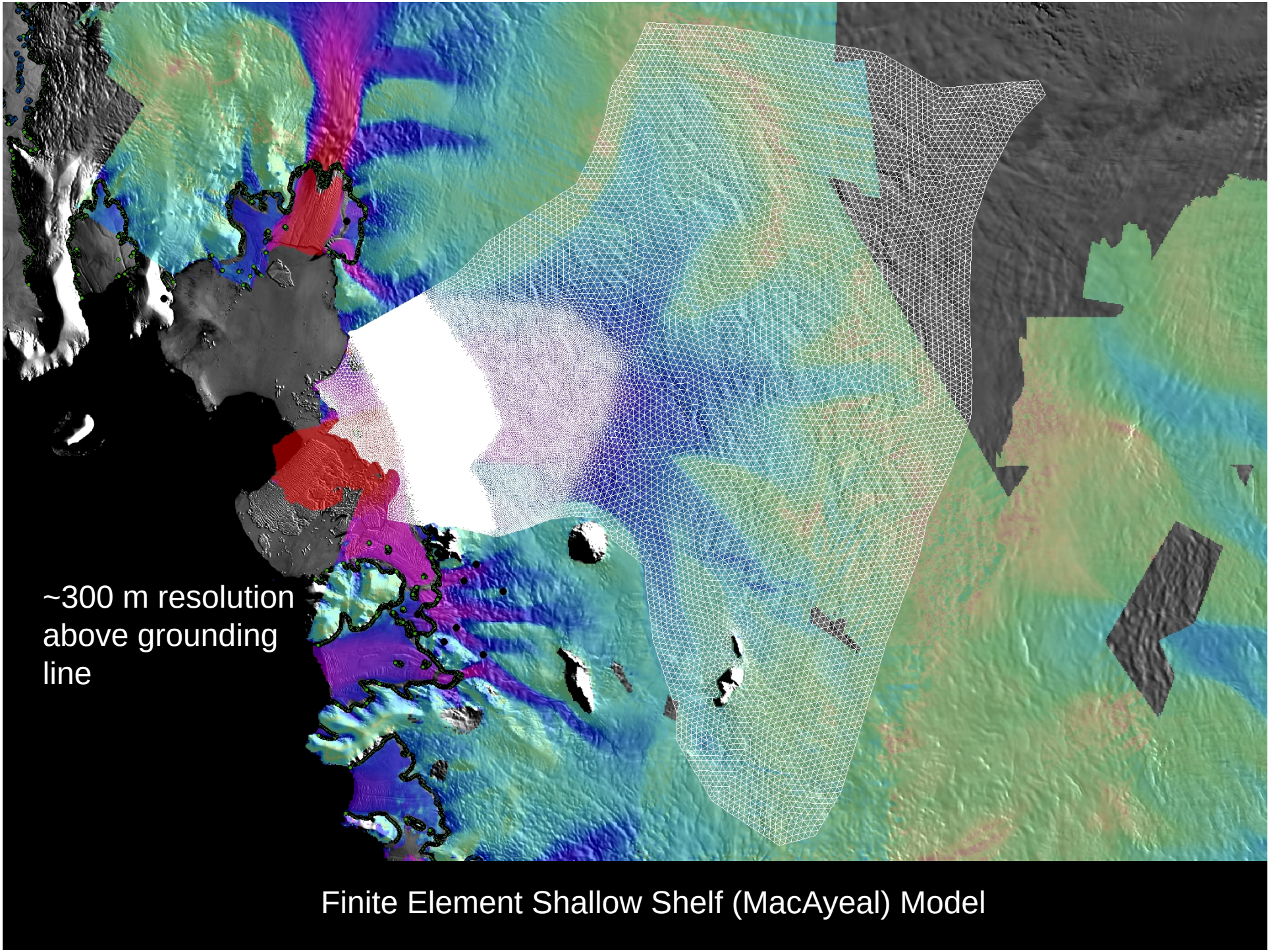
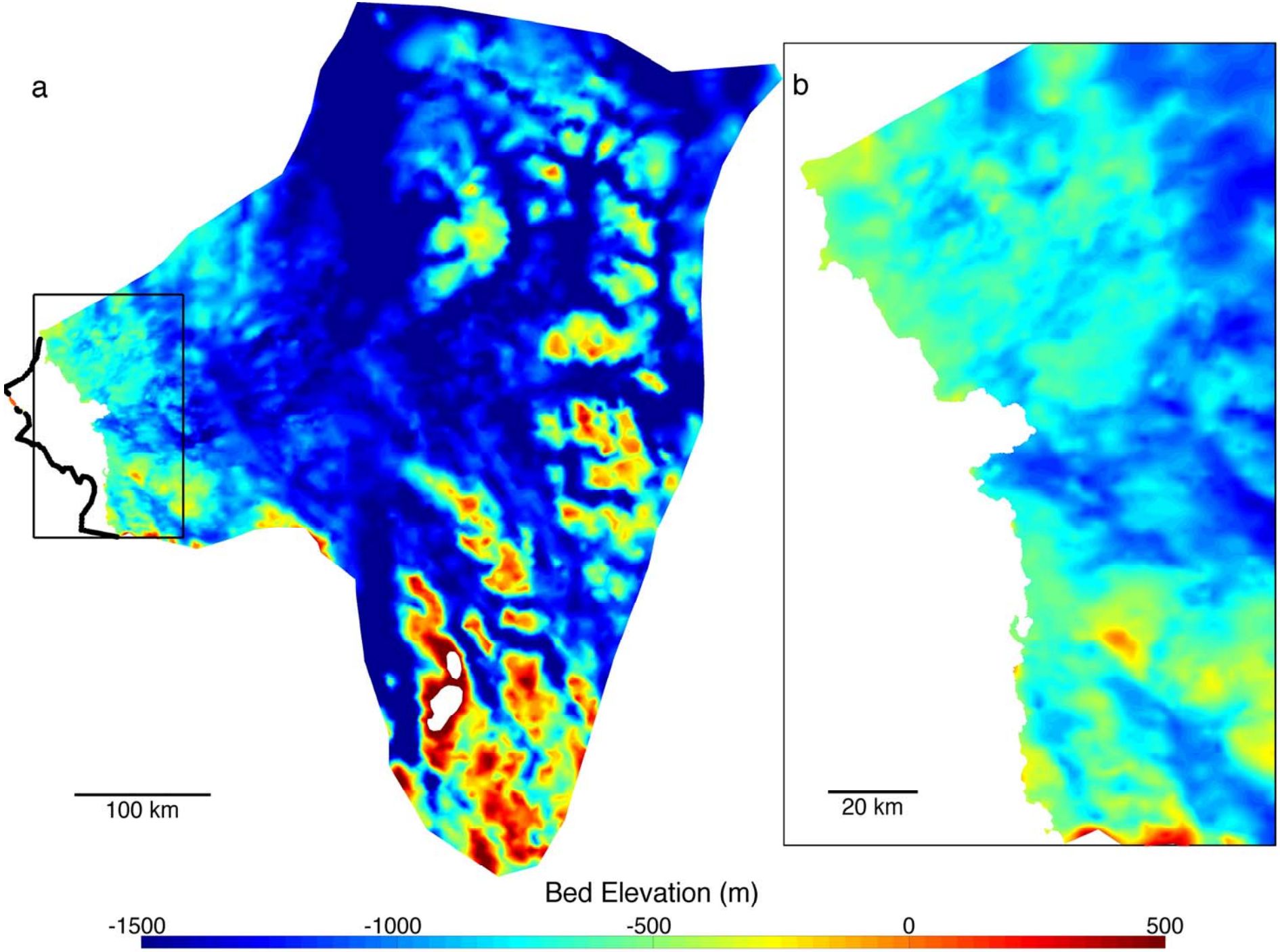
Sensitivity of Thwaites Glacier to Ice Shelf Melting

Ian Joughin and Ben Smith
Polar Science Center, Applied Physics Lab, UW

NSF | CReSIS Center for Remote Sensing of Ice Sheets | NASA | Operation IceBridge NASA


~300 m resolution above grounding line
Finite Element Shallow Shelf (MacAyeal) Model

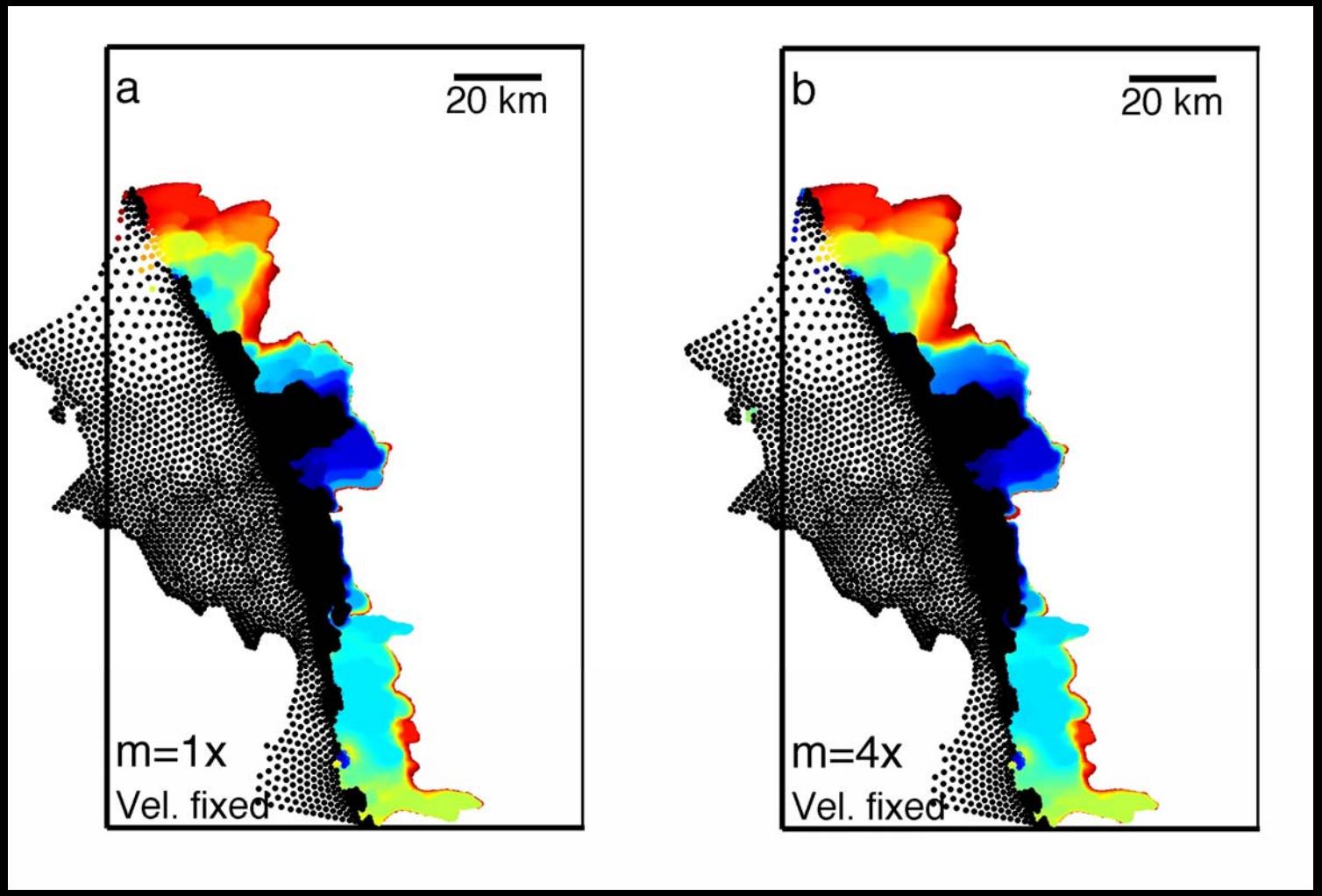
- High Resolution Bed DEM created from AGASEA and Operation Ice Bridge Data Sets (CRESIS)
- New Accumulation Map (Medley et al, in prep)


a
b
100 km
20 km
Bed Elevation (m)
-1500
-1000
-500
0
500

Model Initialization

- No spinup, model initialized by inverting for basal shear stress (n=3 power sliding law) using the 1996 flow speed.
- Reference melt depth-dependent parameterization from PIG simulations where m=1x (melt parameterization) yielded steady state.
- After first year of simulation with reference melt (m=1x) modeled basin-wide loss is 27.6 Gtons/year compared with an estimated 28.8 Gtons/year.
- m=1x loss stays within range of 22 to 43 Gtons/year over a 250 year run.

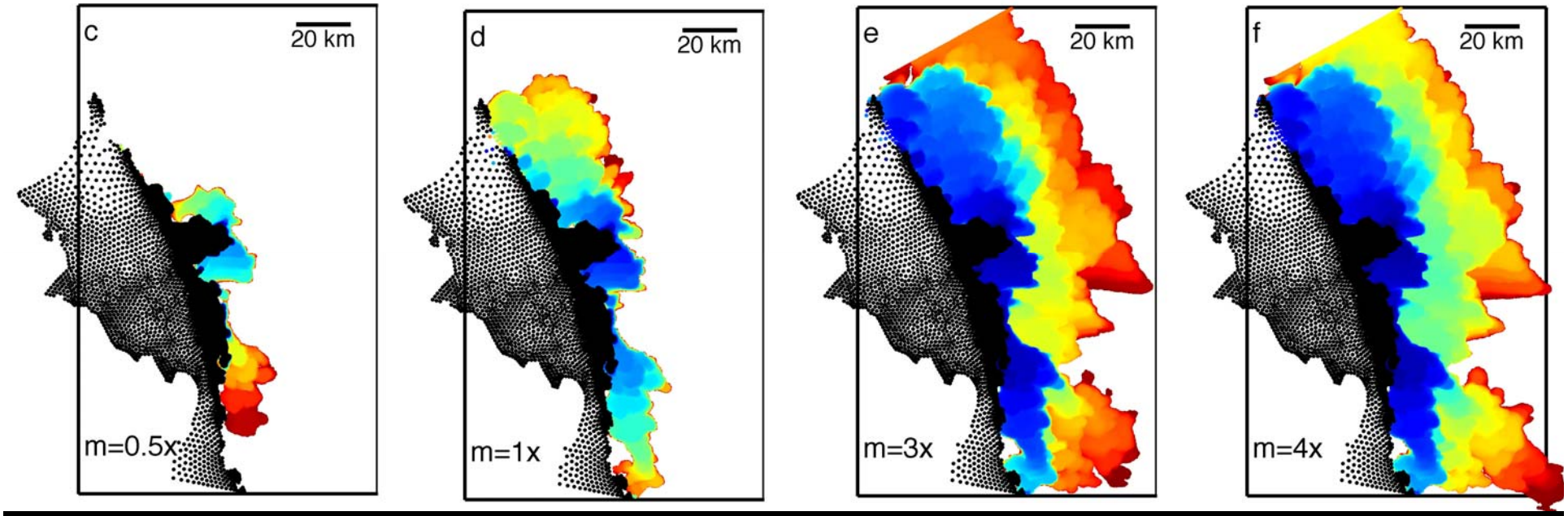
Grounding Line Retreat with Fixed Velocity



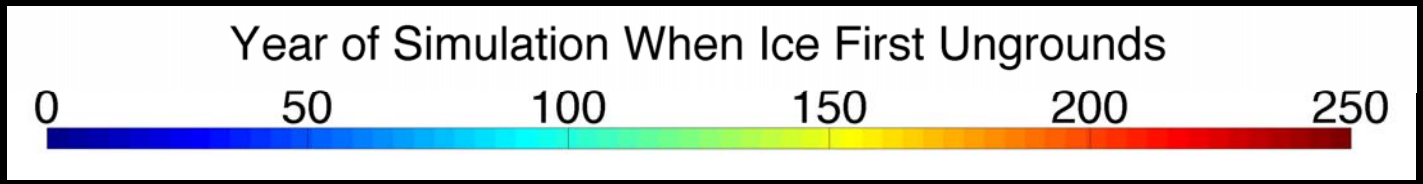
Year of Simulation When Ice First Ungrounds

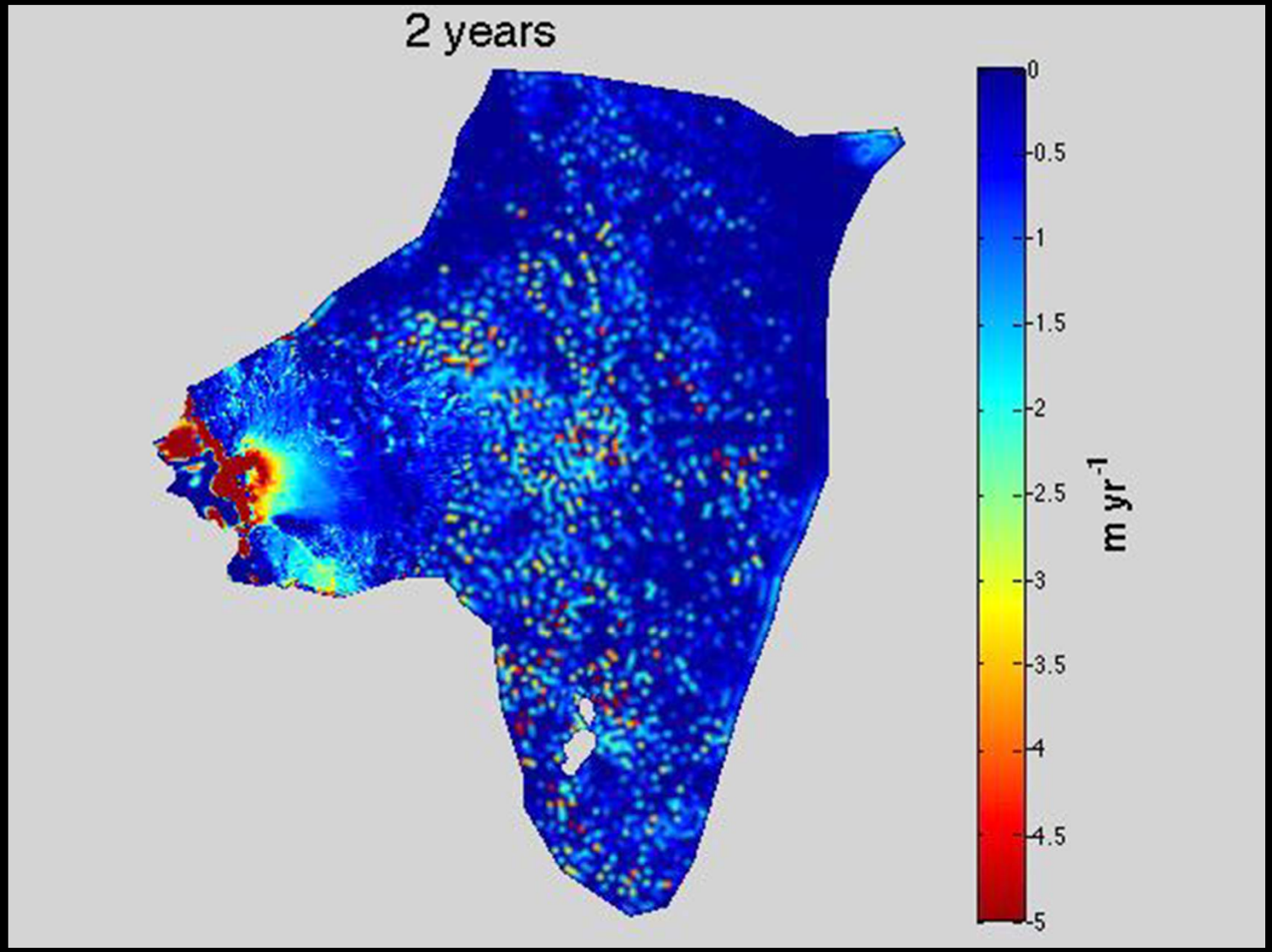
0 50 100 150 200 250

Grounding Line Retreat for Different Melt Scenarios

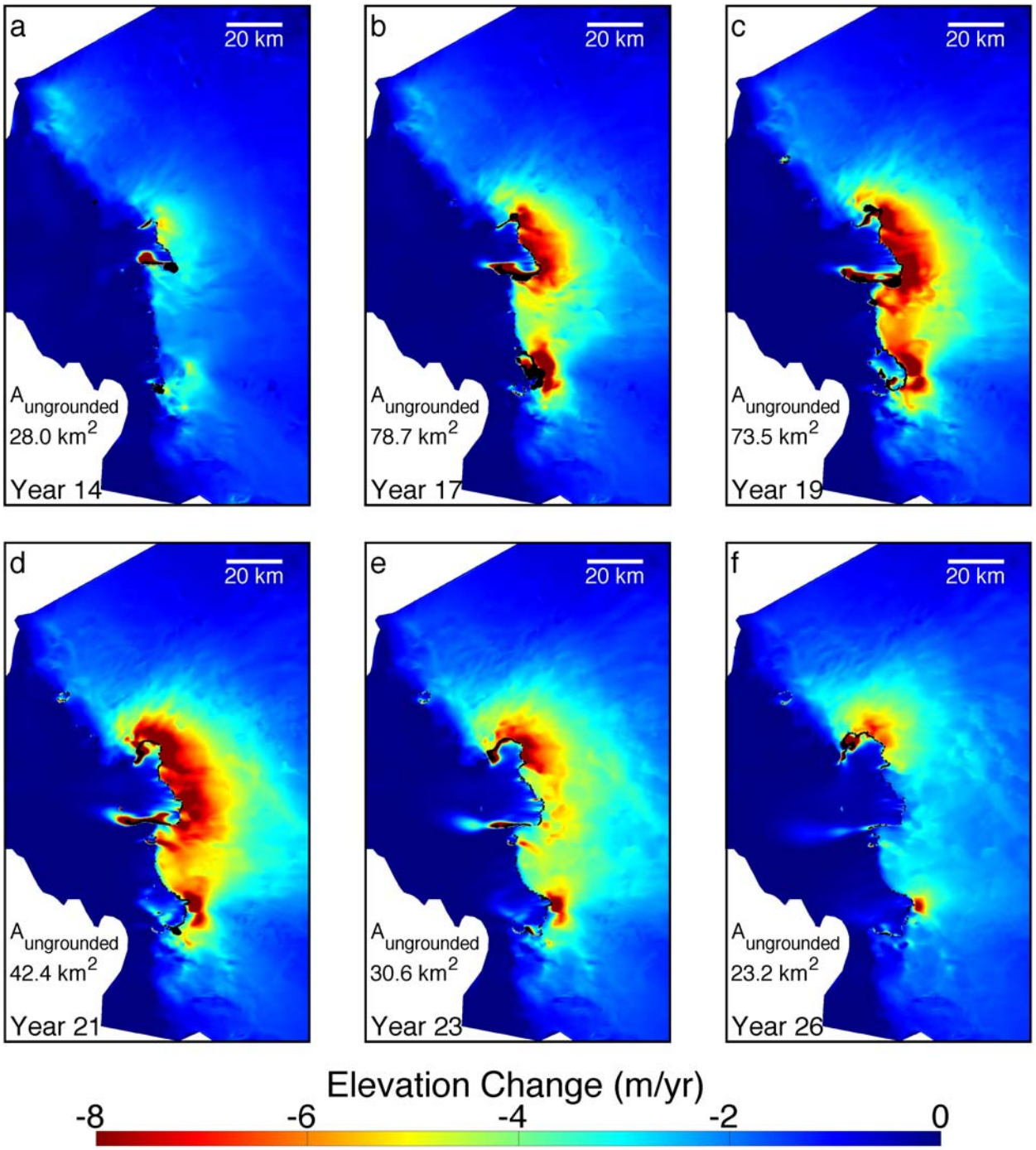


m=0.5x m=1x m=3x m=4x

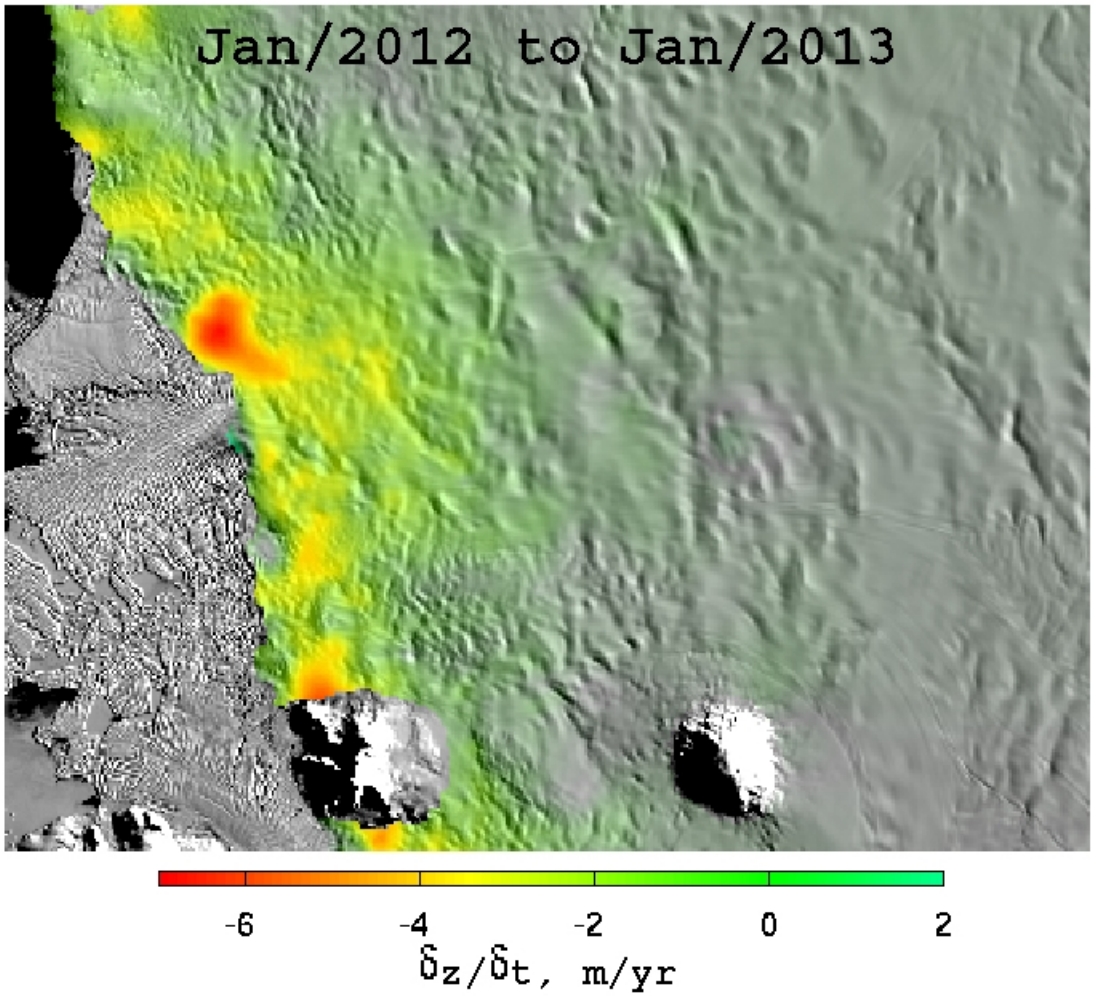


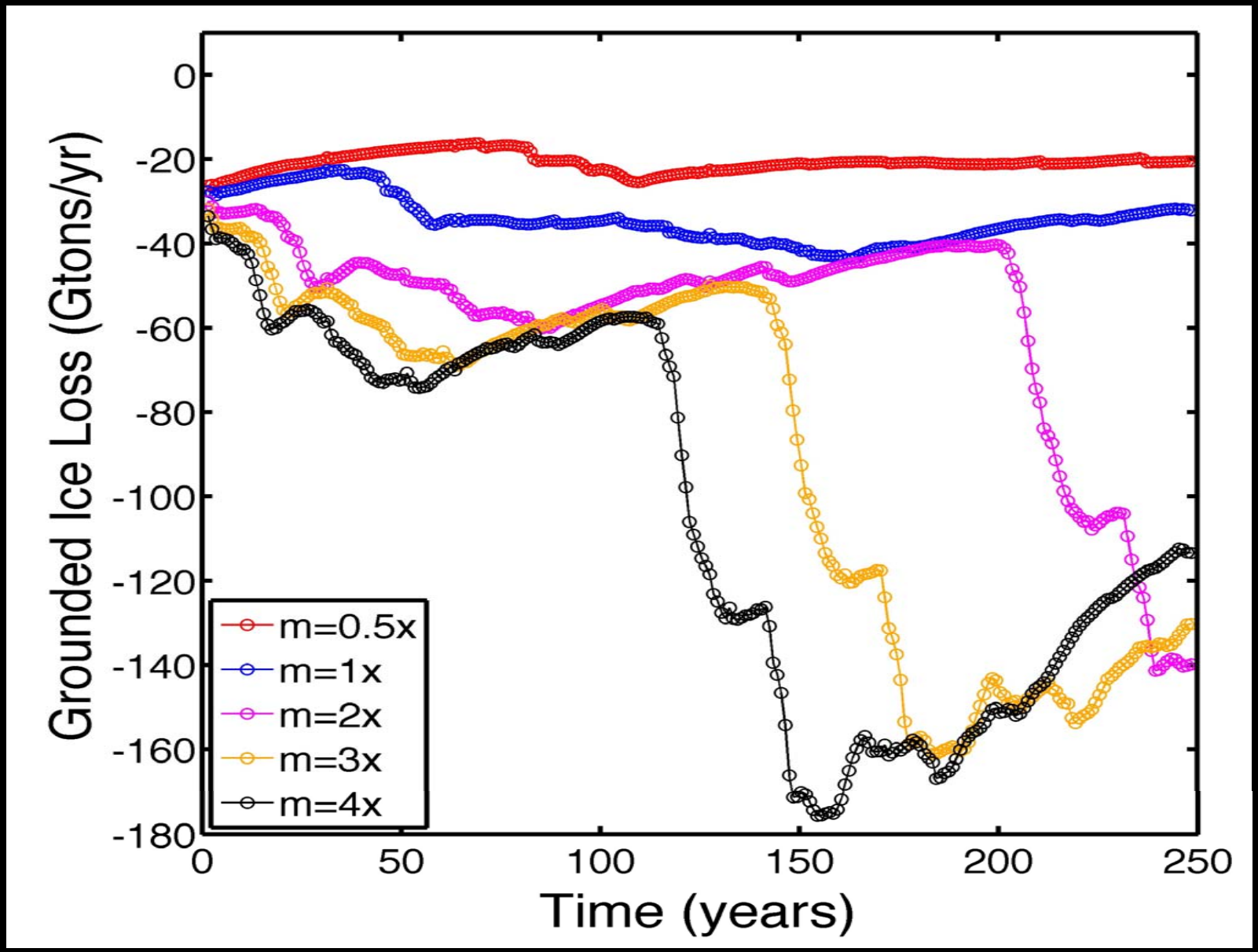


Thinning for the m=3x simulation



Snapshots of thinning for m=3x simulation

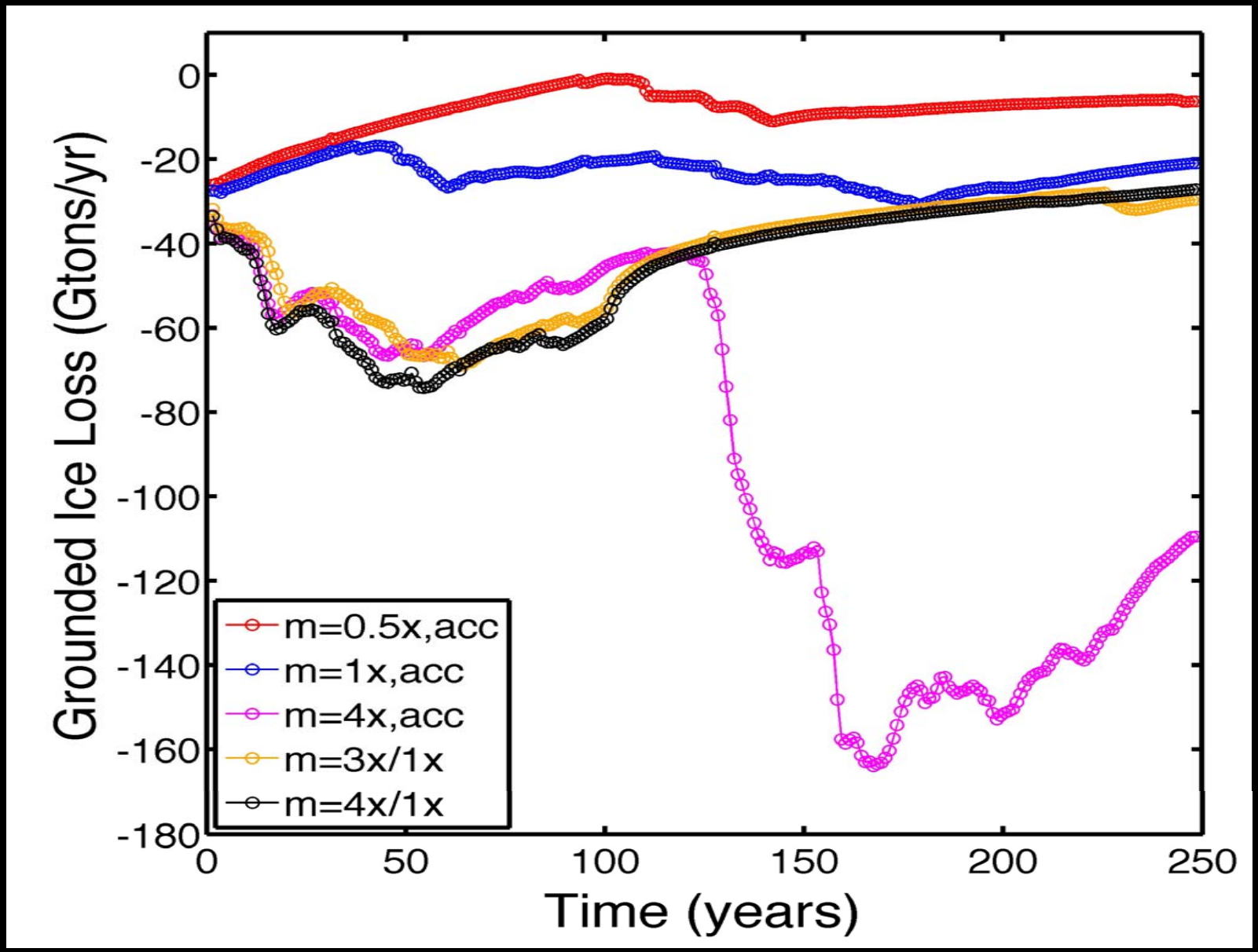

Jan/2012 to Jan/2013
-6
-4
-2
0
2
δz/δt, m/yr



Ice Loss for Different Melt Scenarios over 250 years

Two Additional Simulations

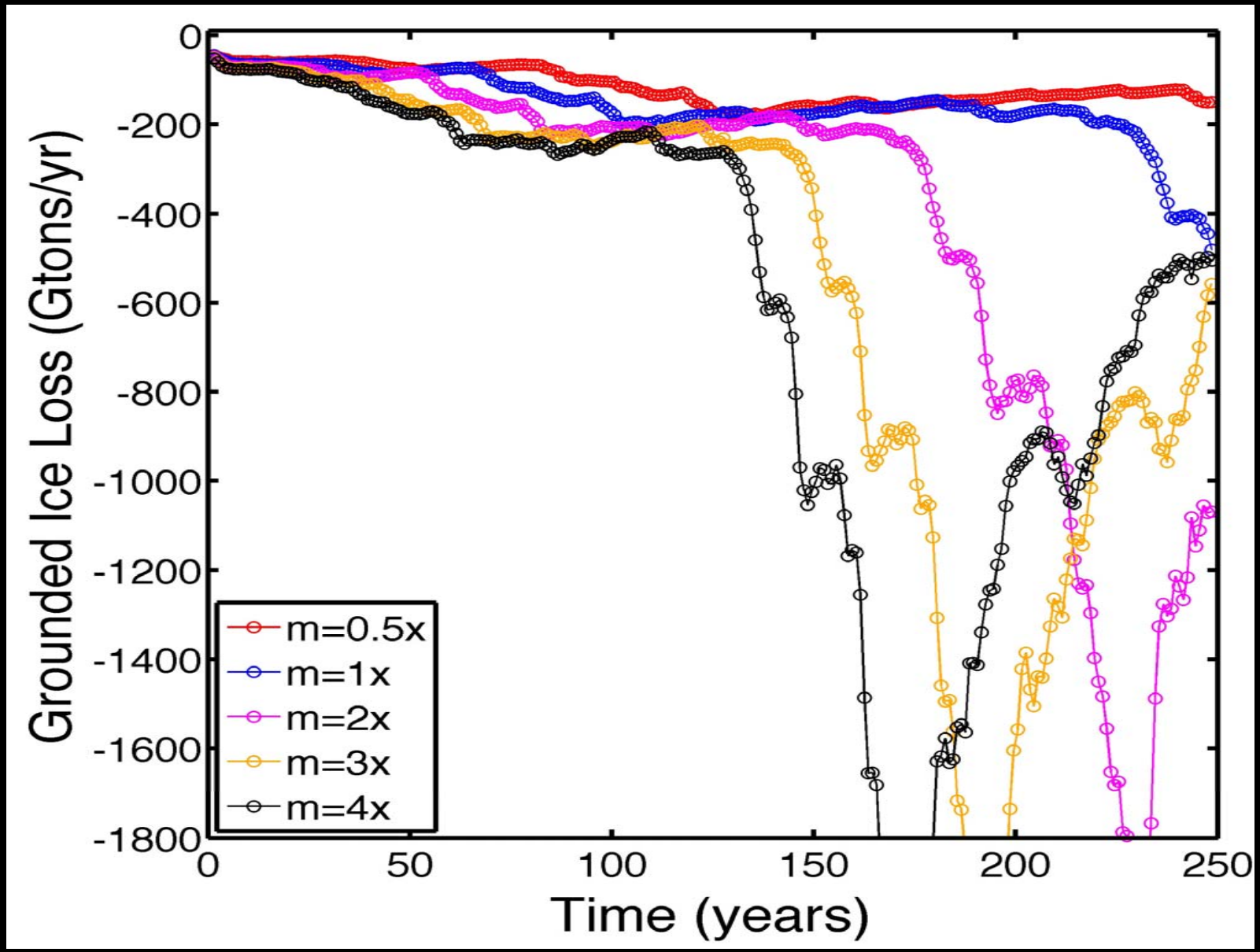
- Increase surface accumulation linearly by 20% over 100 years and then maintain constant value.
- Start with high melt, then decrease melt back to m=1x after 100 years.



Ice Loss for Variable Accumulation/Melt over 250 years

- Previous simulations assume a shelf forms where the ice ungrounds.
- In actuality, a rifted or weakened shelf might form.
- To examine the sensitivity to a weakened shelf, we cut the flow parameter, B, in half on the existing and developing ice shelf.

Note factor of 10 change in y-axis scale



Ice Loss for Shelf with 50% B over 250 years

Summary

- Only a reduction in melt and increased accumulation produce something approaching steady state.
- All other simulations continue to lose mass at rates similar to or greater than present.
- Even with high melt, ice sheet could sustain moderate losses (<0.25 mm/yr) for at least a century and m=1x at (<~0.1 mm/yr) for the entire 250 year simulation.
- High melt scenarios force grounding line retreat to near the edge of the shallow region, at which point much larger losses expected a 2+ centuries in the future.
- Formation of a strong ice shelf as the grounding line recedes is crucial for maintaining small losses over the next 2.5 centuries.
- A weakened shelf (50%B) could increase losses by more than order of magnitude (5+ mm/yr).
- Complete inability to form an ice shelf (i.e., a grounded terminus) would yield a rapid collapse (10+ mm/yr).