Ice modelling: the effect of nonlinearity

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Introduction

- Ice sheet model
- Investigation of ice sheet model resolution:

  20 km (usual), 10 km, 5 km

→ Is a resolution of 20 km sufficient for modelling ice sheets?

http://www.homepage.montana.edu/~geol445/hyperglac/morphology1/ContinentalIce.jpg

Ice sheet modelling

- Vertically integrated continuity equation:

$$\partial H / \partial t = -\nabla \bullet (HU) + B$$

- Where $B = \min[B_{\max}, \beta(h - E)]$
- Numerical solution:

$$H_i^{t+1} \approx H_i^t + \frac{\Delta t}{\Delta x}(F_{i-1/2}^t - F_{i+1/2}^t + B_i^t \Delta x)$$

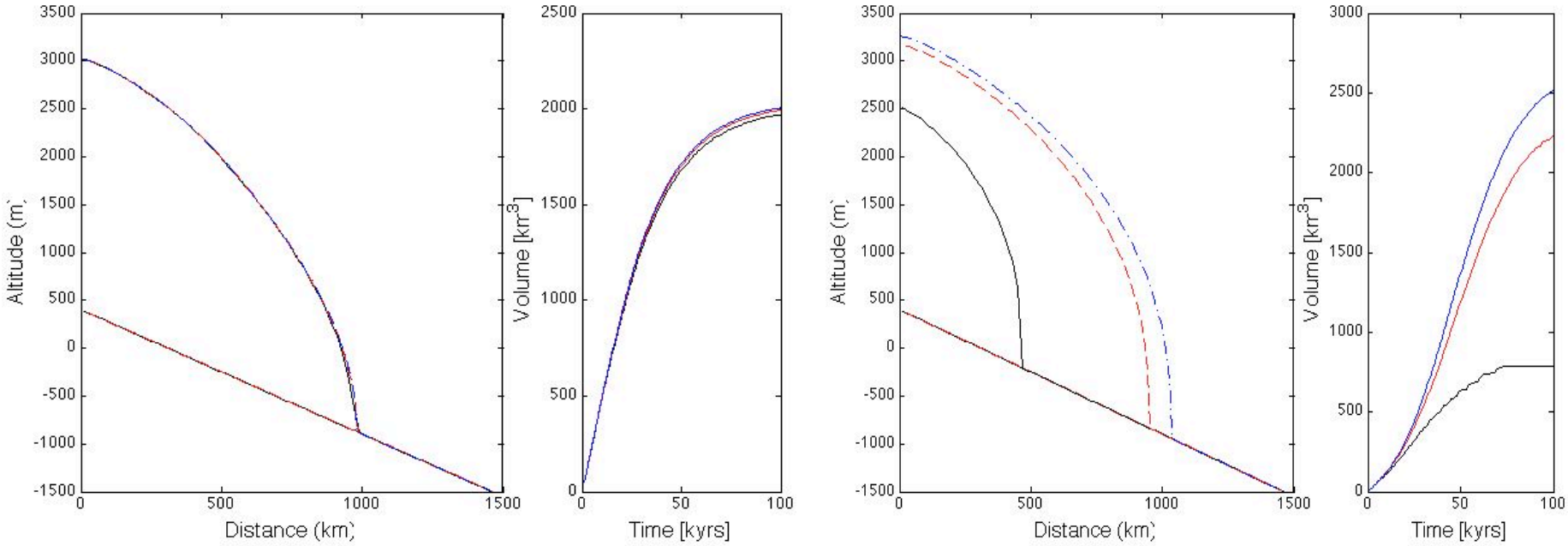
H = ice thickness, U = vertical mean horizontal velocity, B = mass balance

β = mass balance gradient, h = ice surface height, E = equilibrium line altitude

F = horizontal ice flux

Comparison of MB1 and MB2

B = +a for x < |L|, and –a for x > |L| , $B = \min[B_{\max}, \beta(h - E)]$

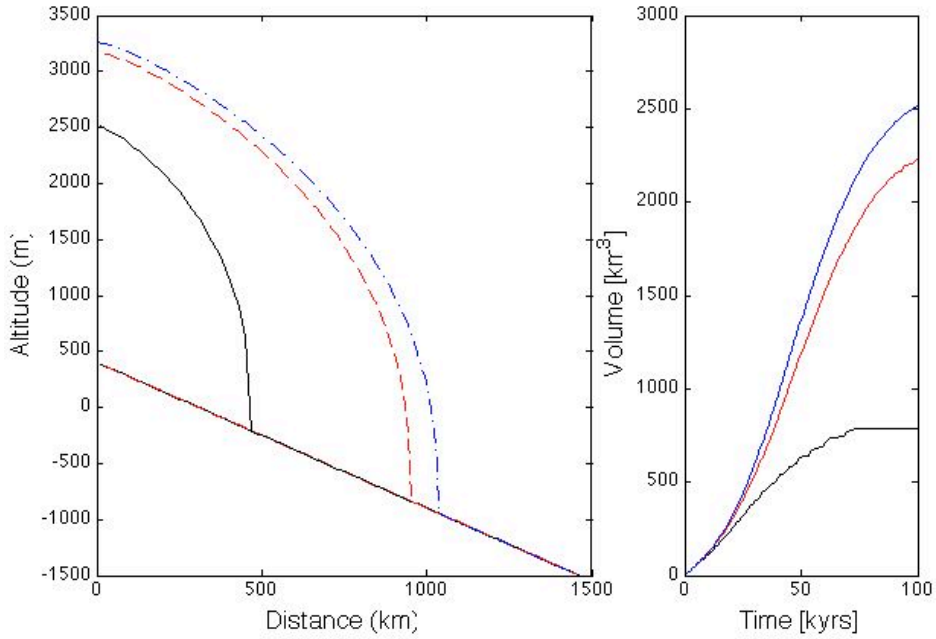


ELA = 250 m, slope = -1.3 m/km, β = 5 m/am, bmax = 1 m/a

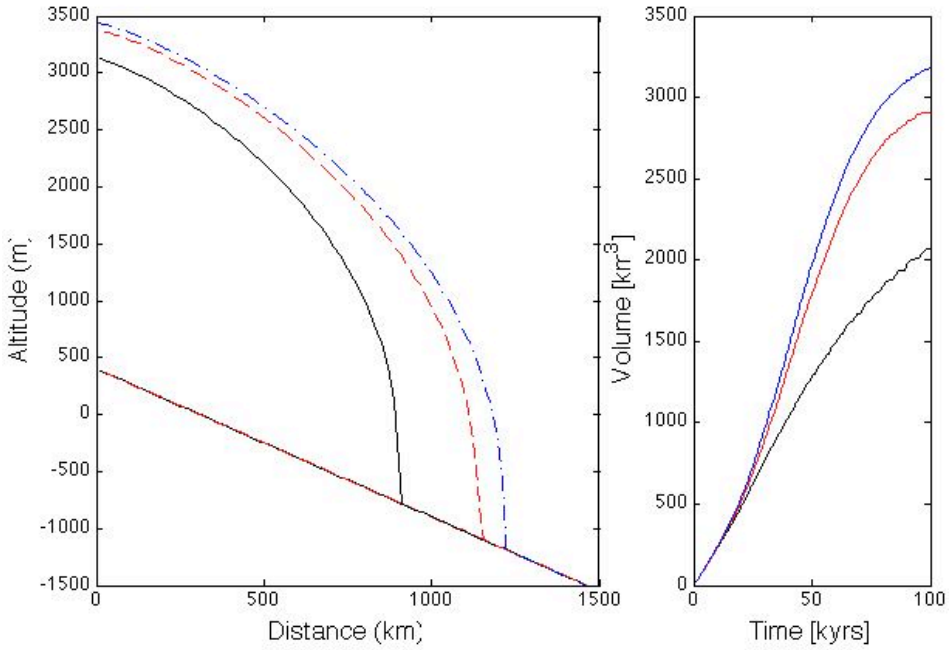
black = 20 km, red = 10 km, blue = 5 km resolution

MB2, changed ELA

ELA = 250 m

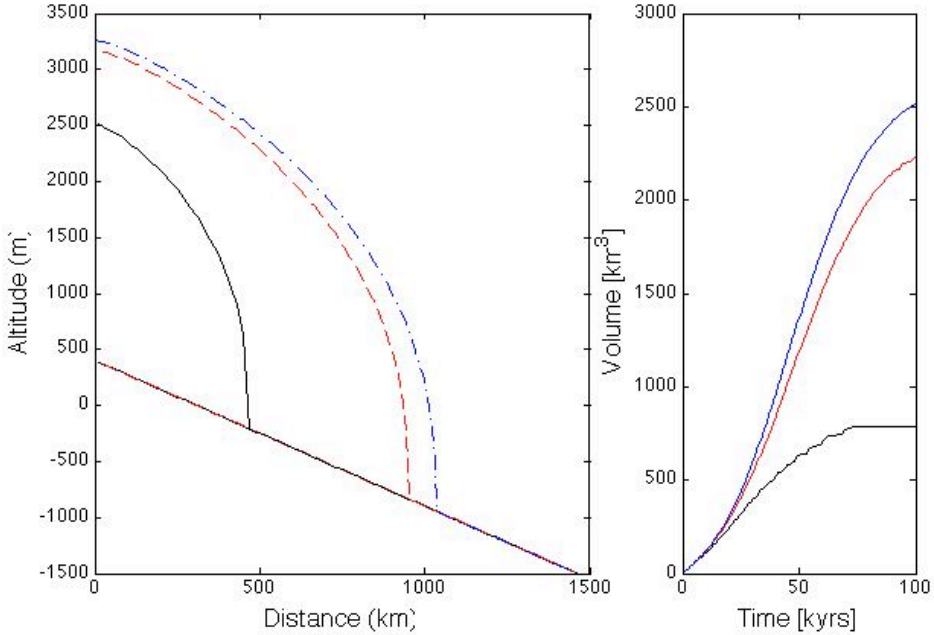


ELA = 100 m

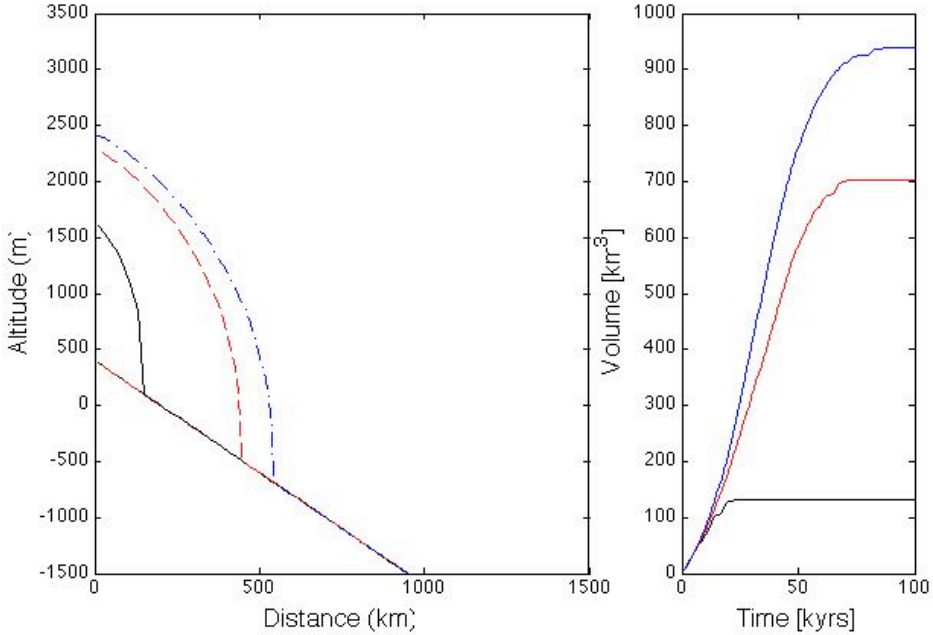


MB2, slope changed

slope = -1.3 m/km

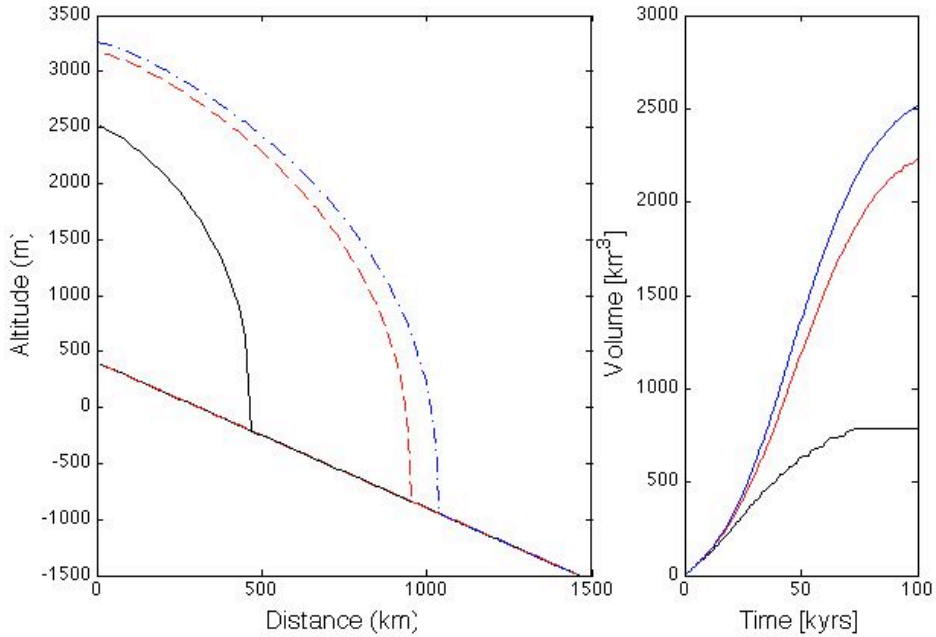


slope = -2.0 m/km

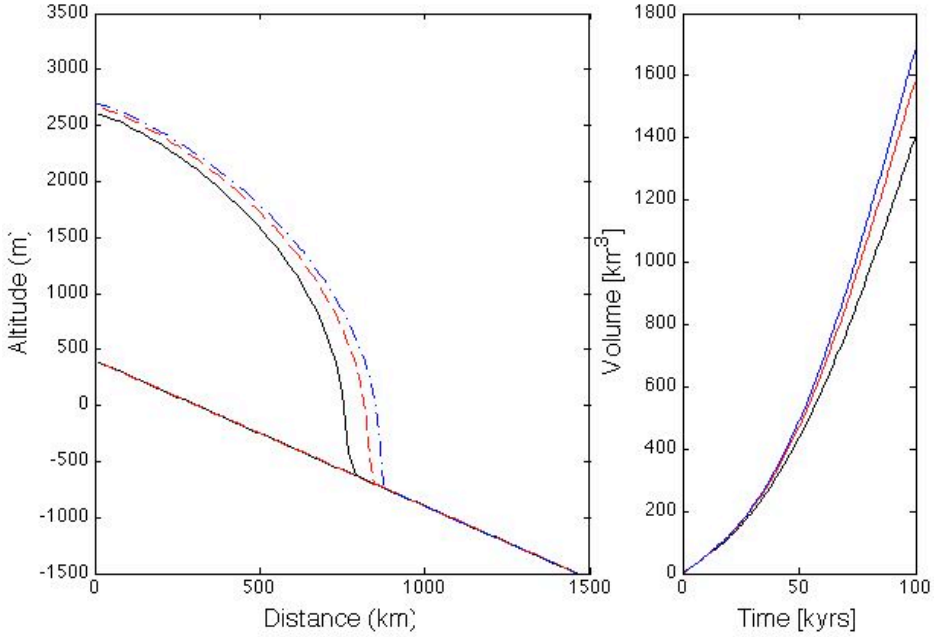


MB2, changed bmax

bmax = 1 m/a

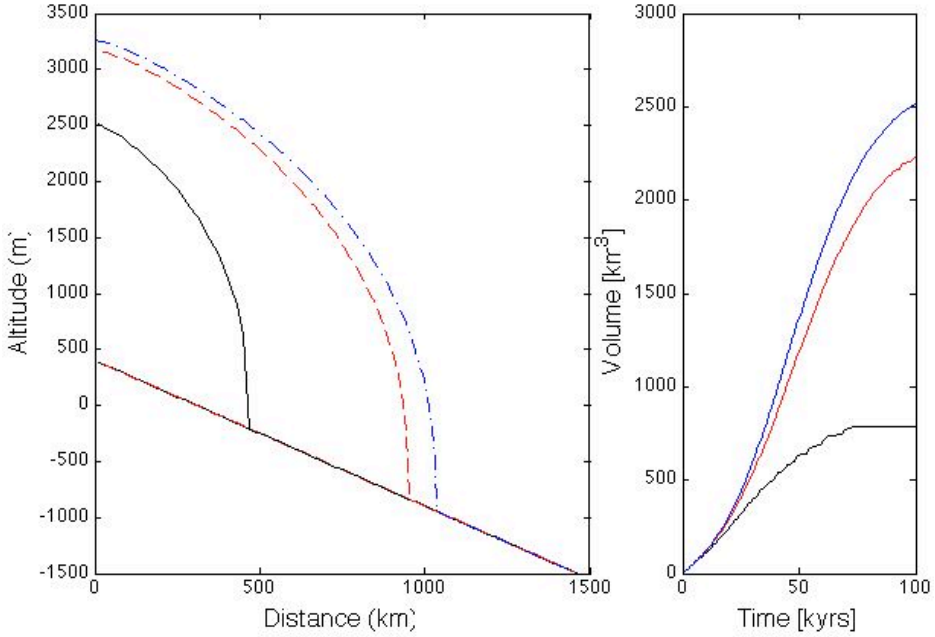


bmax = 0.5 m/a

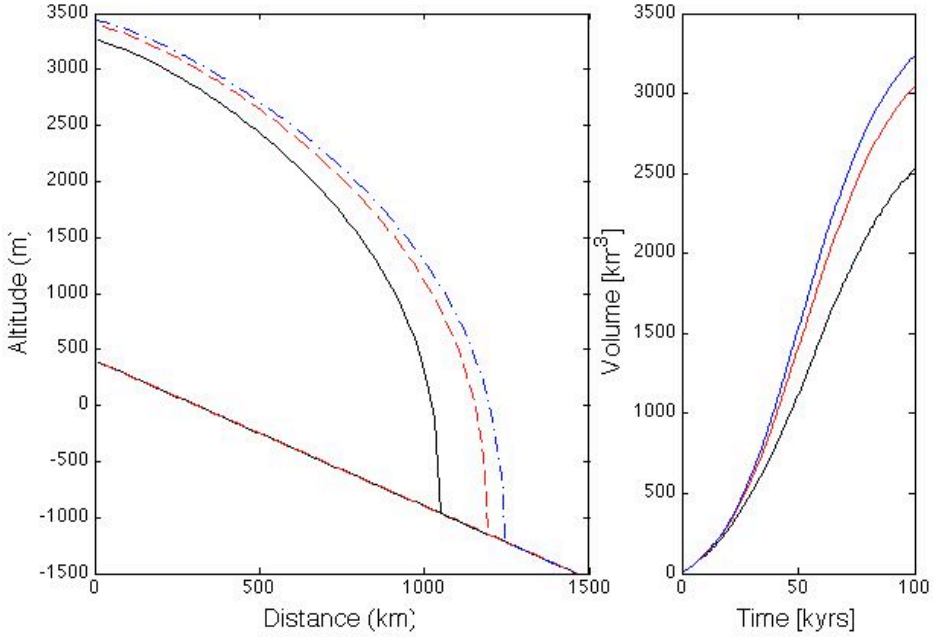


MB2, β changed

β = $5*10^{-3}$ m/am

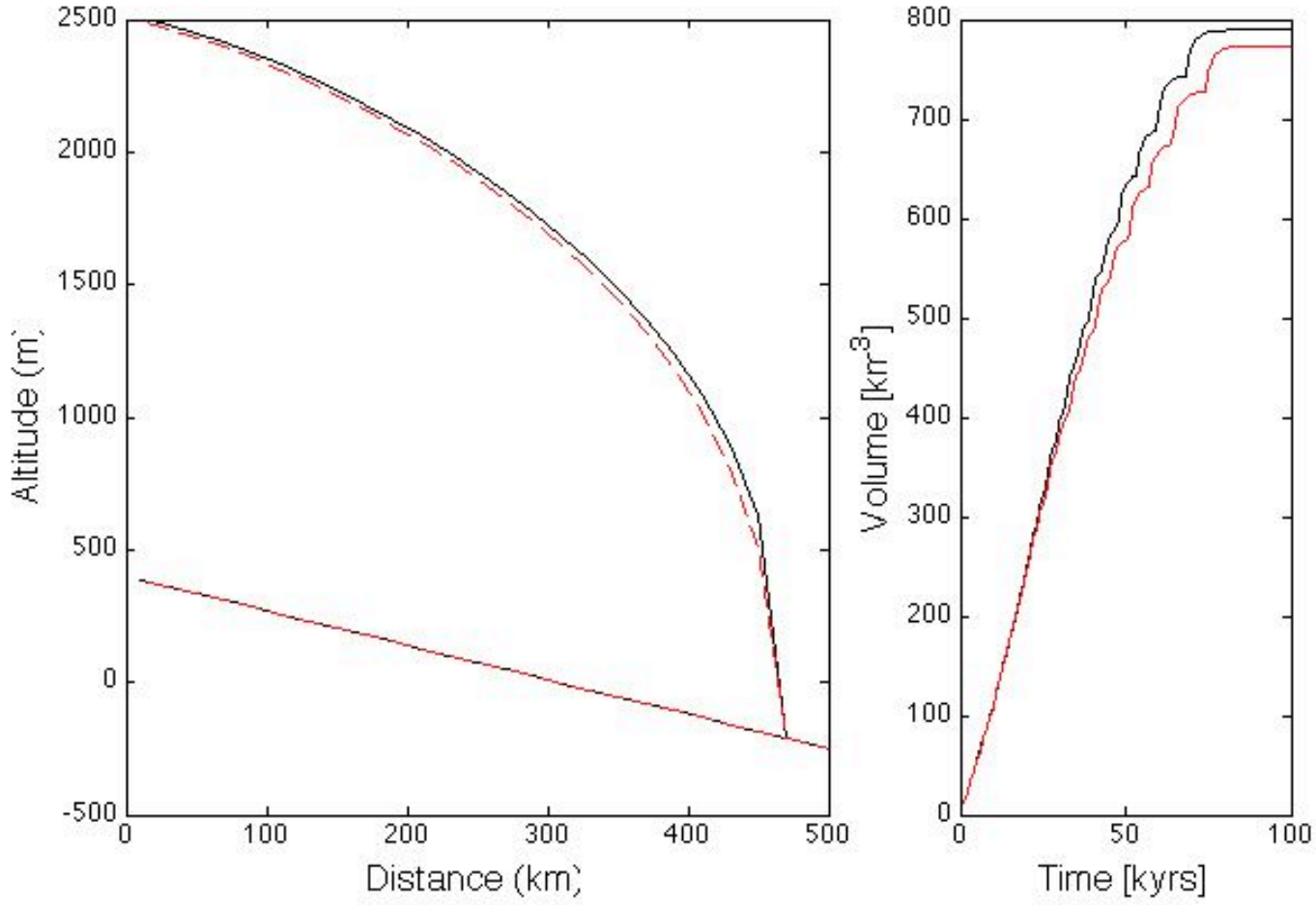


β = $3*10^{-3}$ m/am



MB2, 20 km, with (black) and without (red) improved gradient scheme

$$\left.\frac{\partial h}{\partial x}\right|_i \approx \left.\frac{\partial h}{\partial x}\right|_{i-1} + \left.\frac{\partial^2 h}{\partial x^2}\right|_{i-1} \Delta x$$



Summary

- 5 km and 10 km seem to be a great improvement to 20 km resolution when mass balance is function of height.
- Model is relatively insensitive to changes in ELA however there is a larger change at coarse resolution.
- The steeper the slope the more important resolution is.
- bmax is most sensitive to resolution due to nonlinearity of B

→ A 20 km resolution is not sufficient for this ice sheet model!