduction is underestimated, the melting rate would be bigger rather than smaller.

3. ocean response

- T/S is changes by
  - heat/salinity transport
  - melt water mixing

$$\frac{\partial T}{\partial t} = \left[\gamma_T (T - T_B) - \frac{q}{\rho}(T - T_B) \right] \times \text{FrontArea} / \text{CellVolume}$$

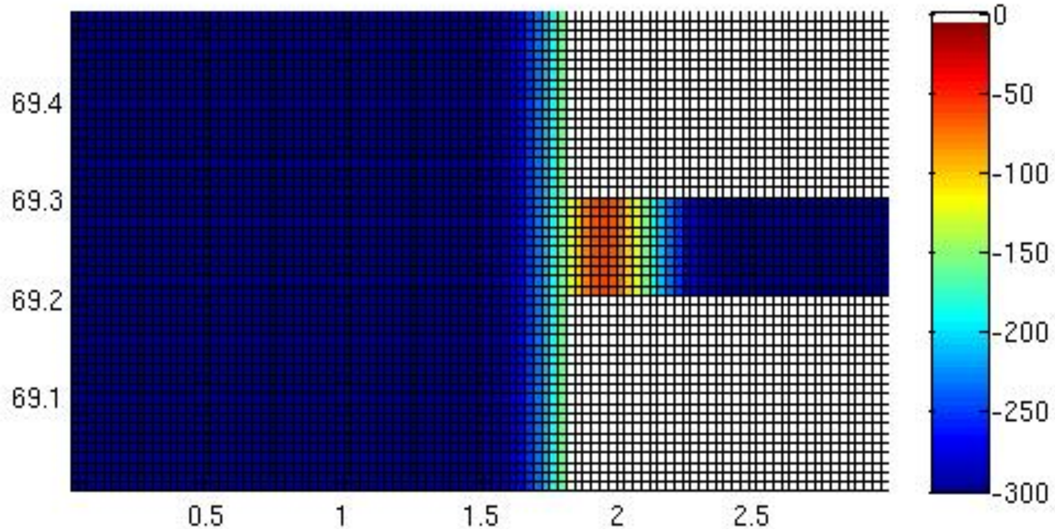
$$\frac{\partial S}{\partial t} = \left[\gamma_S (S - S_B) - \frac{q}{\rho}(S - S_B) \right] \times \text{FrontArea} / \text{CellVolume}$$

Sub-glacial Runoff

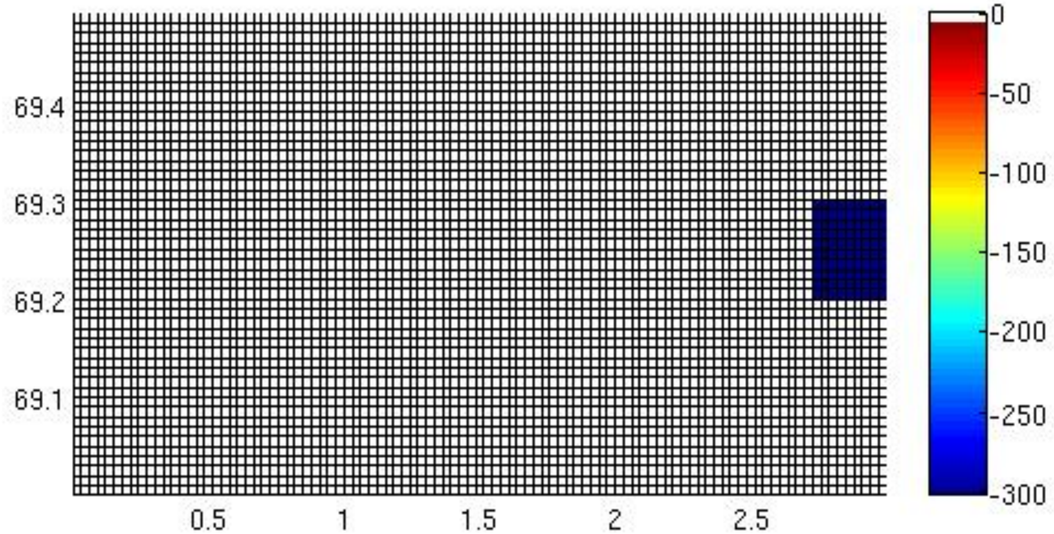
Add its affect by setting boundary conditions?

Application

Bathymetry:



Ice depth:



- **Initial Condition**
  - 3-D fields from large scale running
  - Equilibrium state from control run.
- **Boundary Condition**
  - Prescribed T/S at the open ocean boundaries; no U/V flux
  - No T/S flux on the walls; U=V=0
  - Sub-glacial runoff is represented by given T/S/U/V flux

Expected results

- Reasonable melting rate [m/day]
- Velocity field: inflow and outflow
- The effect of sub-glacial runoff?
- The effect of the ridge?

Melting rate at the front of an Antarctic ice shelf (m/year)

QuickTime™ and a
decompressor
are needed to see this picture.

Summary

- So far, I have the icefront package to compute the melting rate on the vertical face.
- Primarily result shows more melting at depth, and less at surface.
- Need to decide boundary conditions to represent the warm ocean water and the sub-glacial runoff
- Hope to get better T_ice distribution in order to improve the heat balance calculation.