Hysteresis of idealized marine outlet glaciers under variation of pinning-point buttressing

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ANTARKTIS FORSCHUNG
mit vergleichenden Untersuchungen in arktischen Eisgebieten

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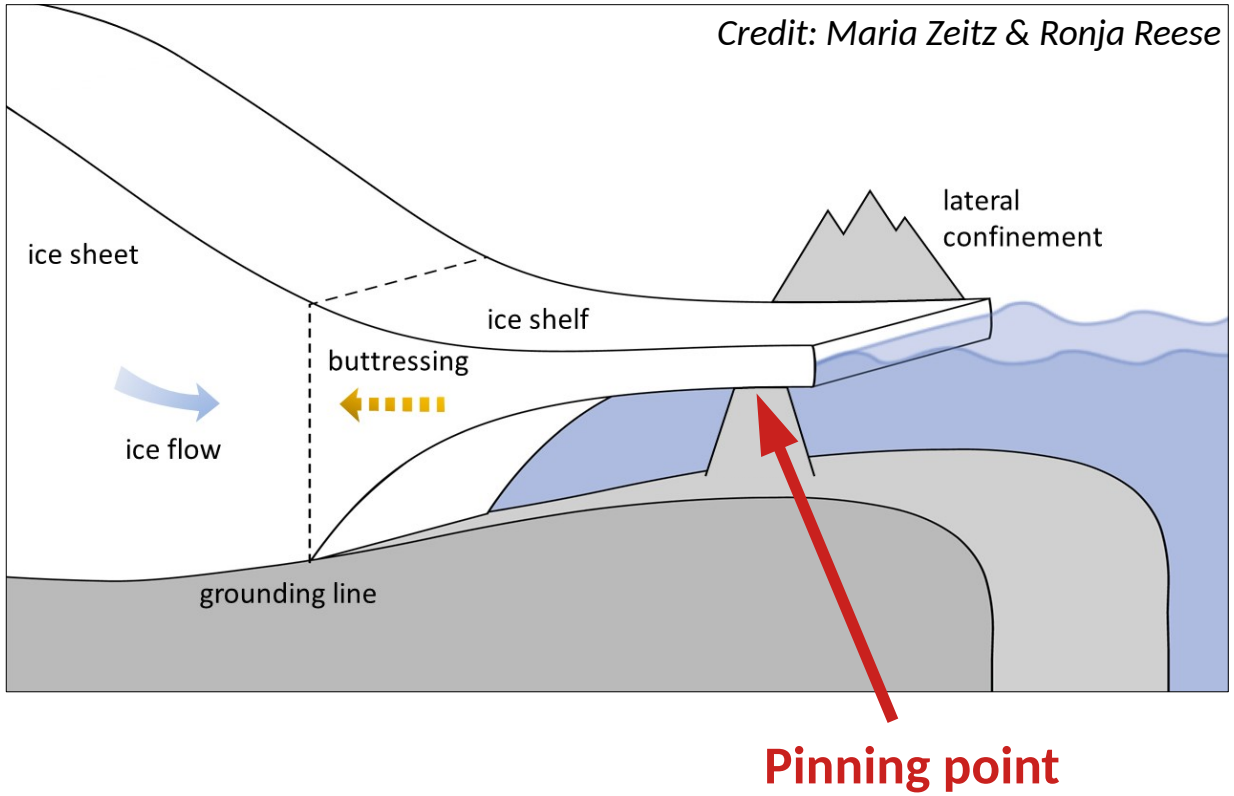
Leibniz Association

Motivation

- **Ice-shelf pinning points** can have important role in **regulating discharge of marine outlet glaciers**
- **Weakening** of **pinning point (PP) diminishes** its **buttressing effect**
- Popular example: **gradual ungrounding of Thwaites Glacier**, West Antarctica, from its last pinning points **contributes to destabilization of outlet**

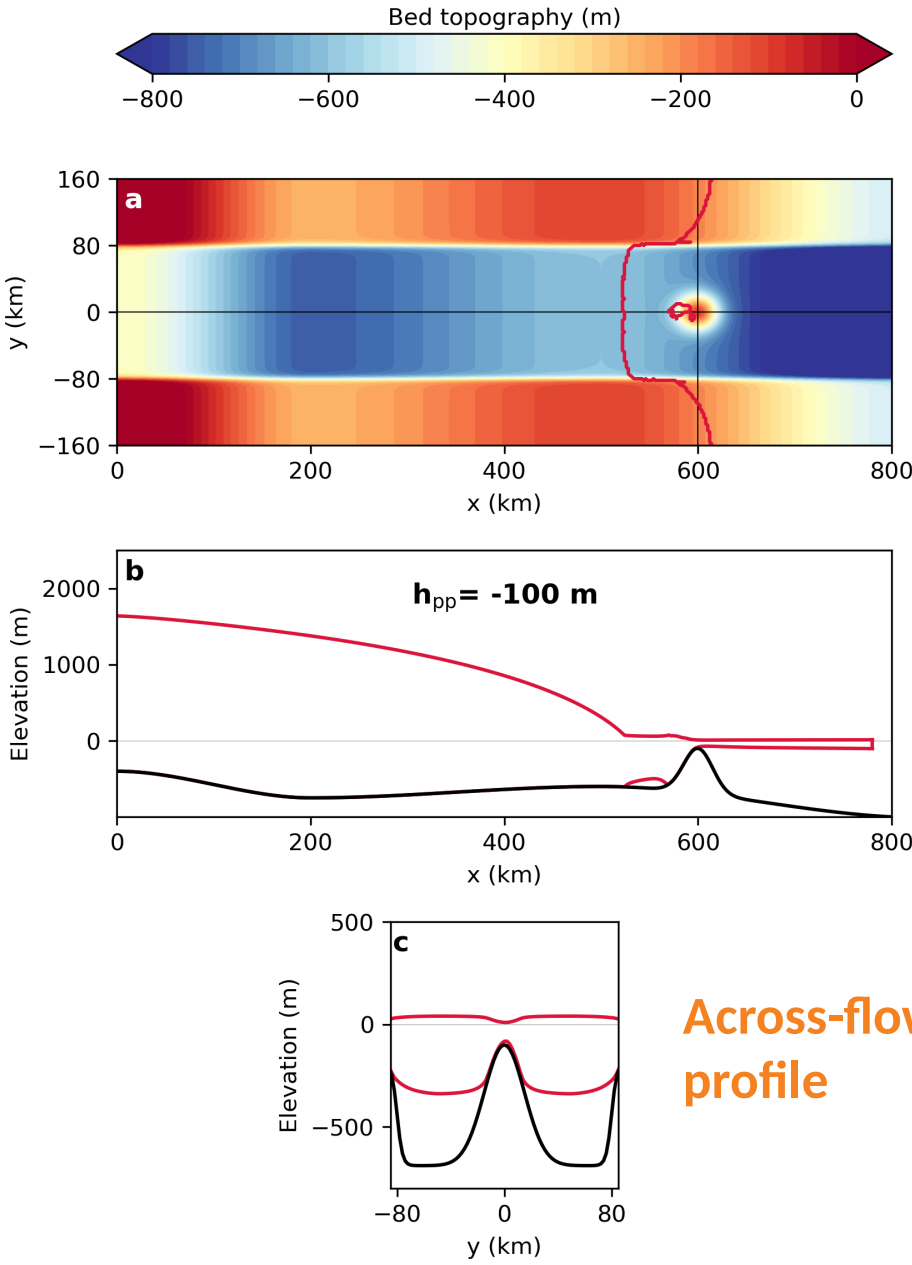


Here we take a **conceptual and idealized approach** to investigate the **response** of a marine outlet glacier system **to progressive PP ungrounding and re-grounding**

Experimental design I

- Modified version of MISMIP+ channel-type, isothermal, **marine outlet glacier on retrograde slope** (no fractures, melting, fixed calving front)
- **Simulations** on 2-km regular grid with PISM
- **Tripled glacier width reduces buttressing** effect due to ice-shelf confinement
- **Superpose a topographic high in ice-shelf center**

  → **Spinup** yields glacier with PP that stabilizes **GL upstream of retrograde slope**



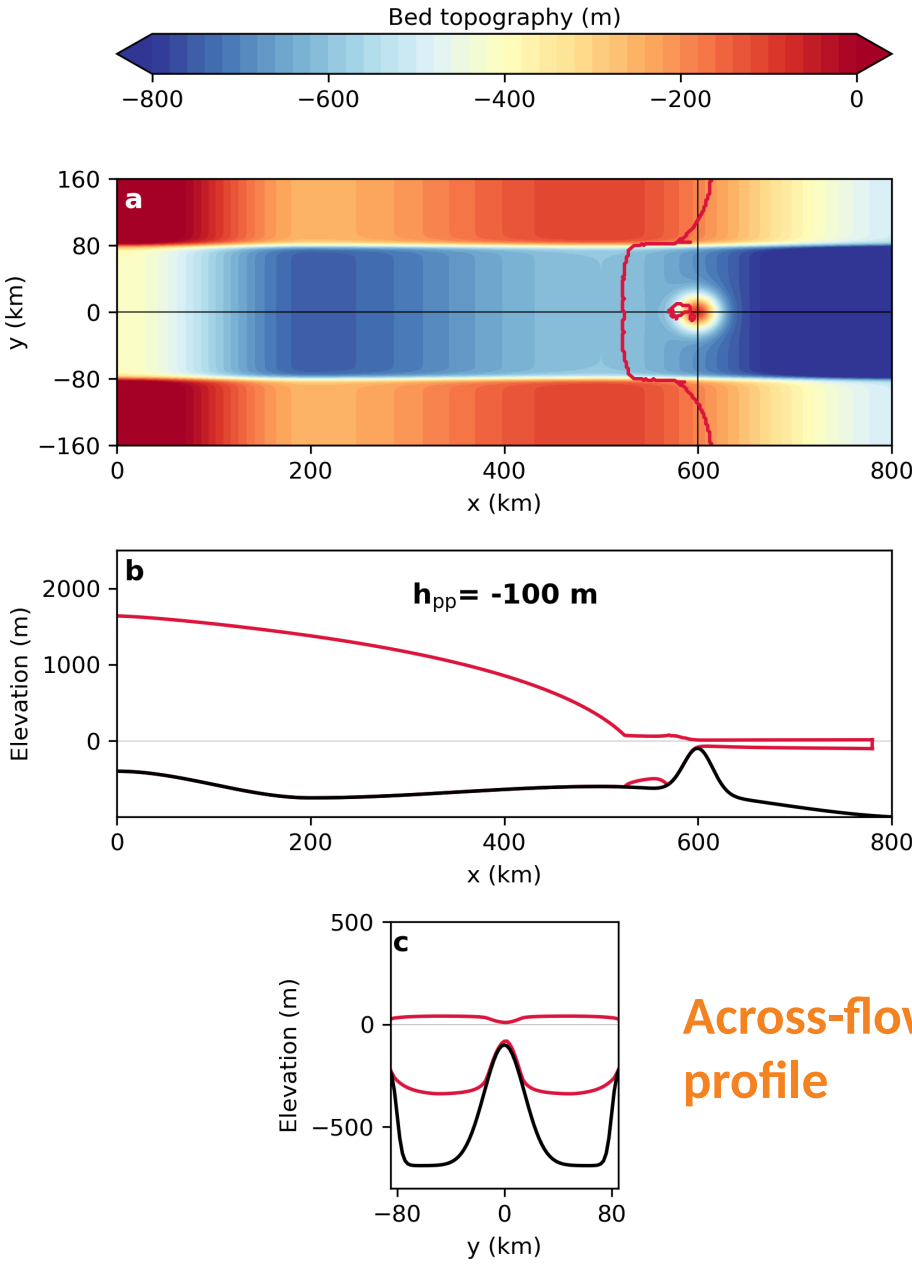
Bed topography

Along-flow profile

Across-flow profile

Experimental design II

- **Aim:** apply minimal-invasive **variation of PP induced buttressing** to analyze glacier response
- **Idea:** alter pinning-point elevation step-wise → synthetic approach but excludes unwanted side effects on ice dynamics (e.g., through basal ice-shelf melting – zero here)
- **Realization**: perturb initial state by lowering pinning-point elevation by 20 m → run into equilibrium → perturb again… until ice shelf ungrounds from PP
- Afterwards **reverse pertubation sequence**



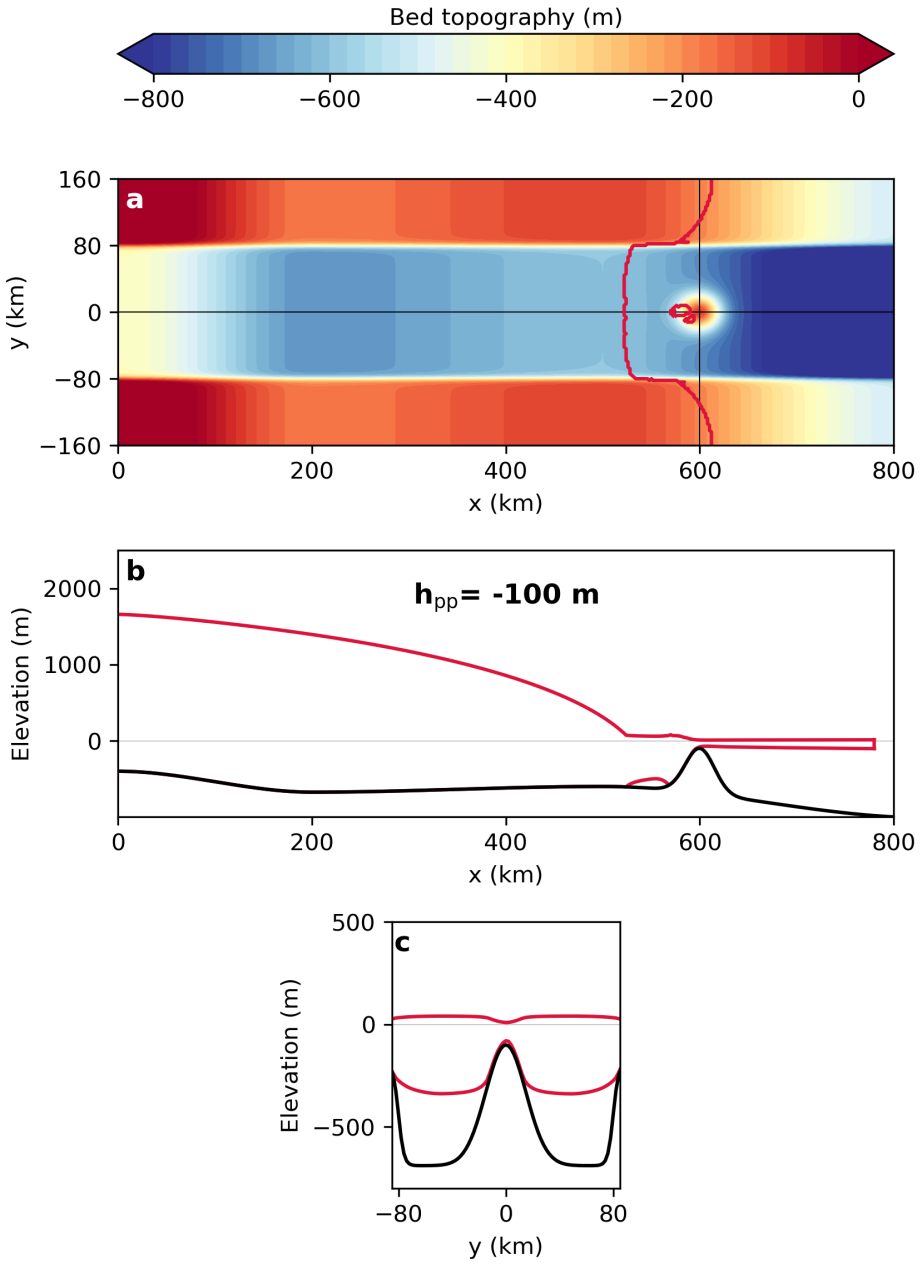
Bed topography

Along-flow profile

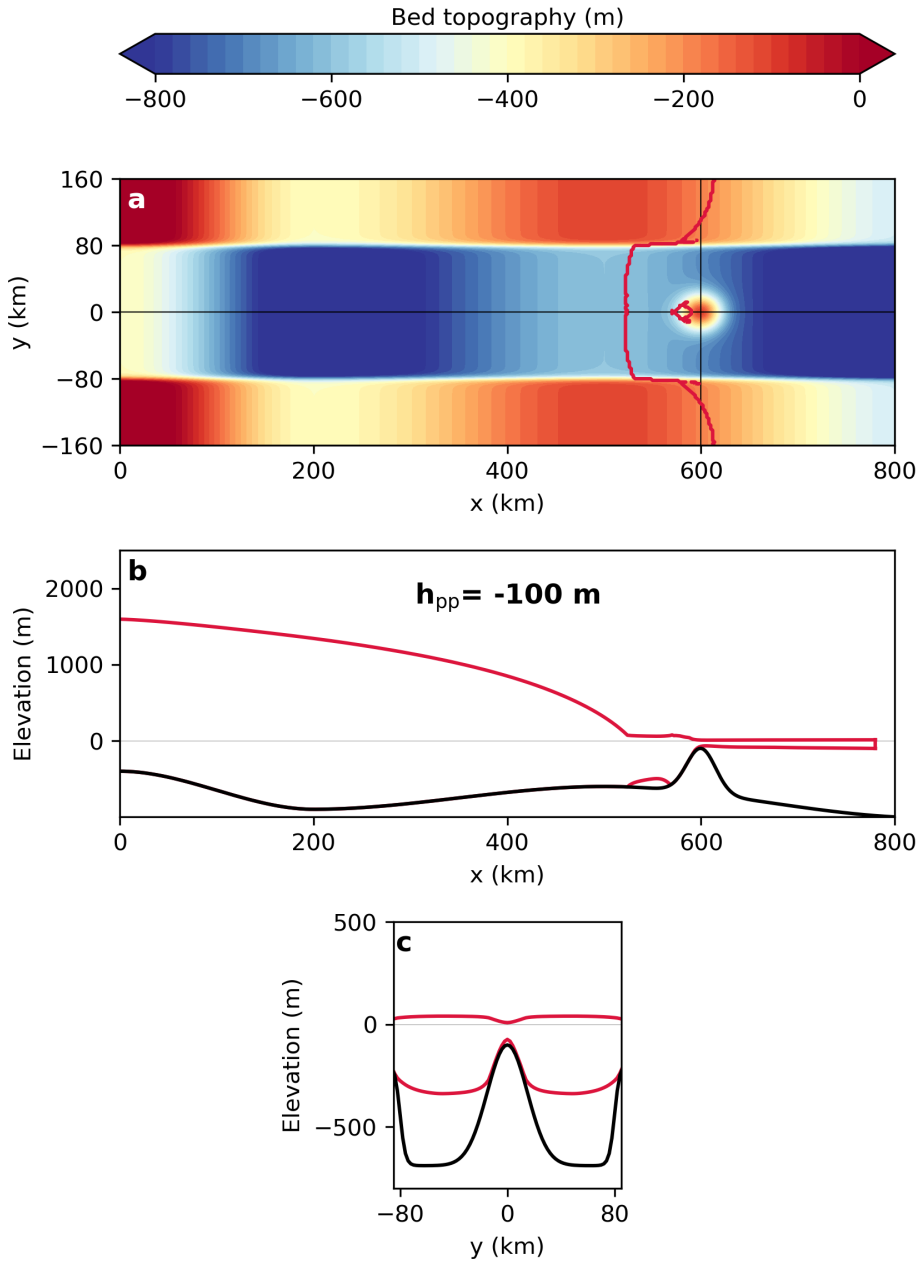
Across-flow profile

Results

Flat slope (*s*)



Steep slope (4·*s*)



Results

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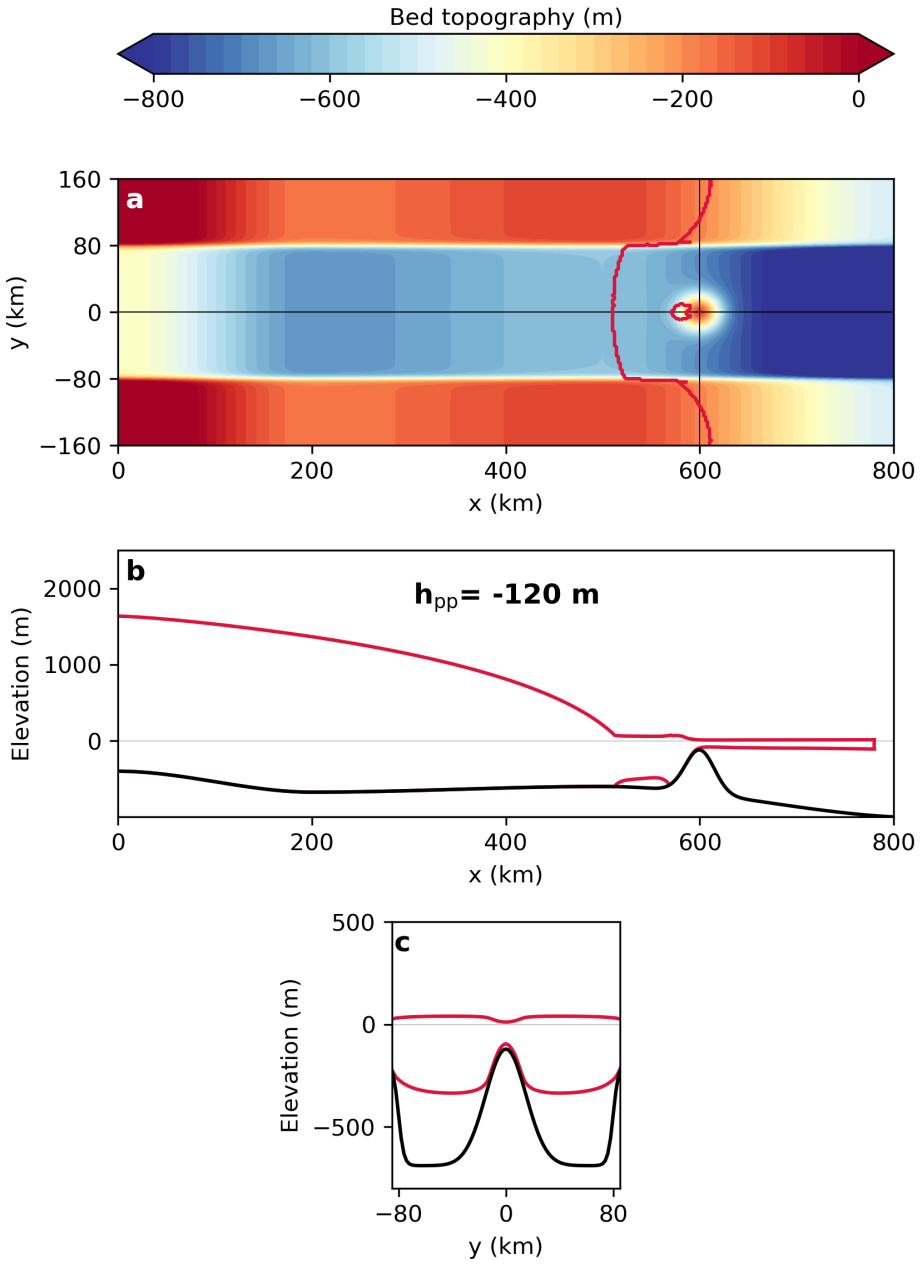

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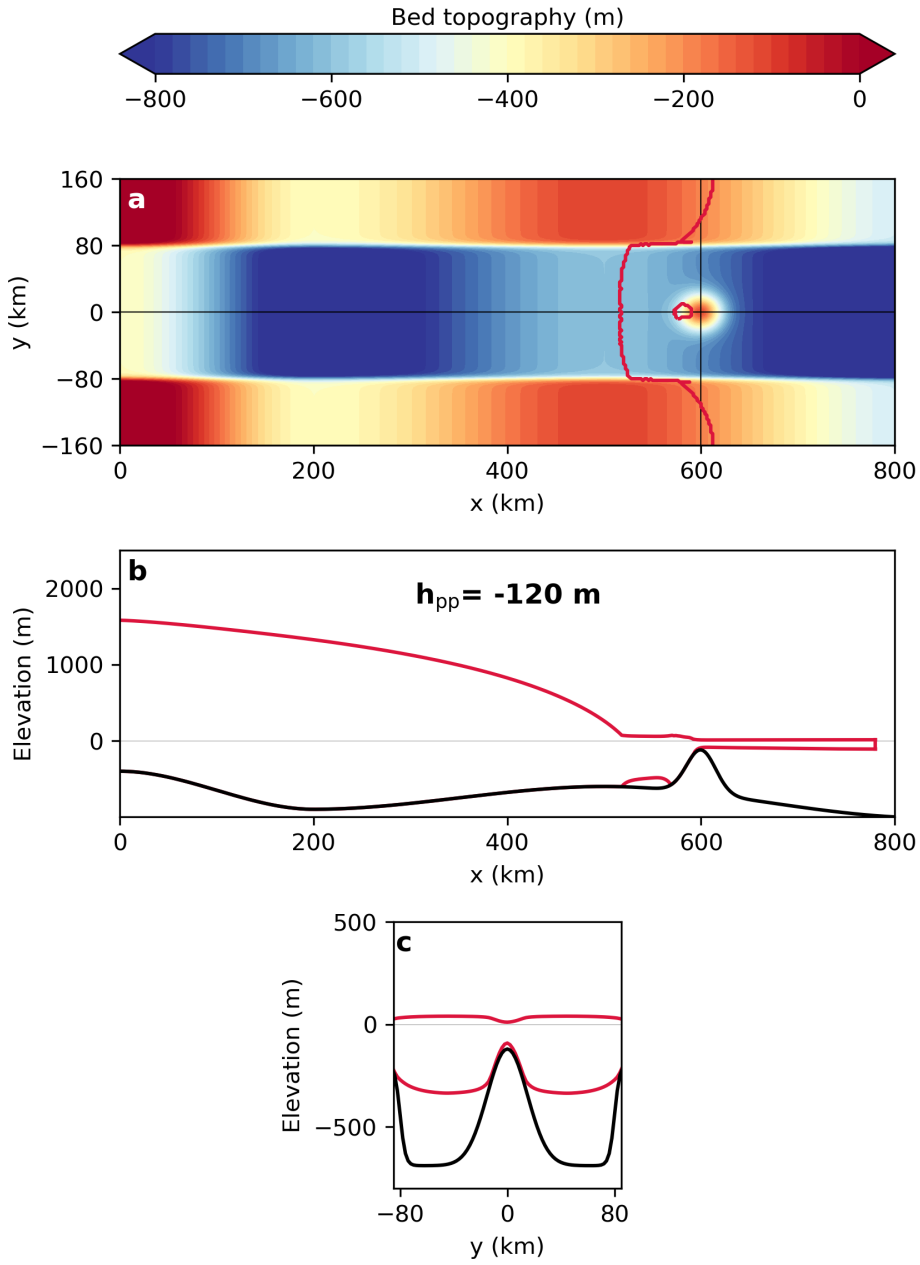

Results

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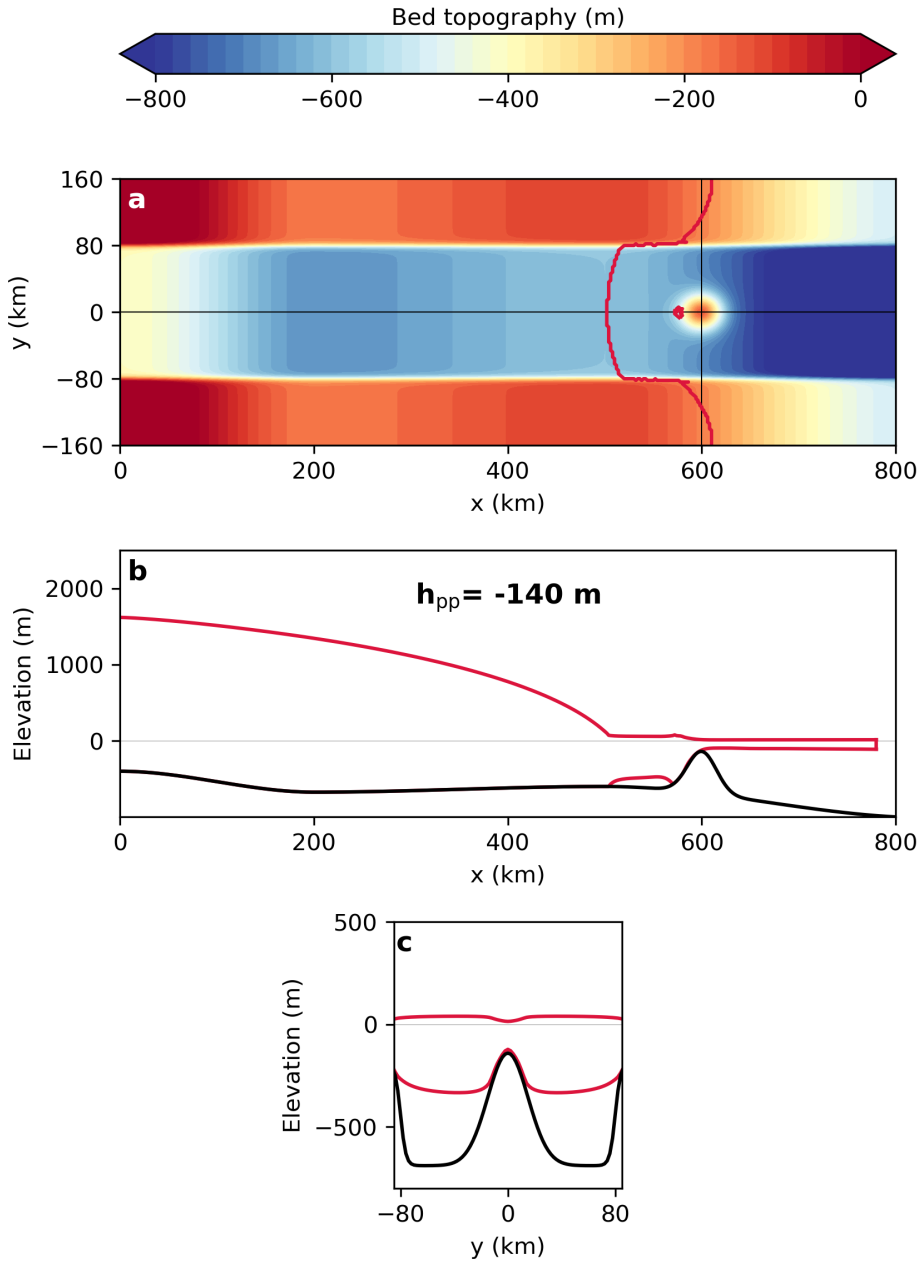

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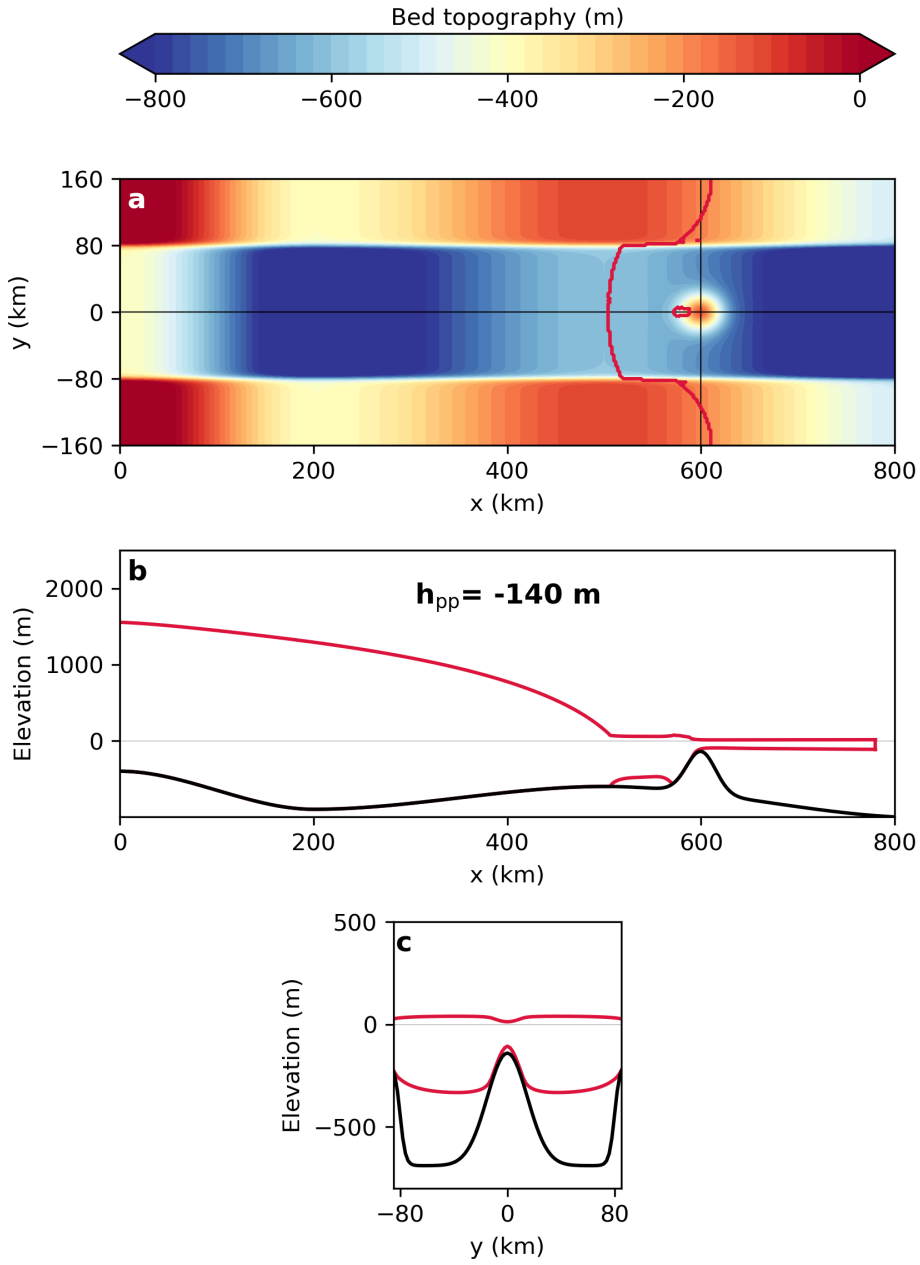

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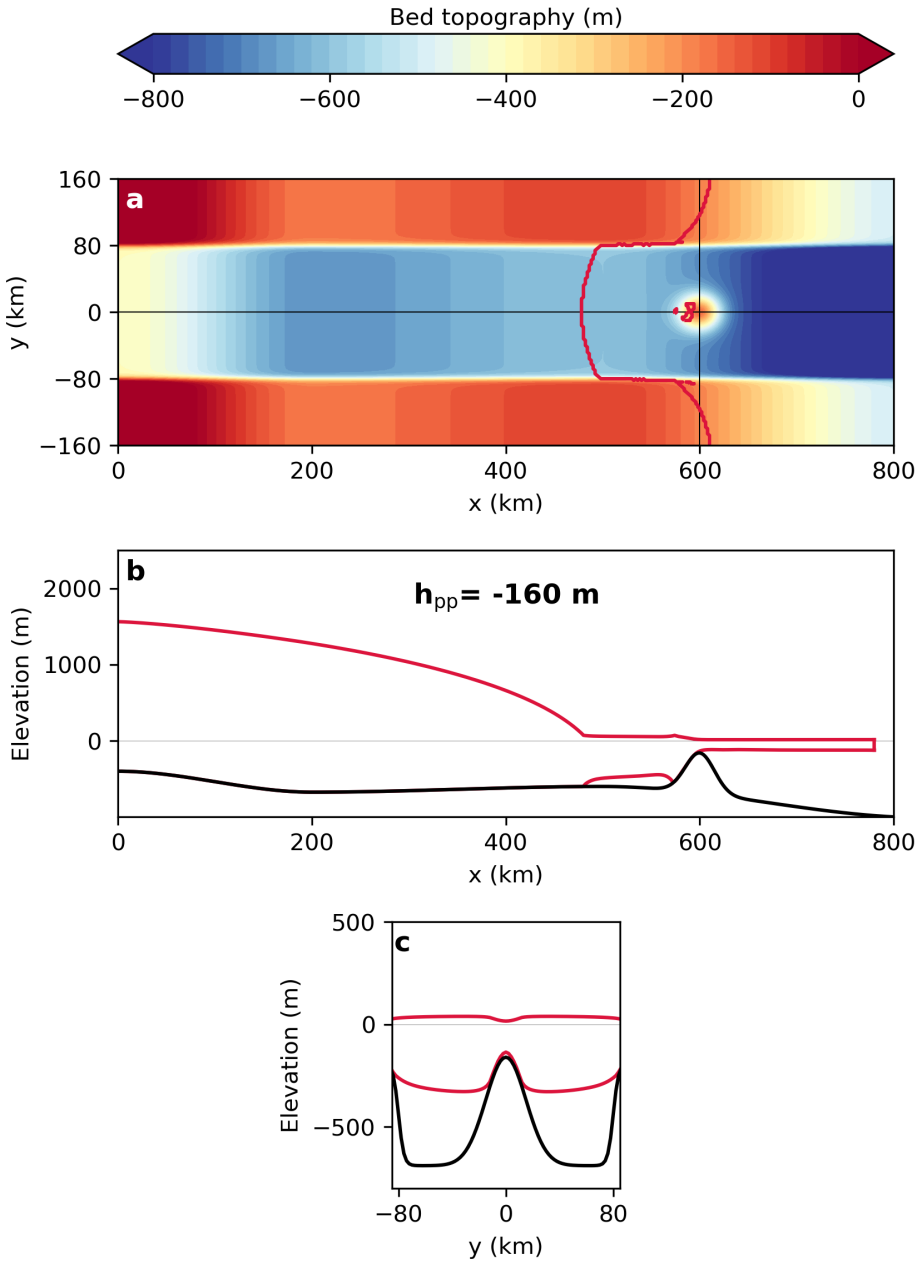

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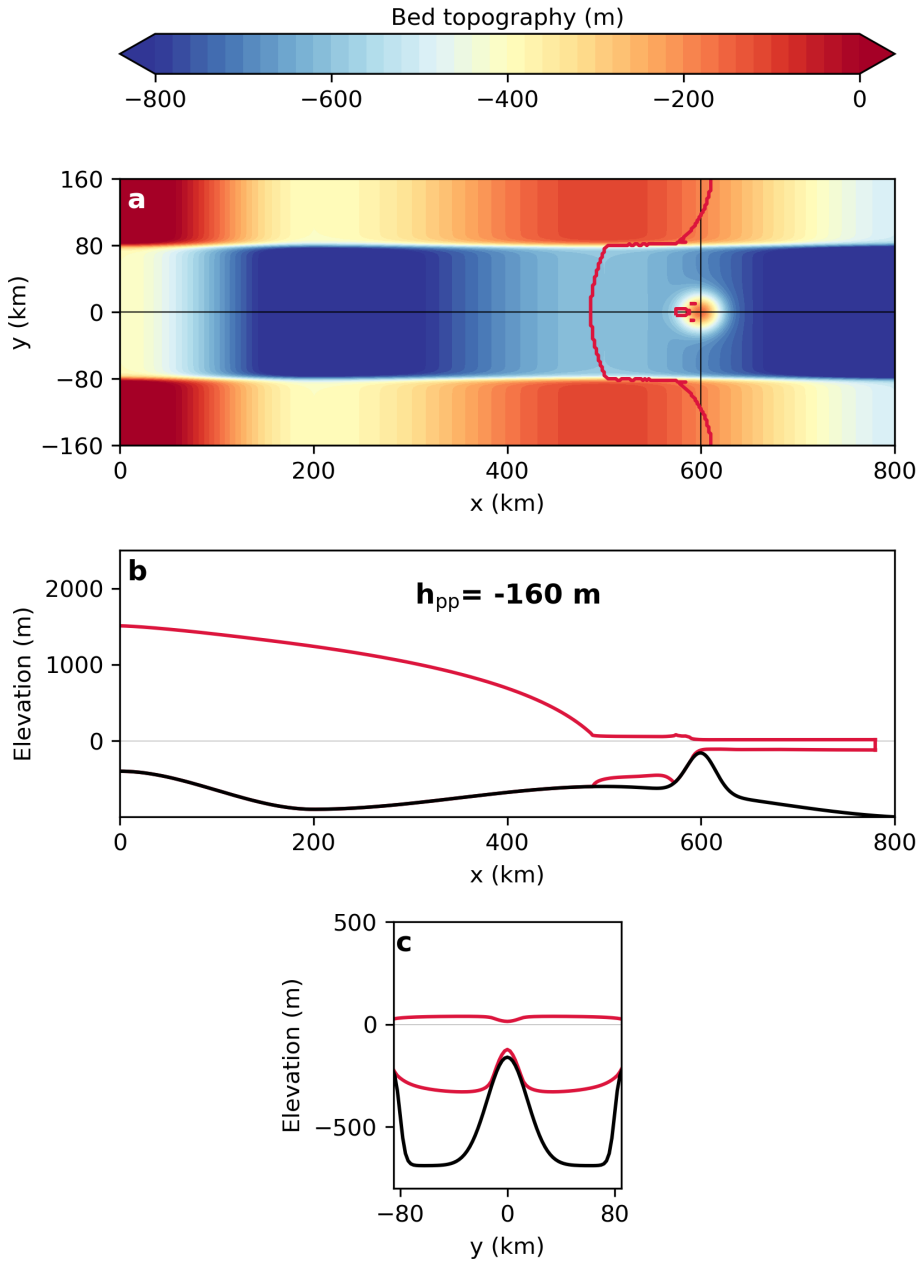

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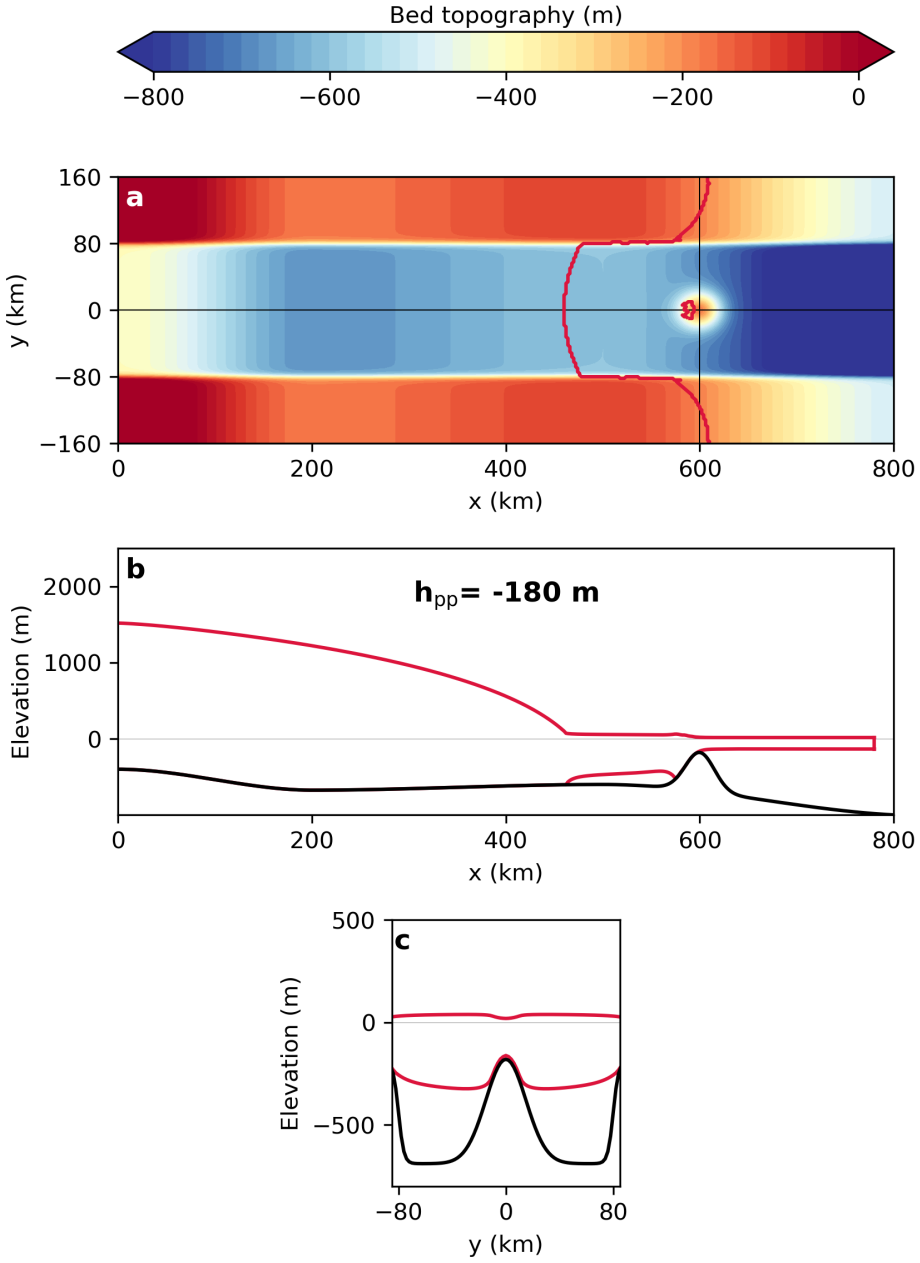

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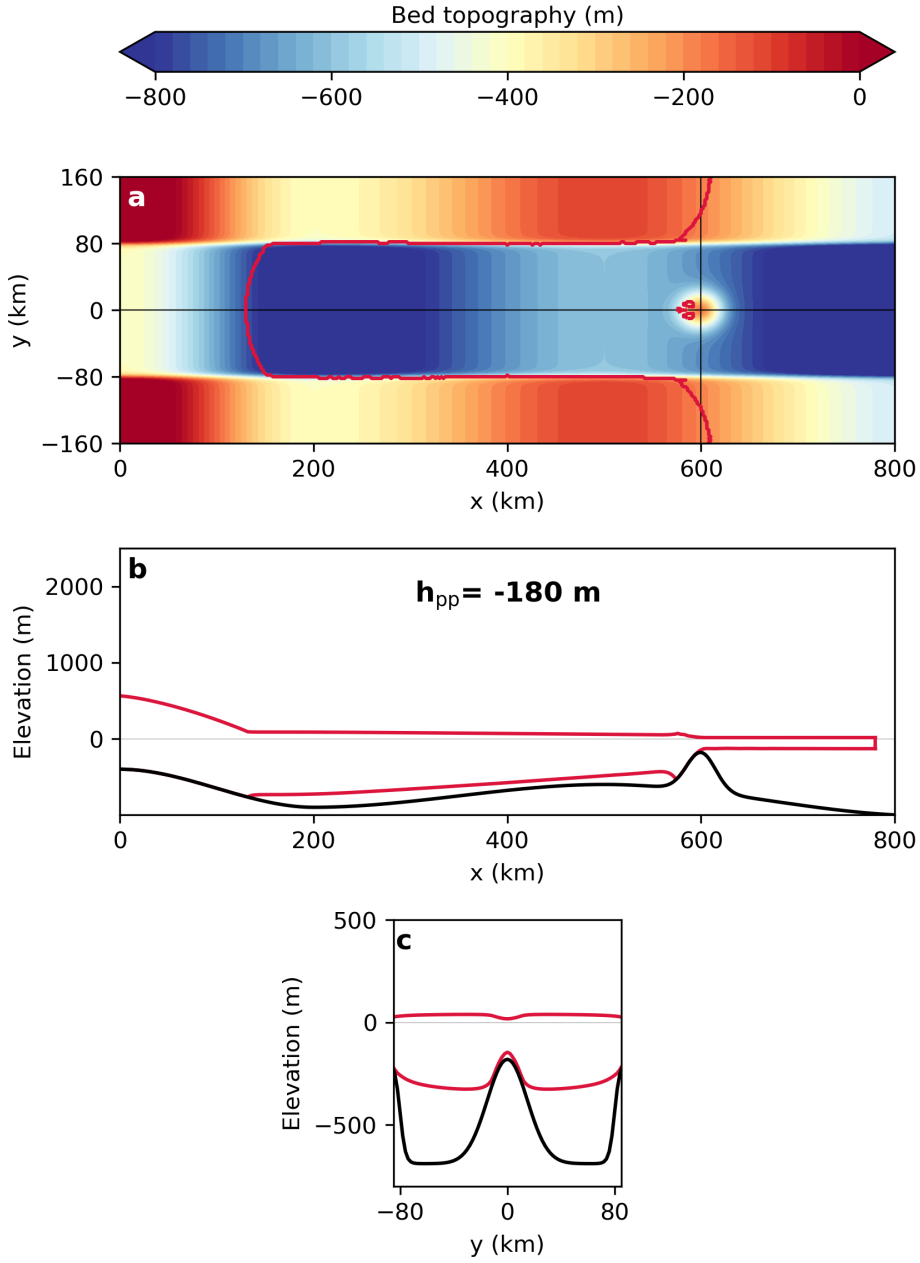

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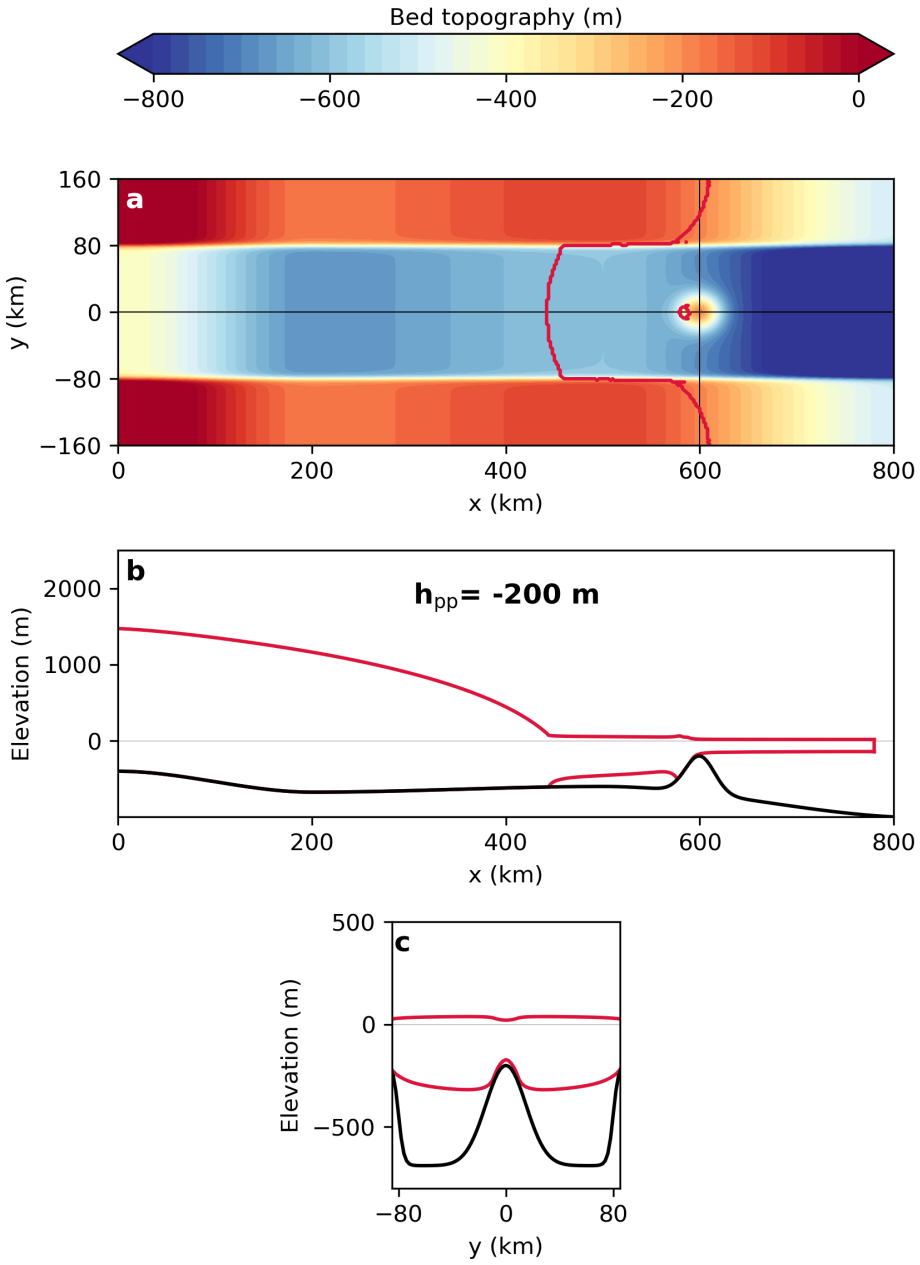

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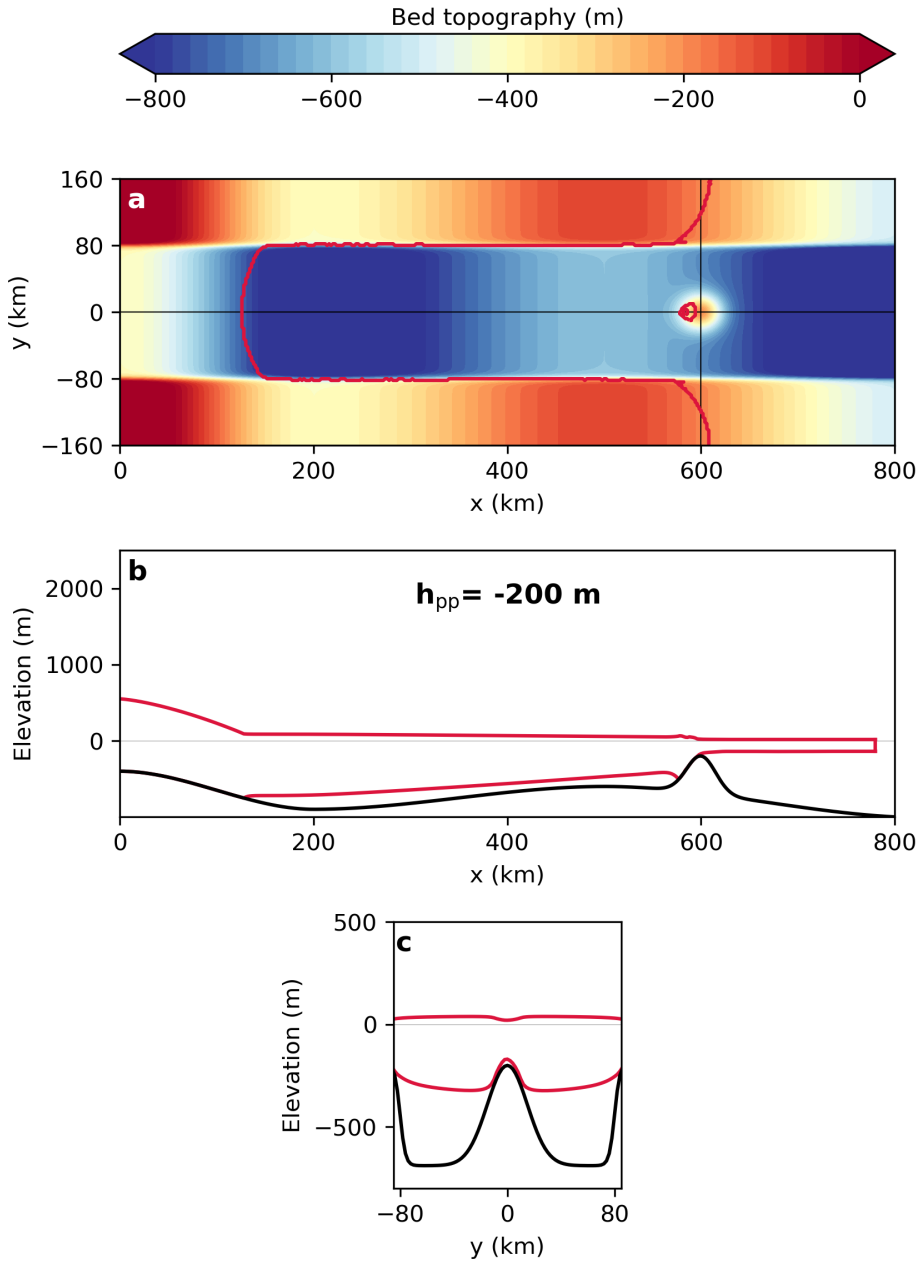

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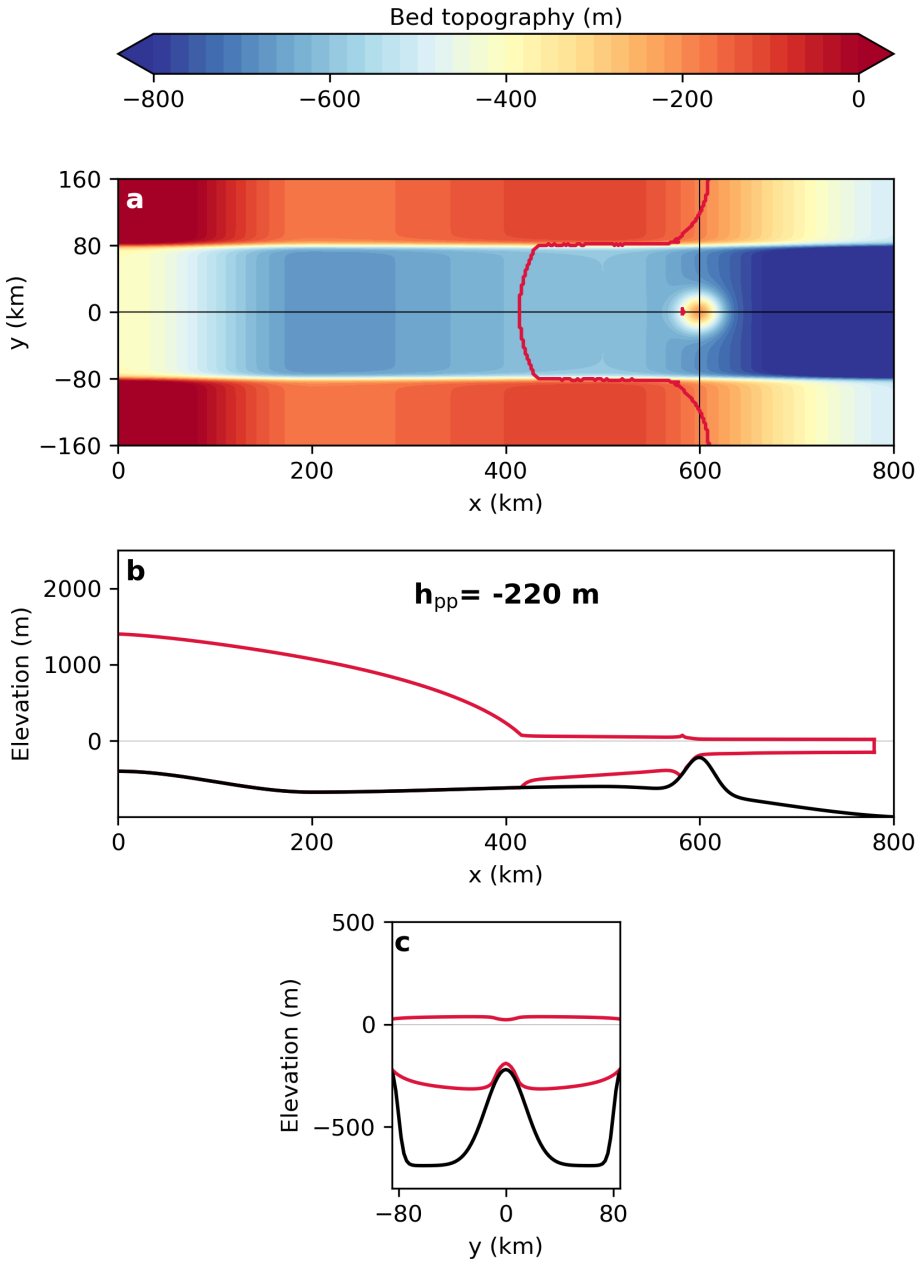

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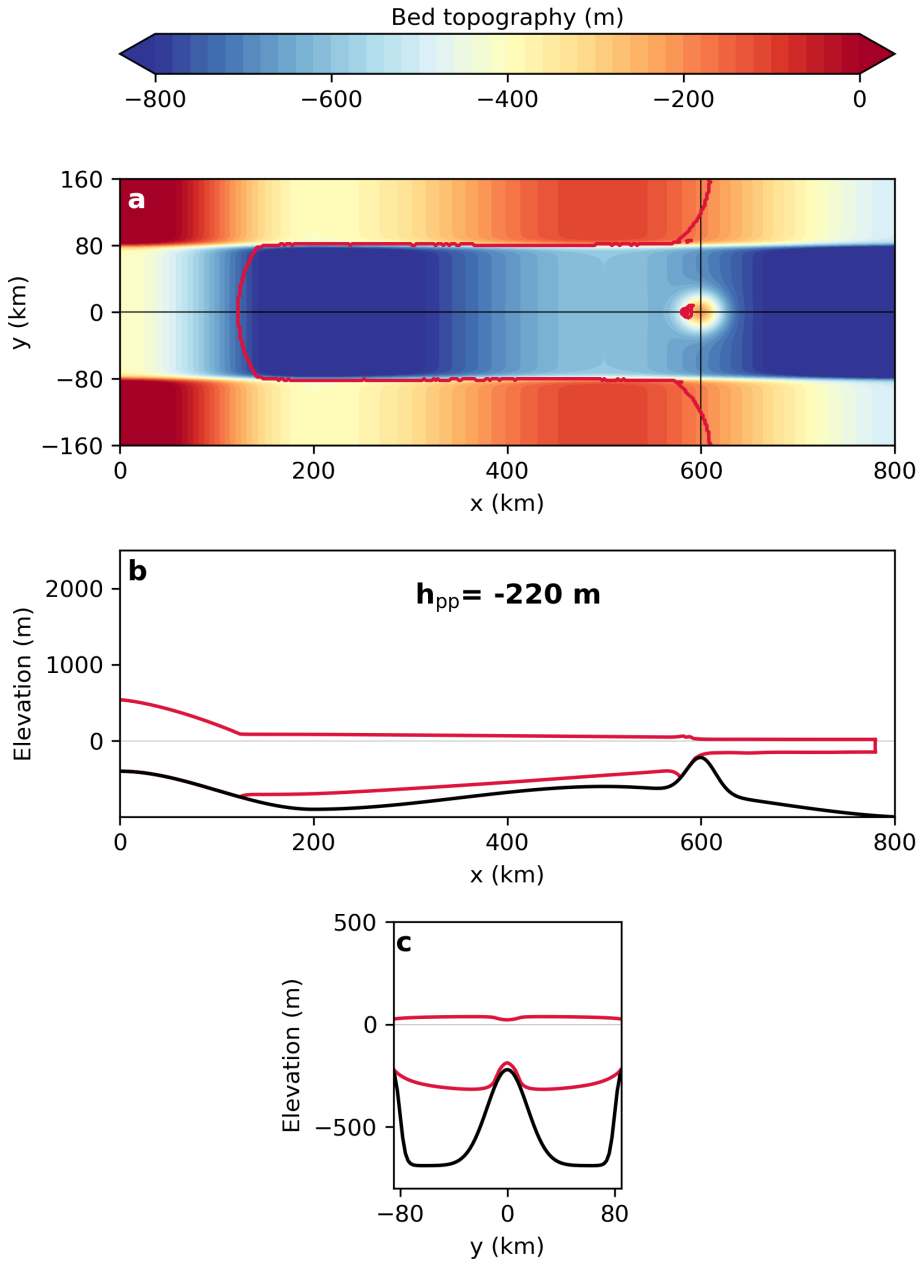

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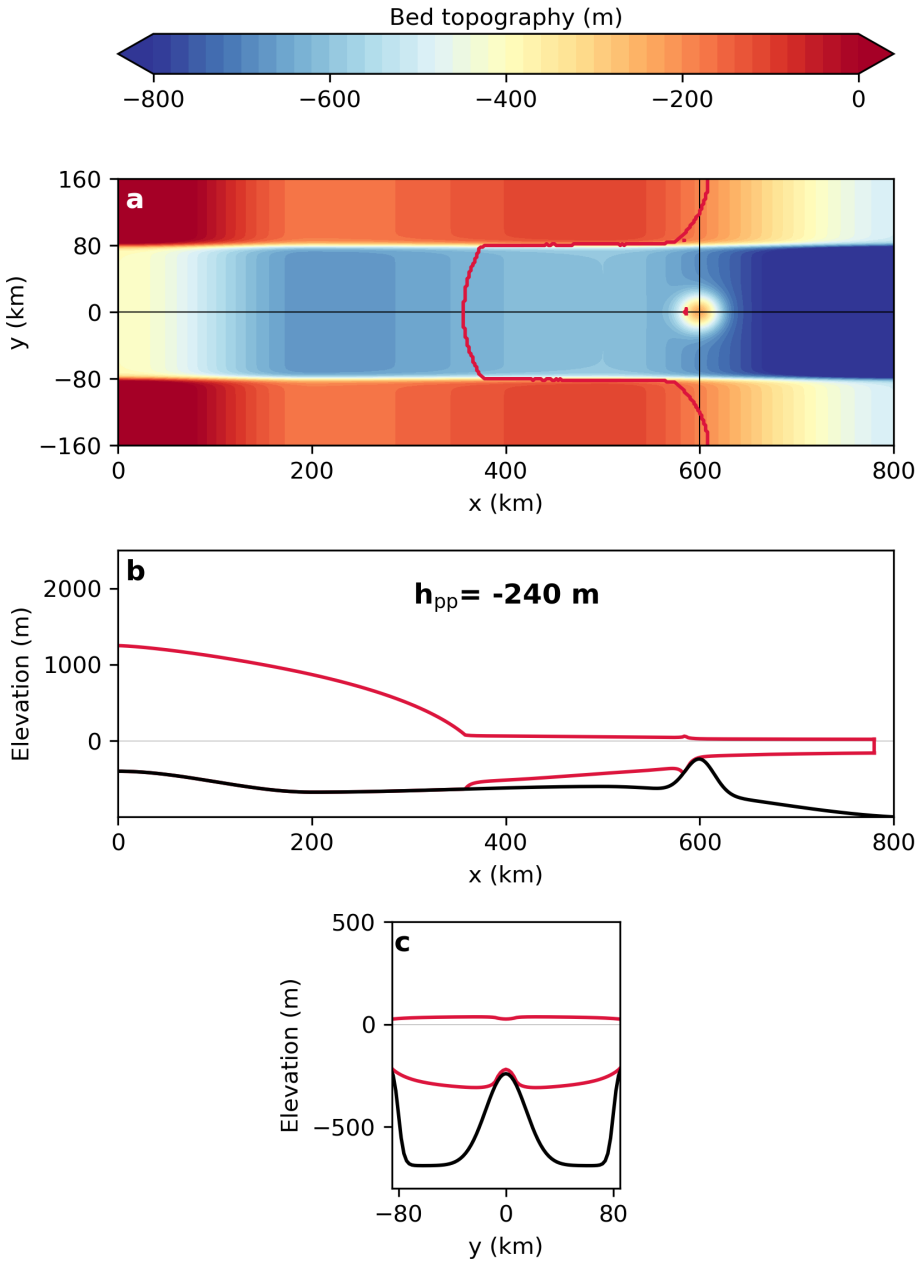

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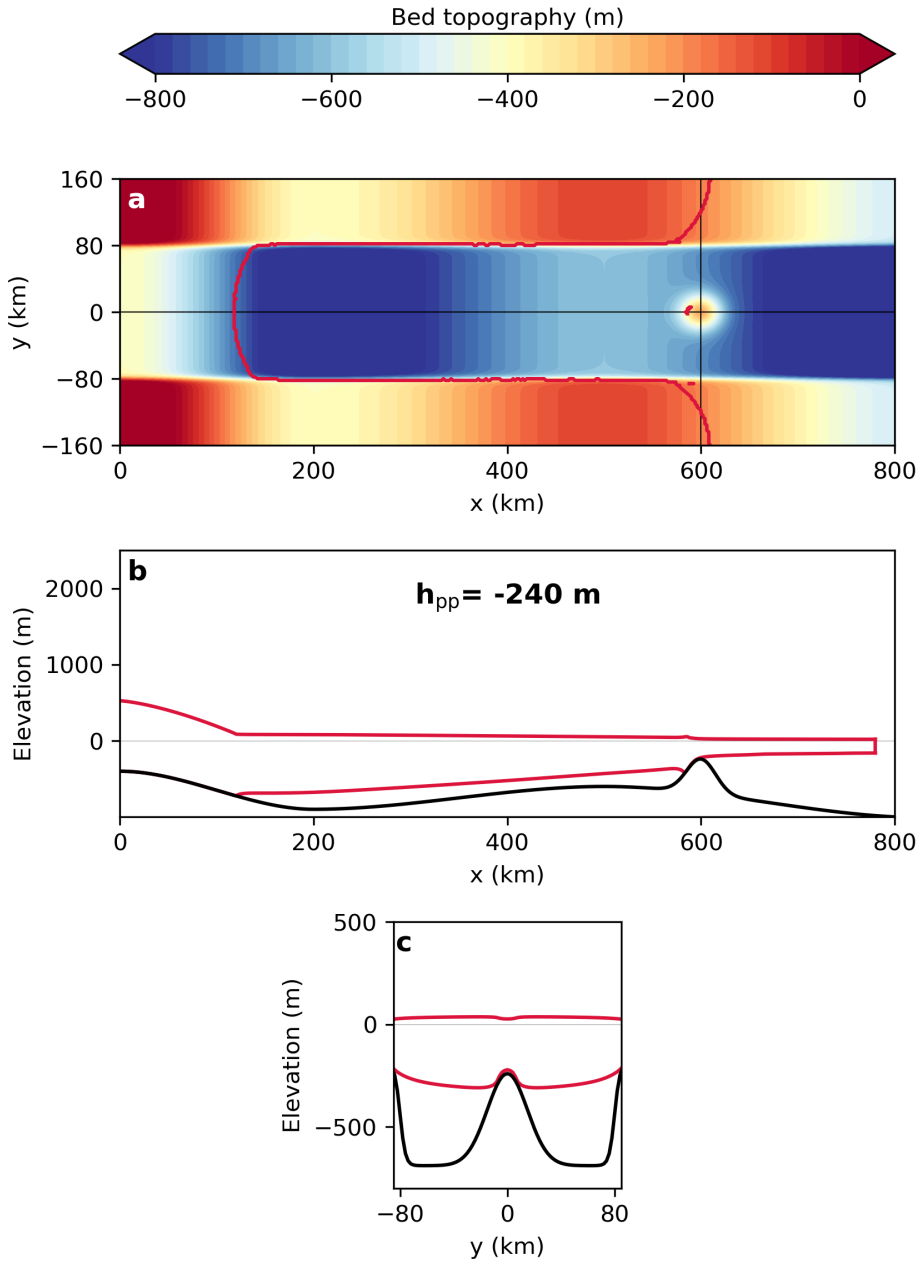

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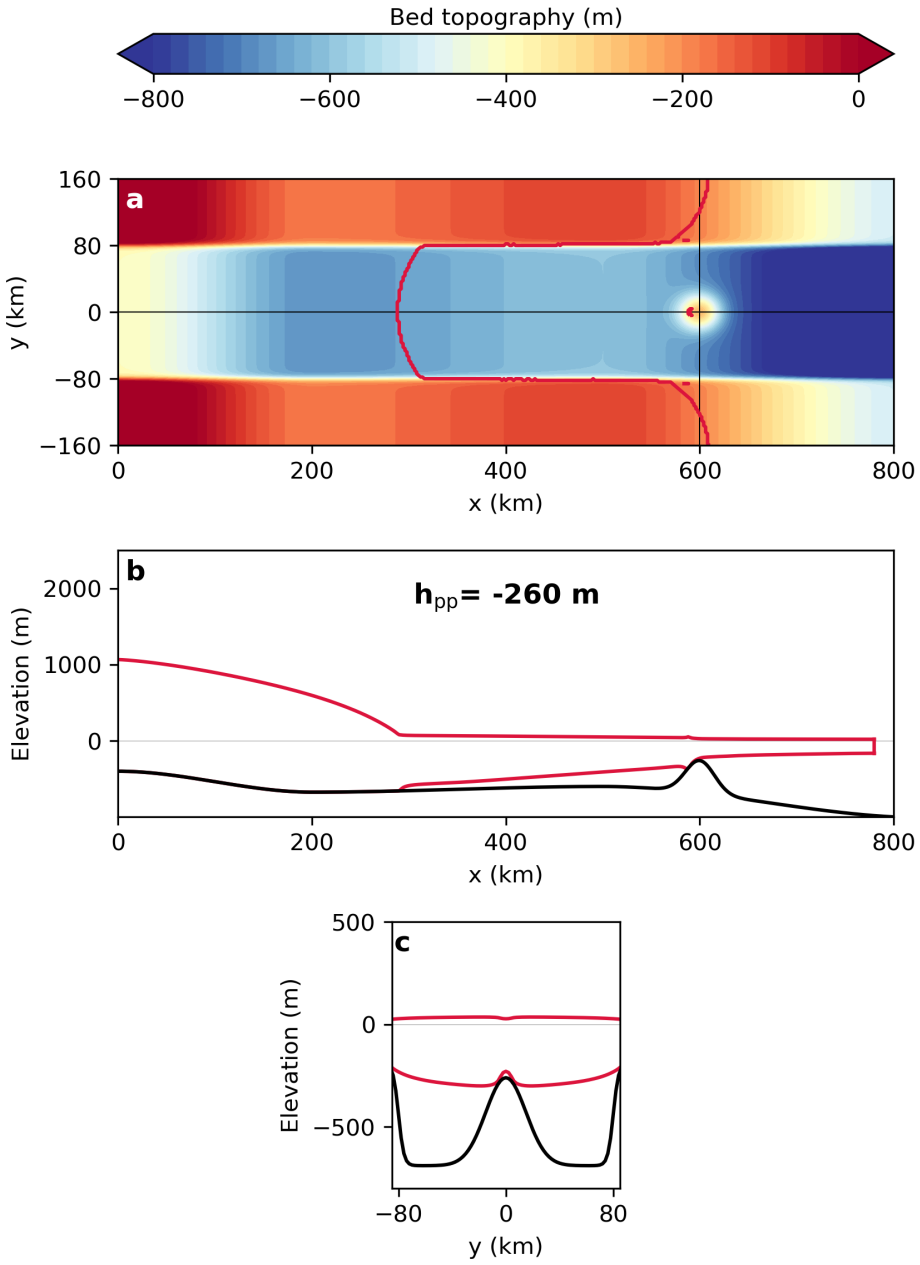

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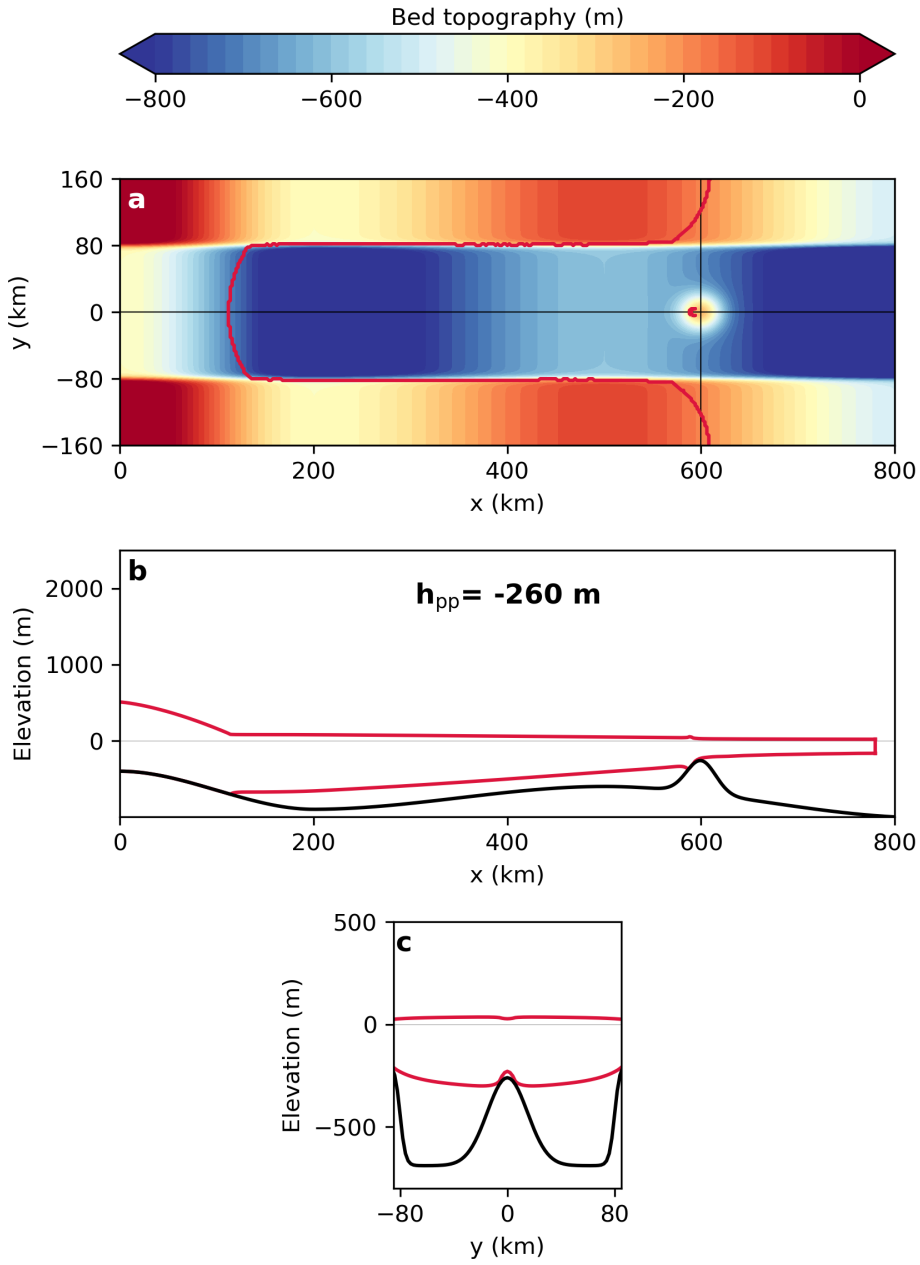

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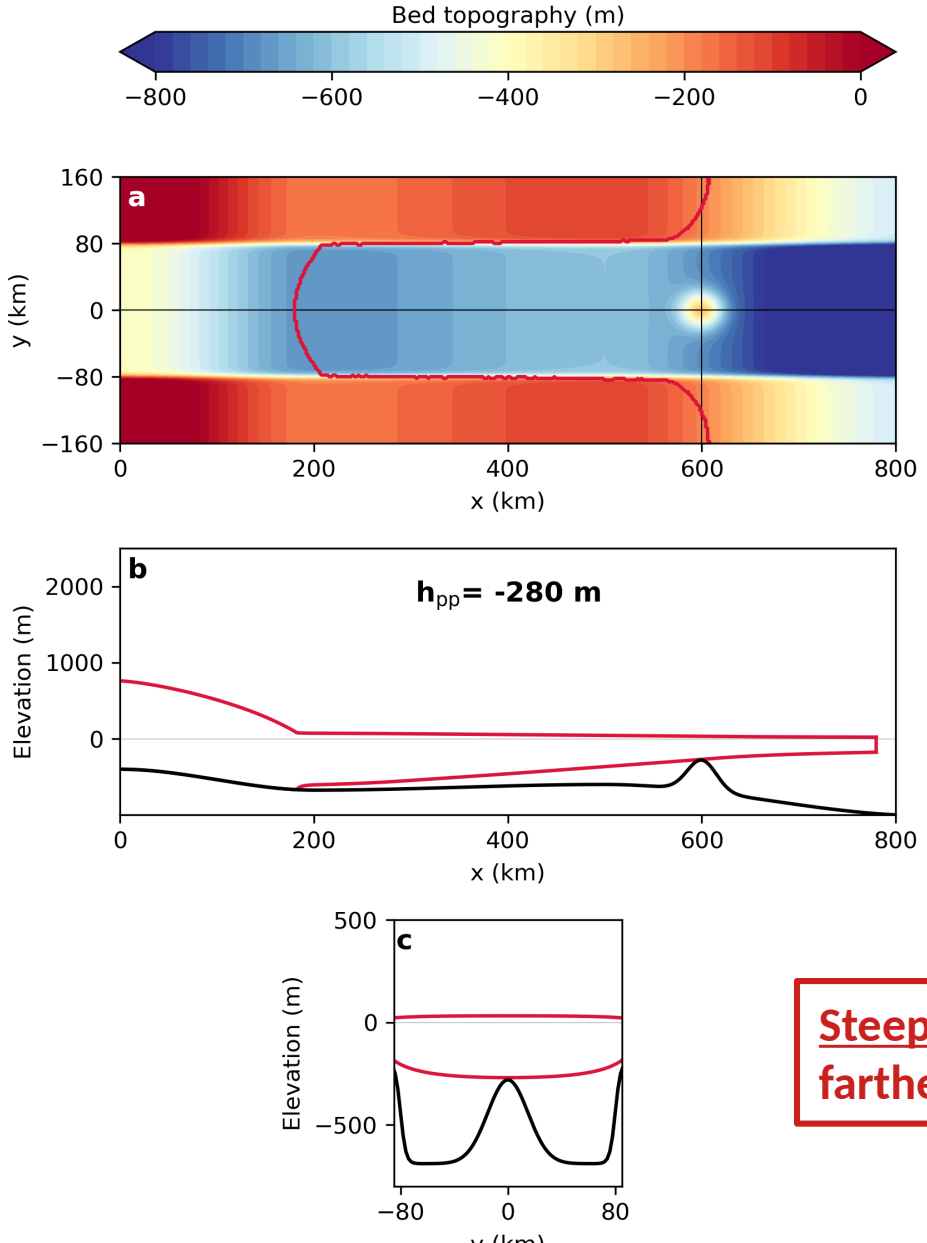

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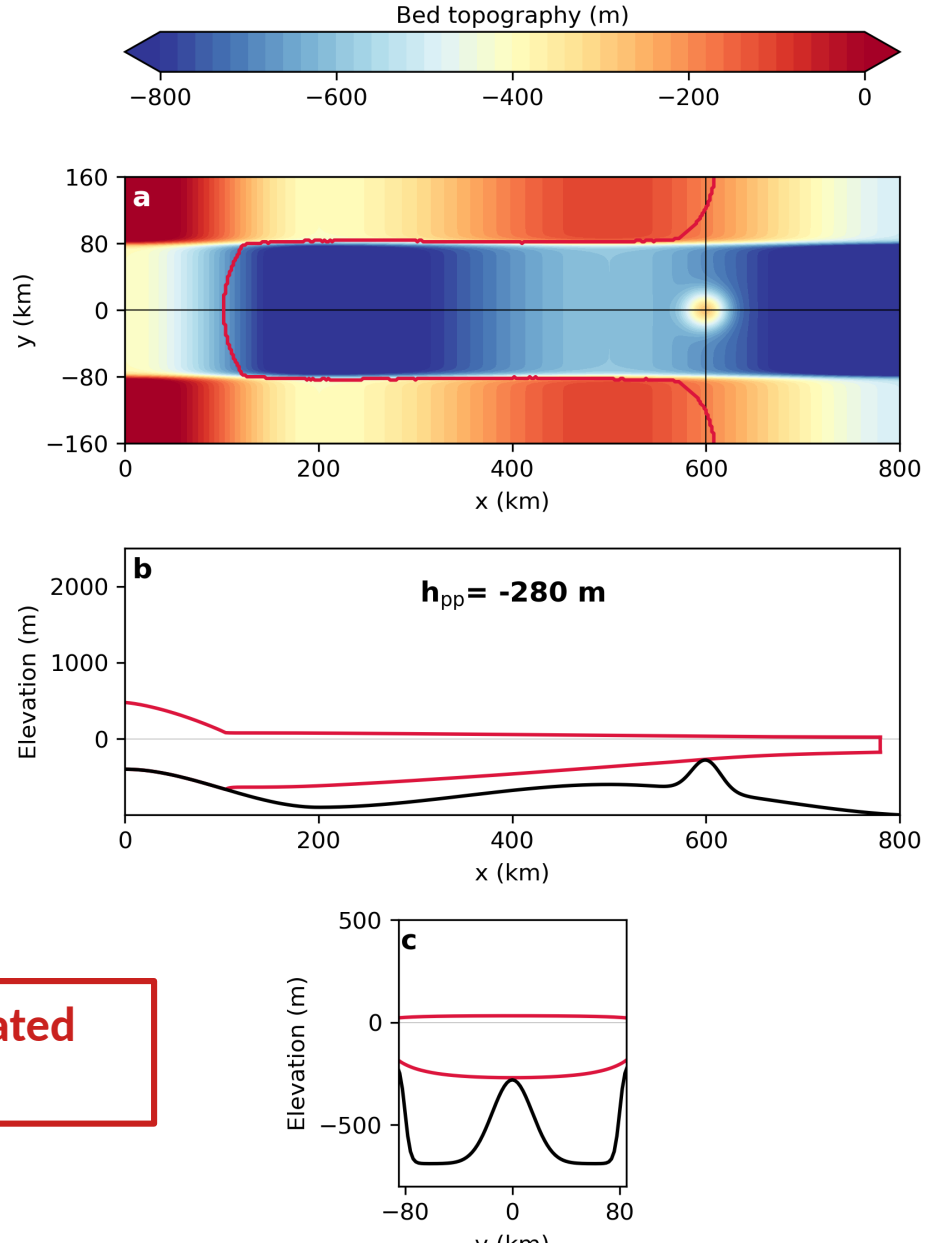
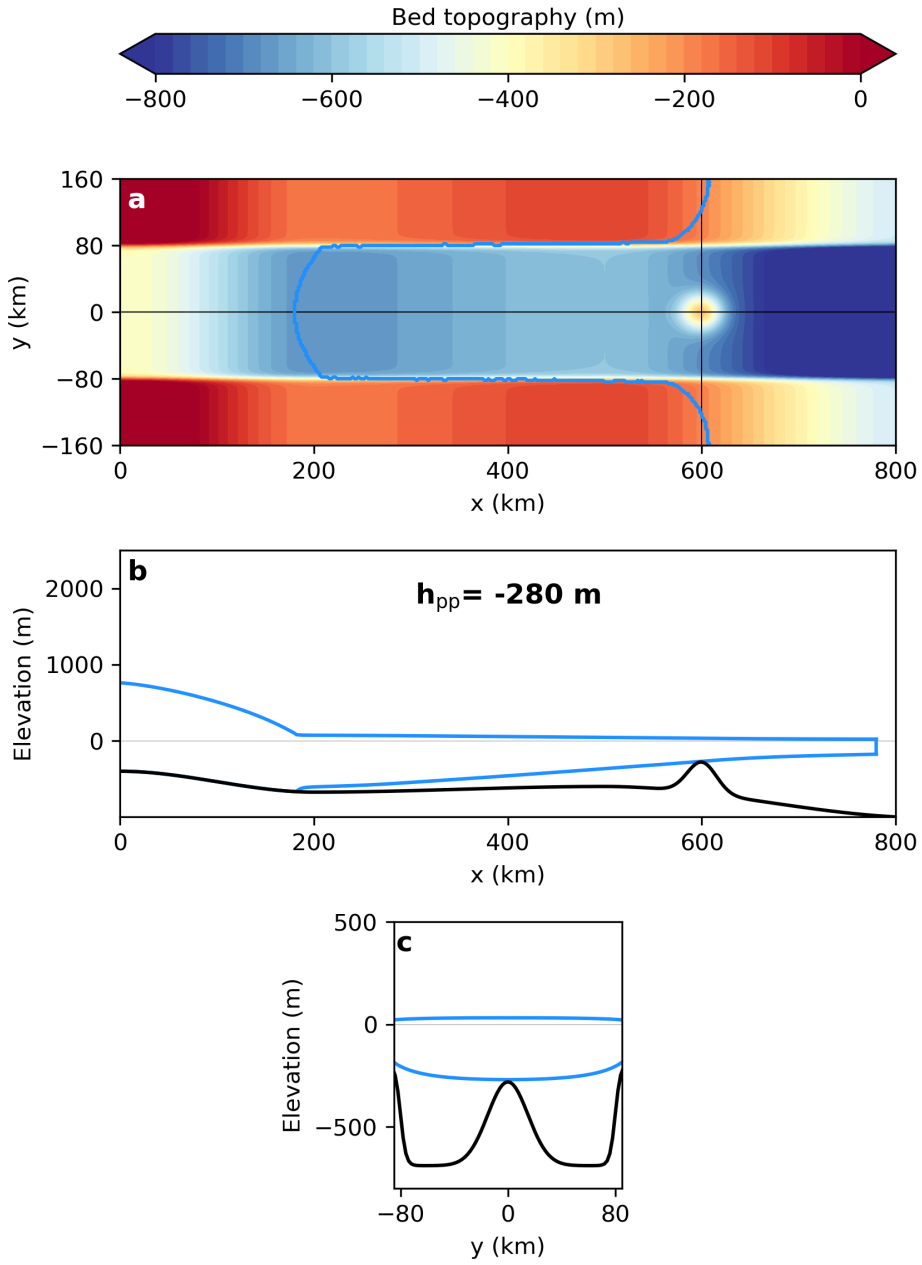


<u>Steep case:</u> unpinned glacier retreated farther inland → much smaller

Results

Flat slope (*s*)



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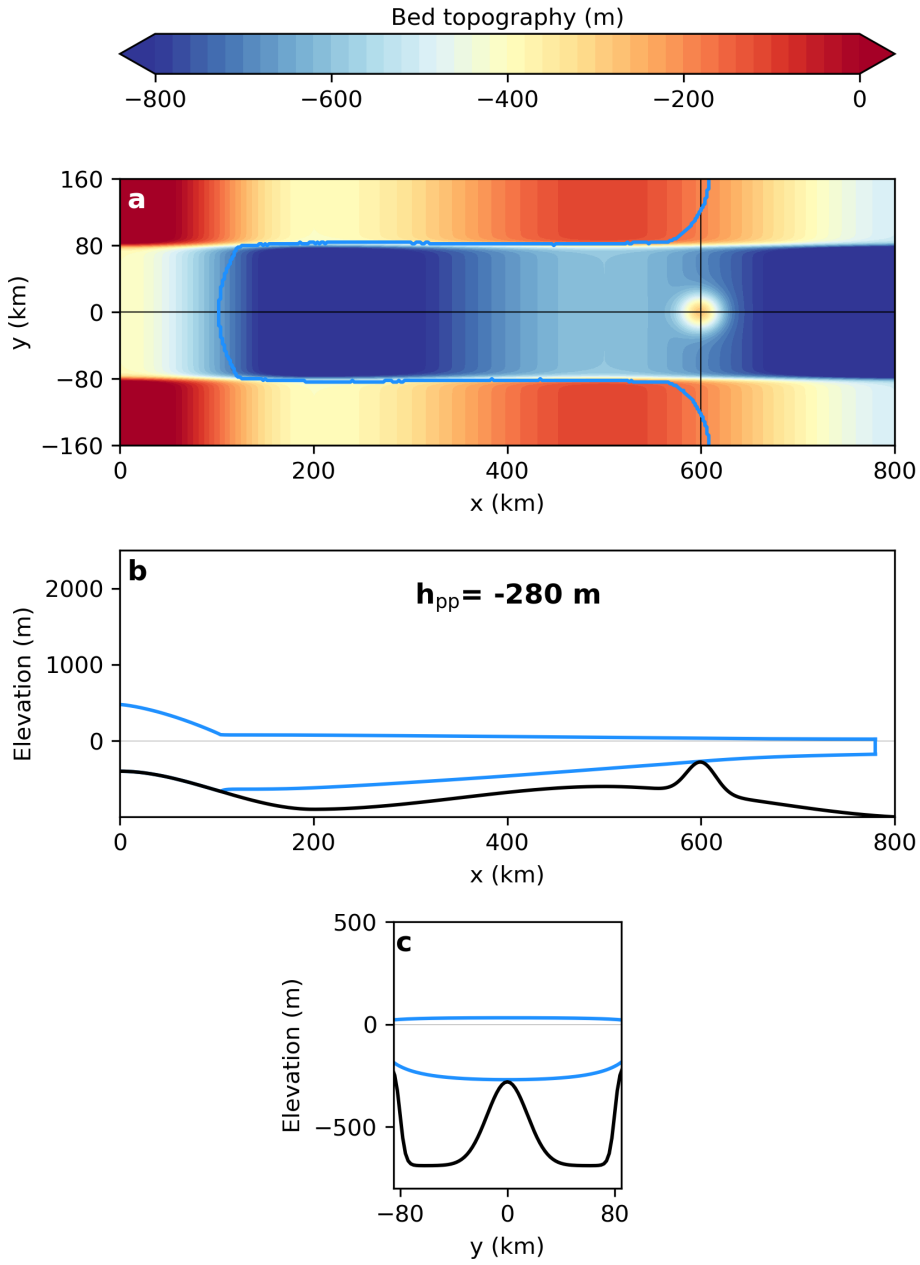

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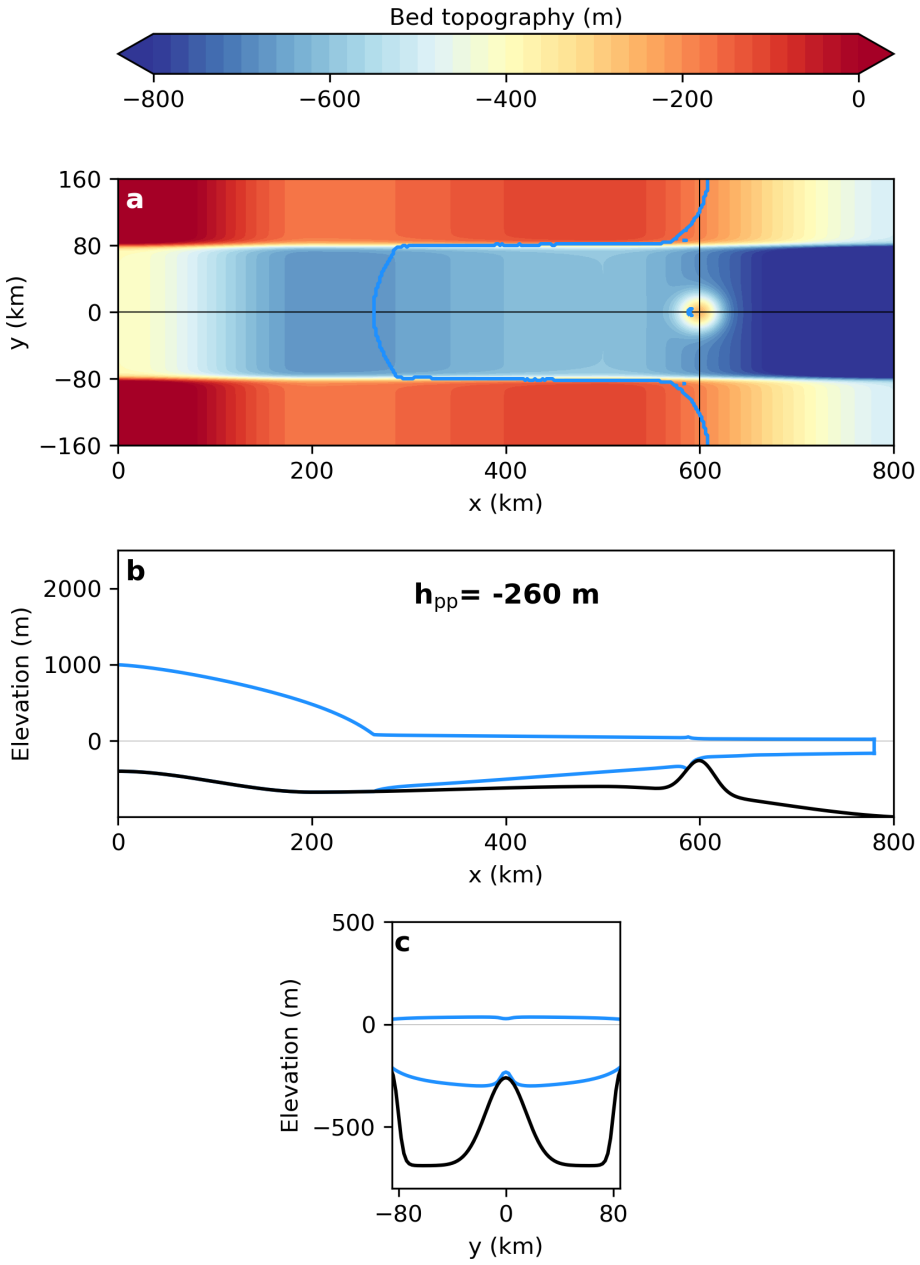
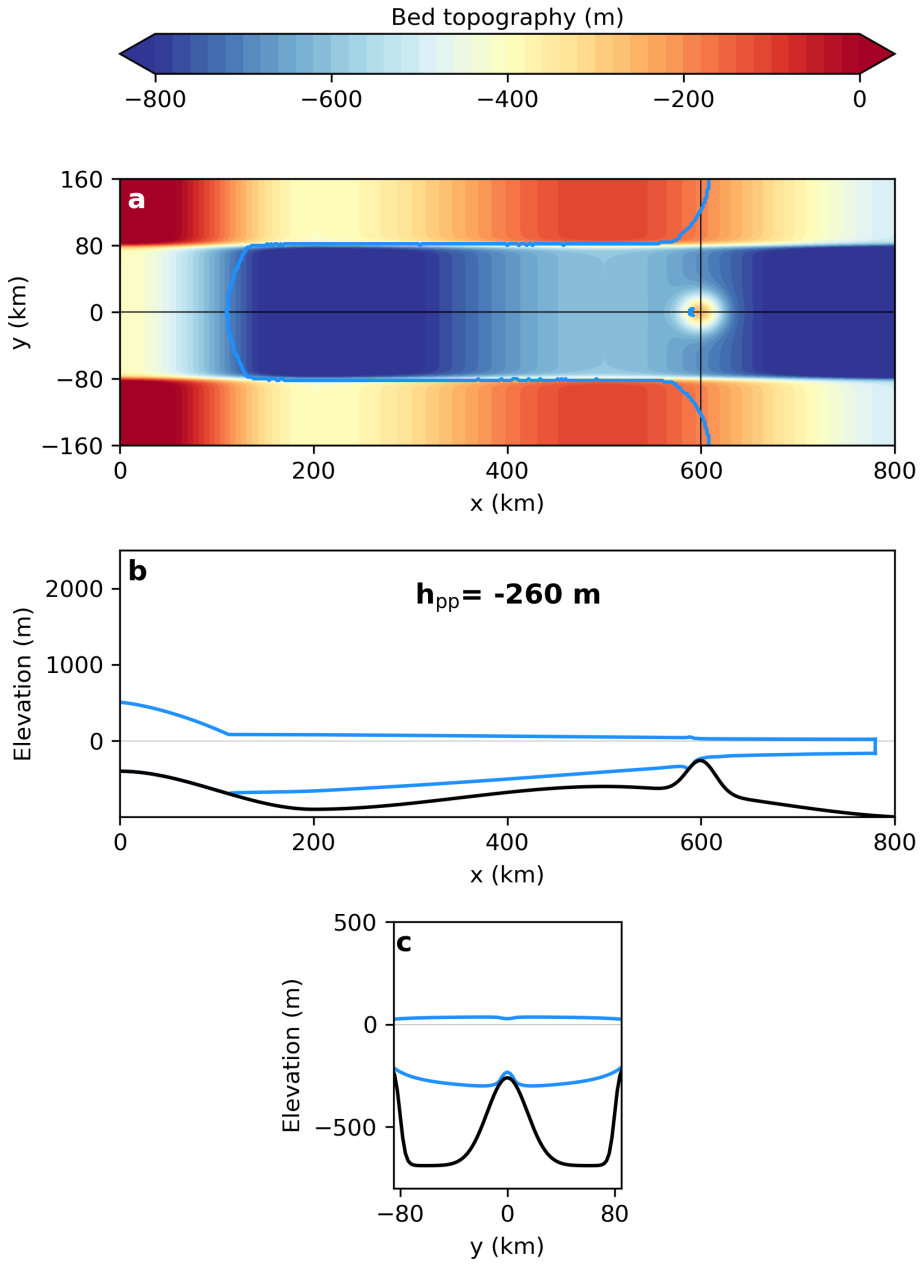


Steep slope (4·*s*)



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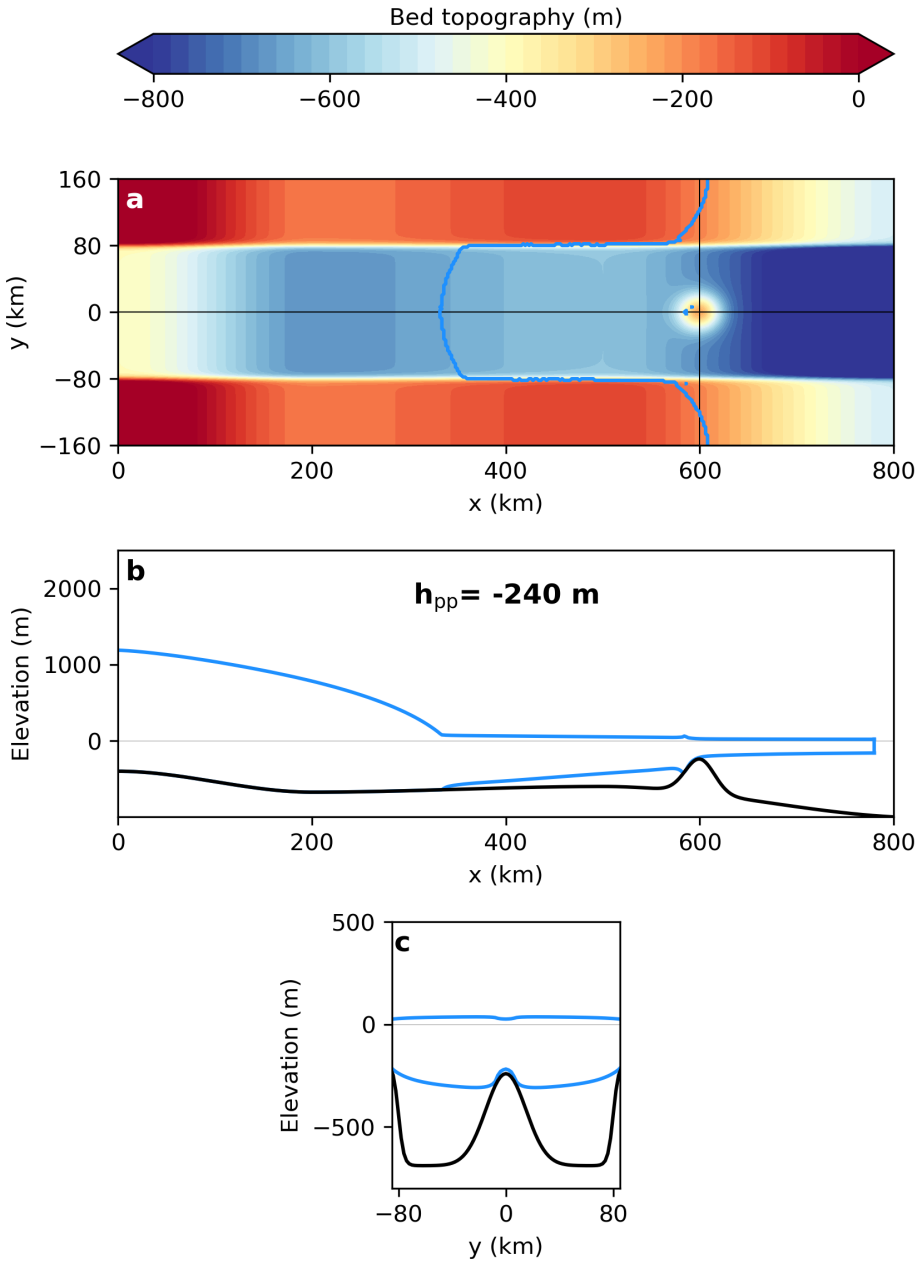

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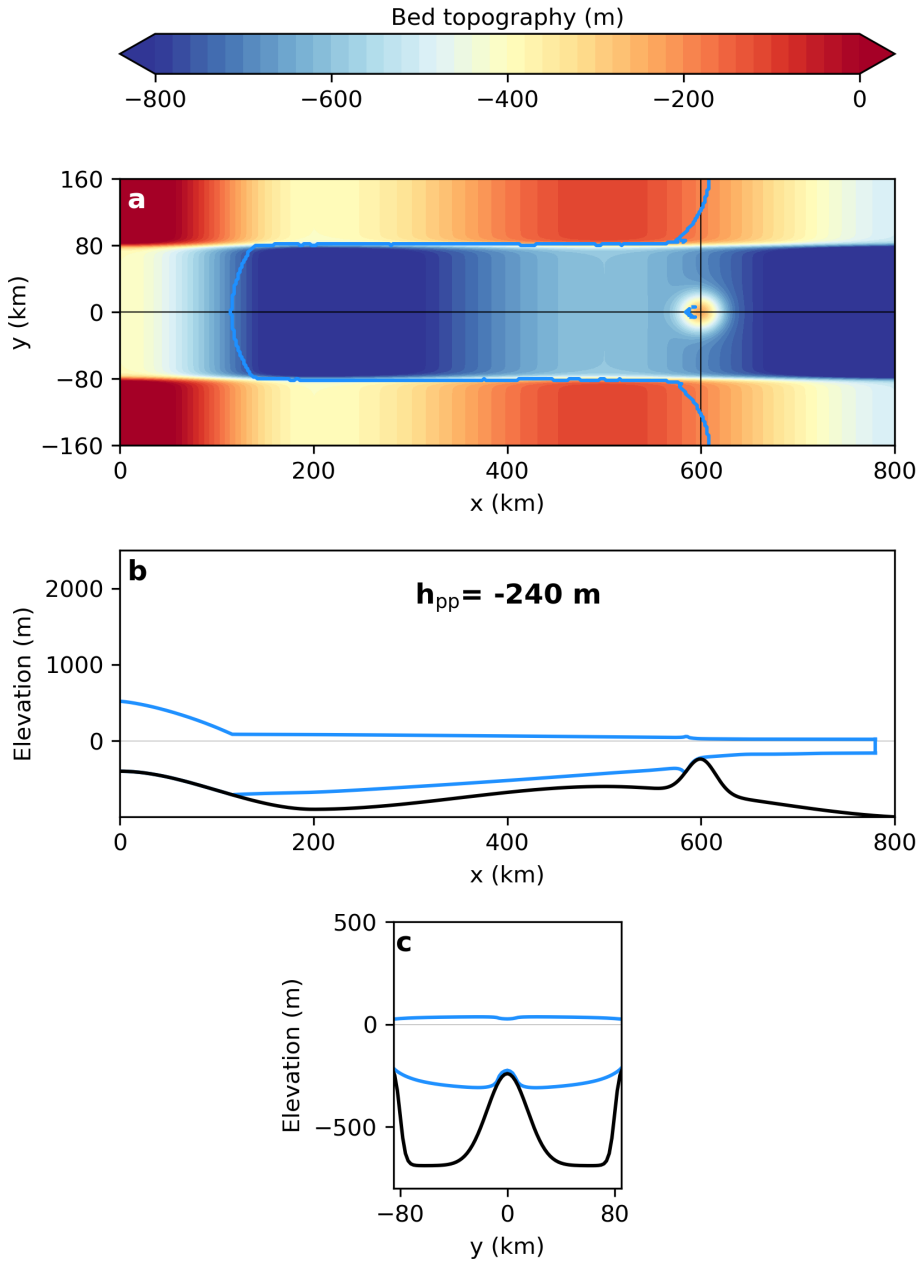

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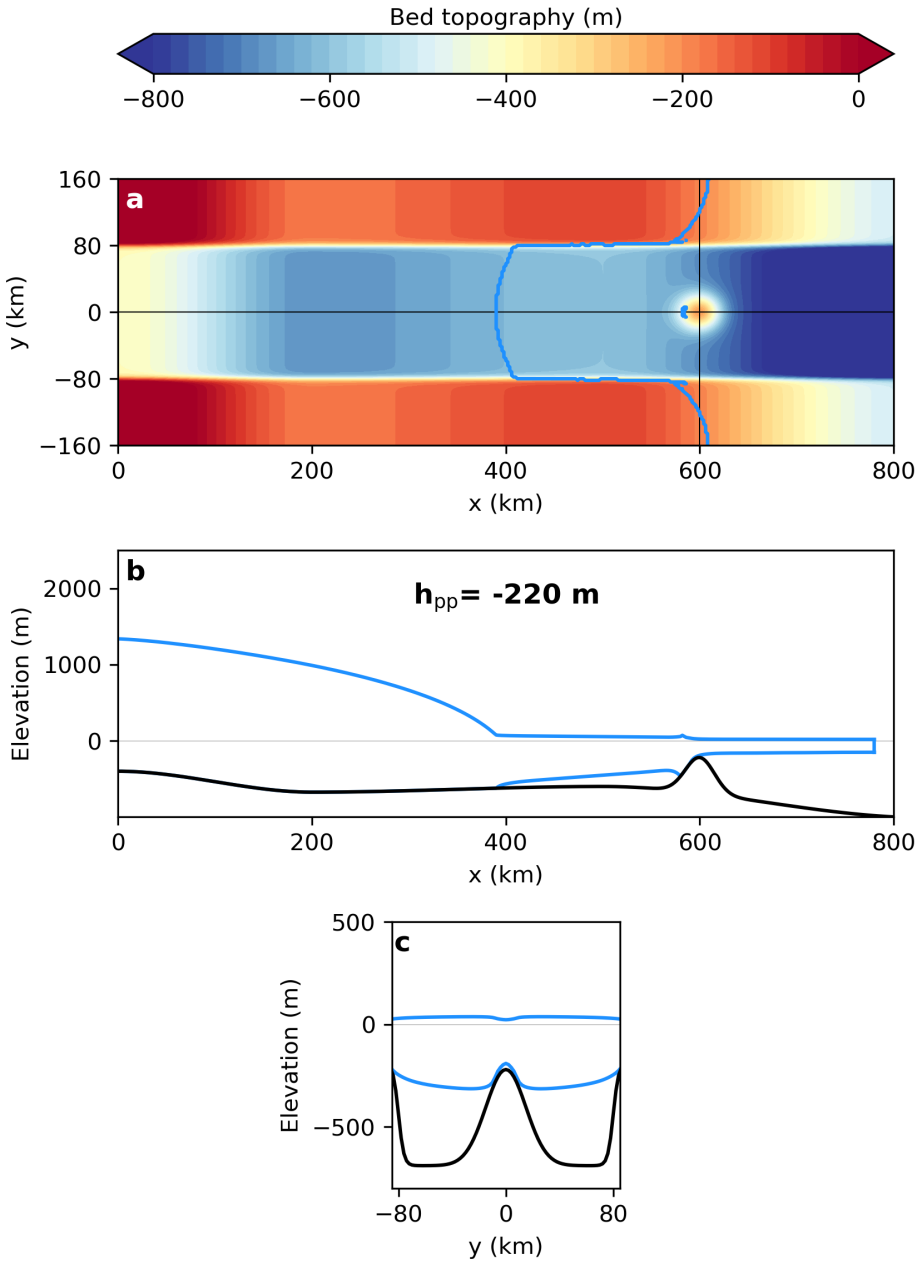

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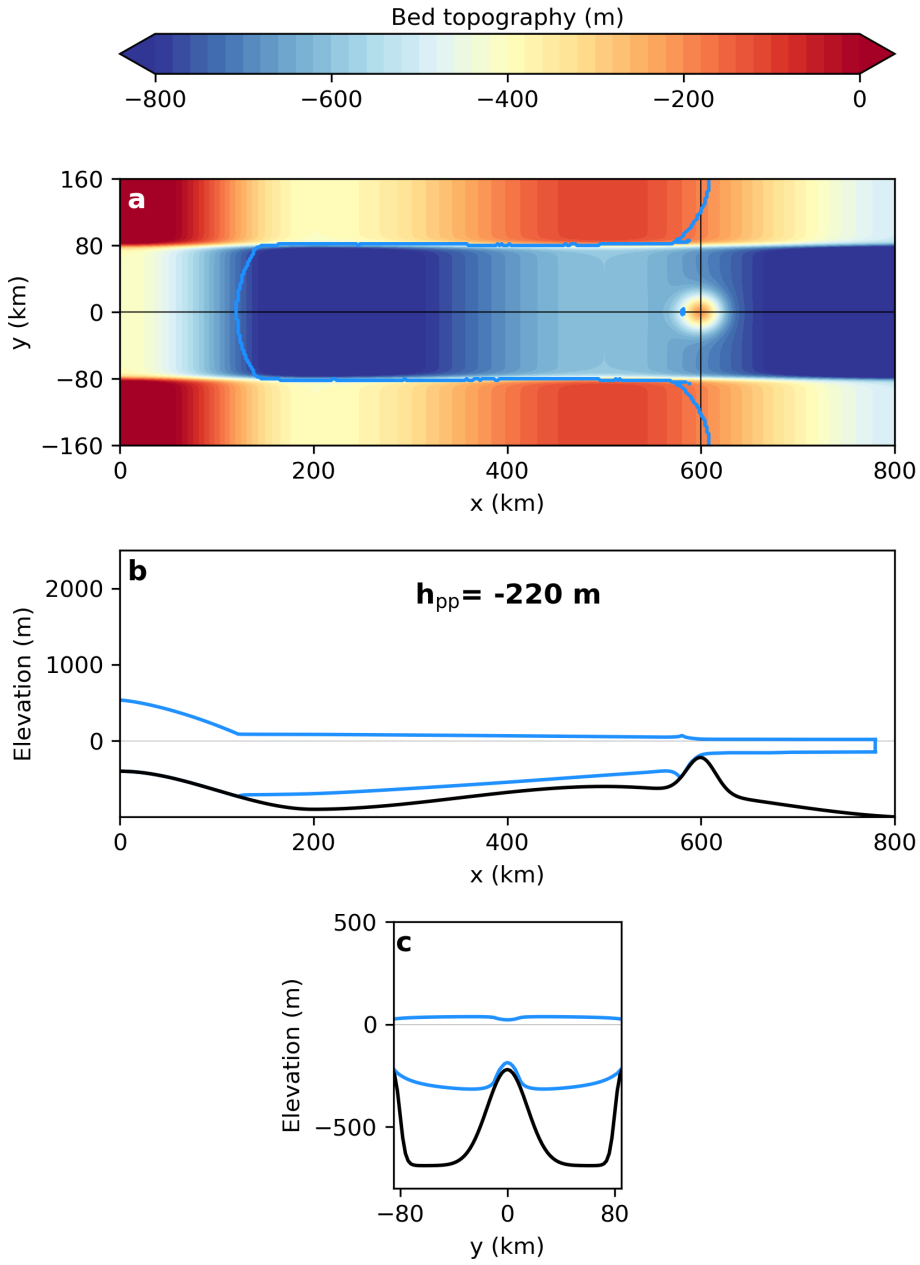

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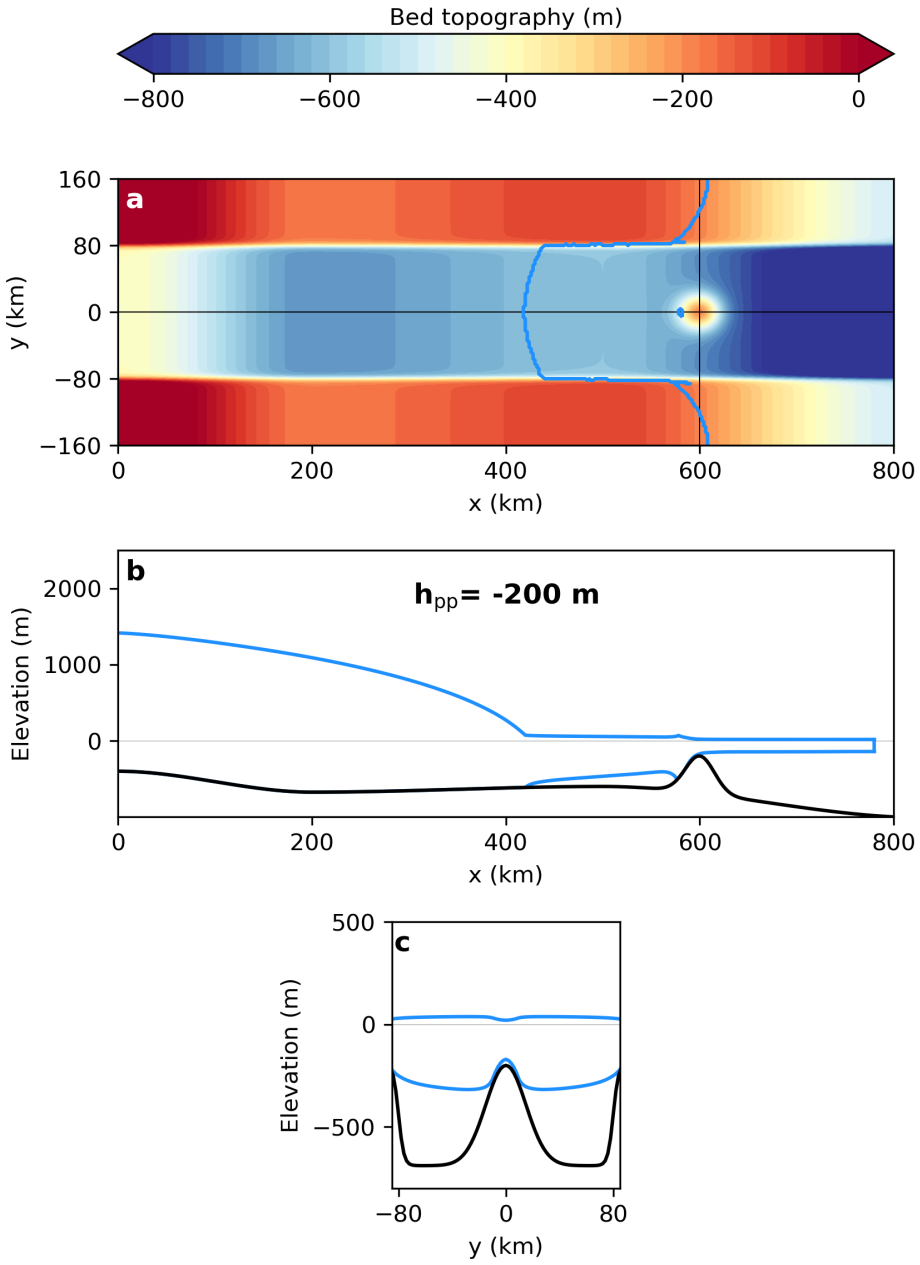

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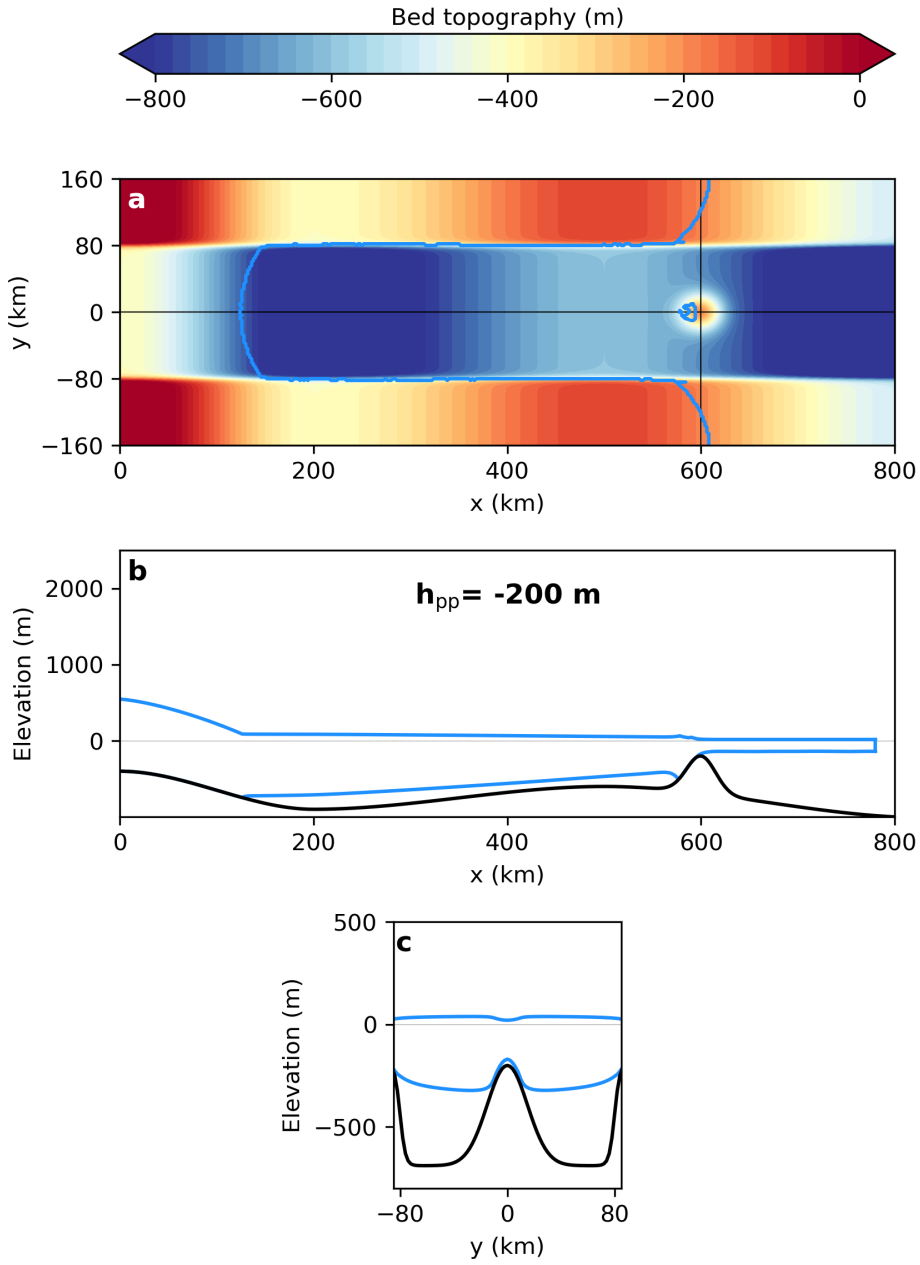

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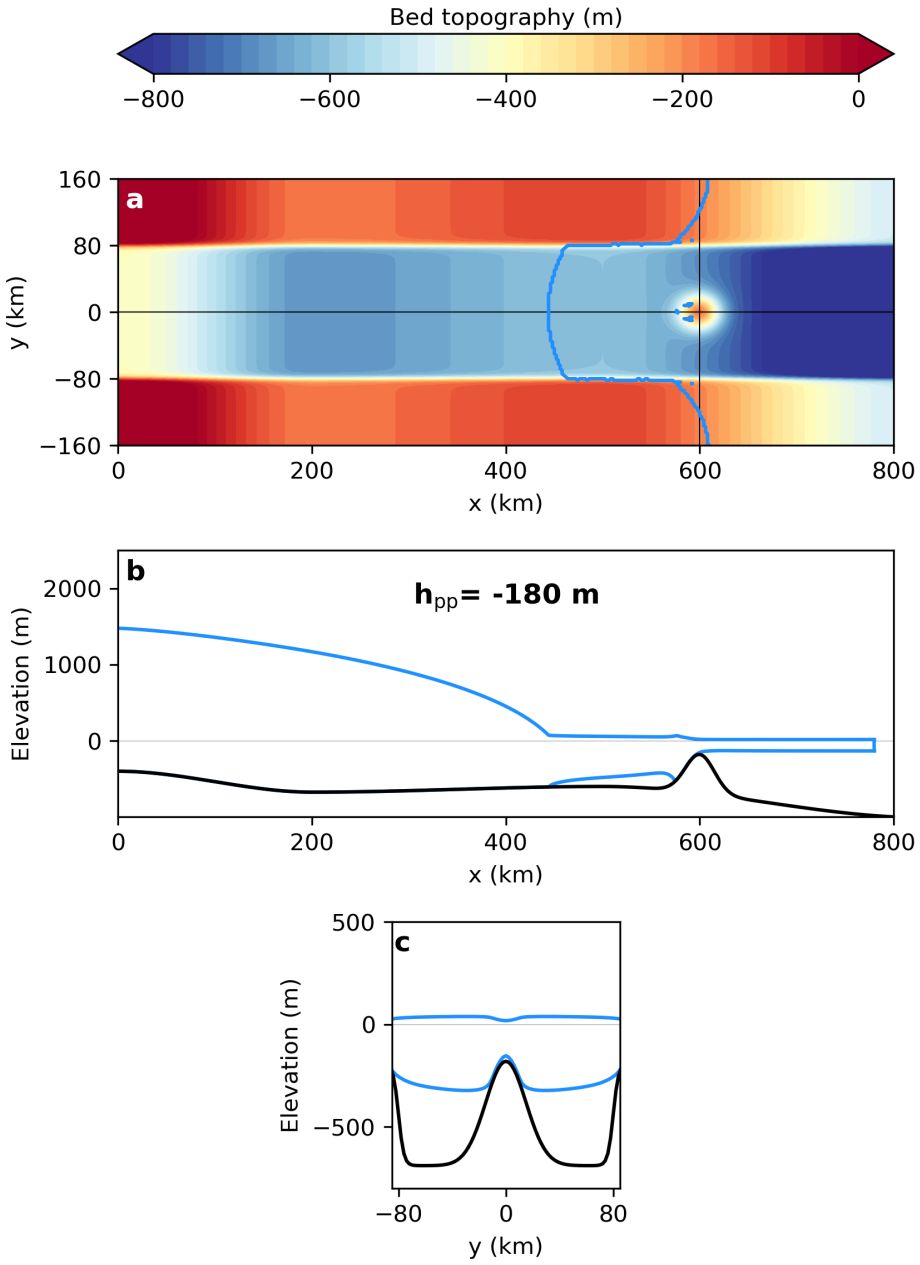

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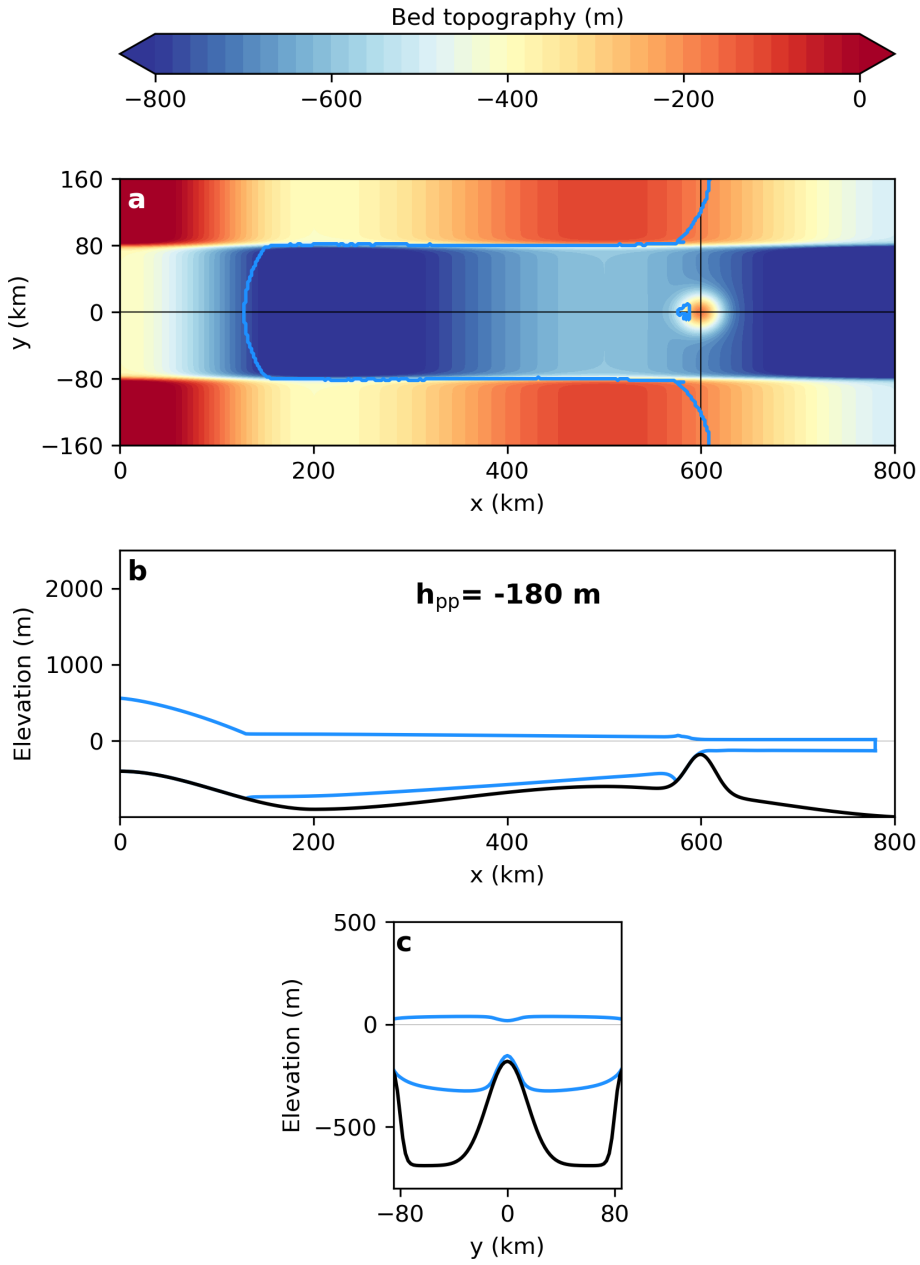

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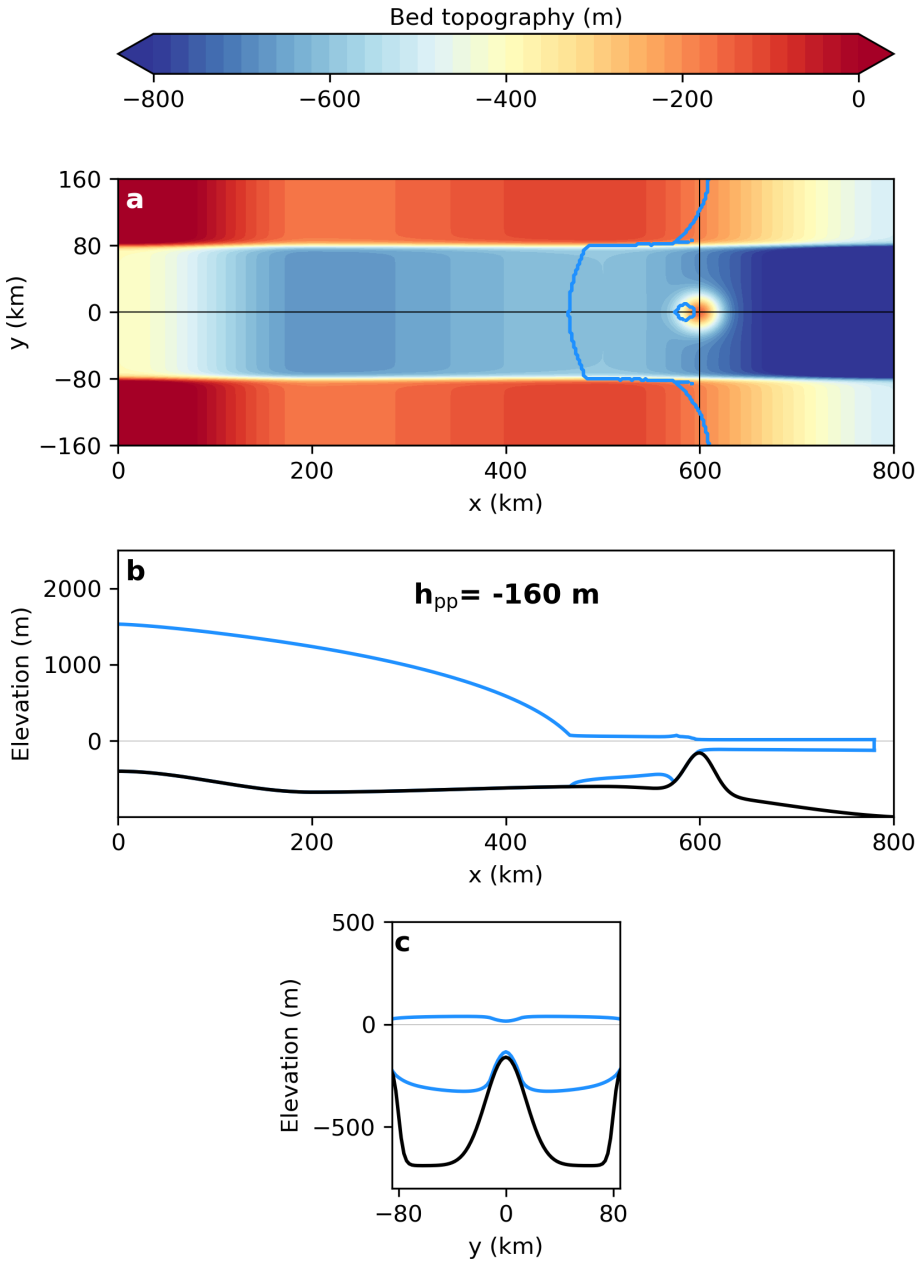

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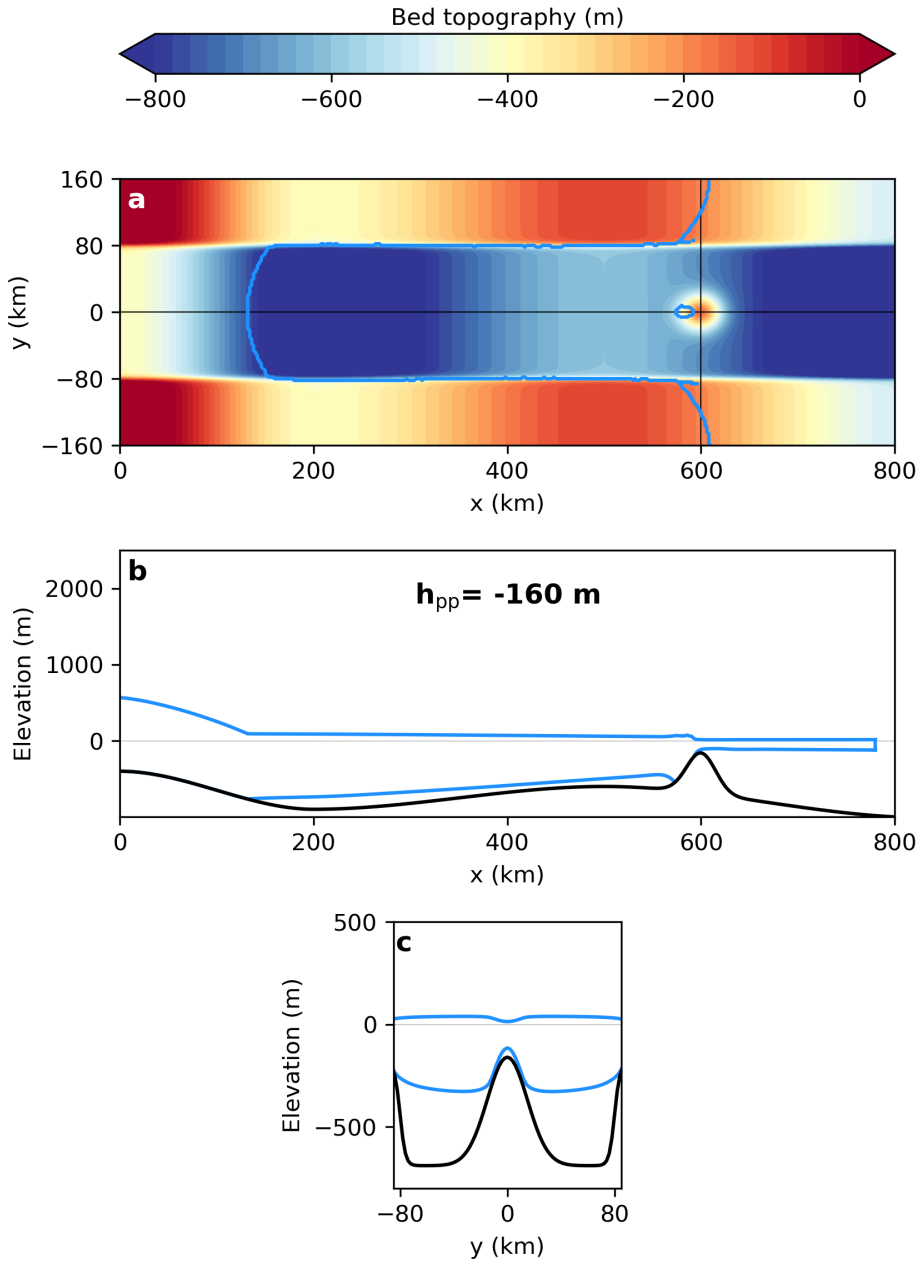

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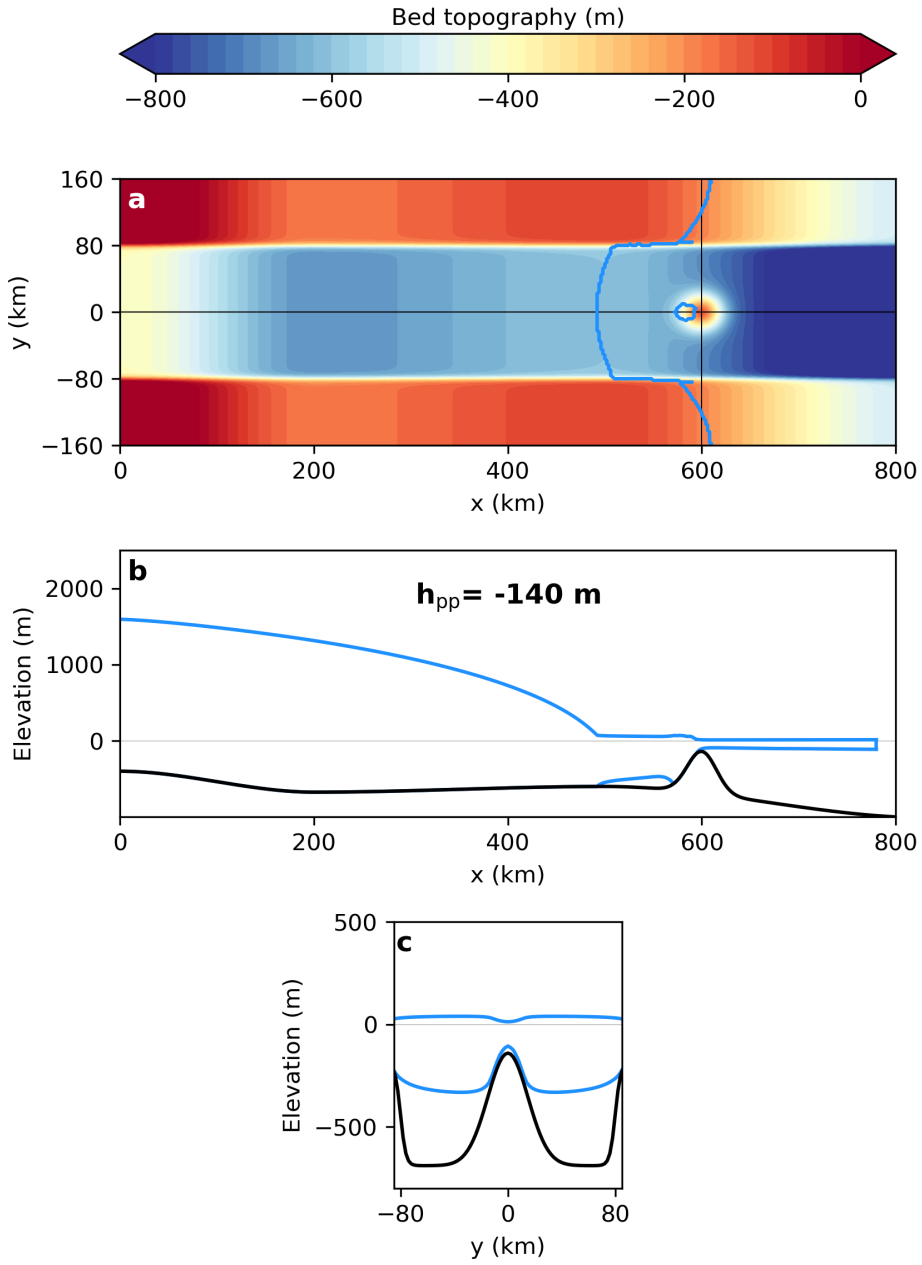

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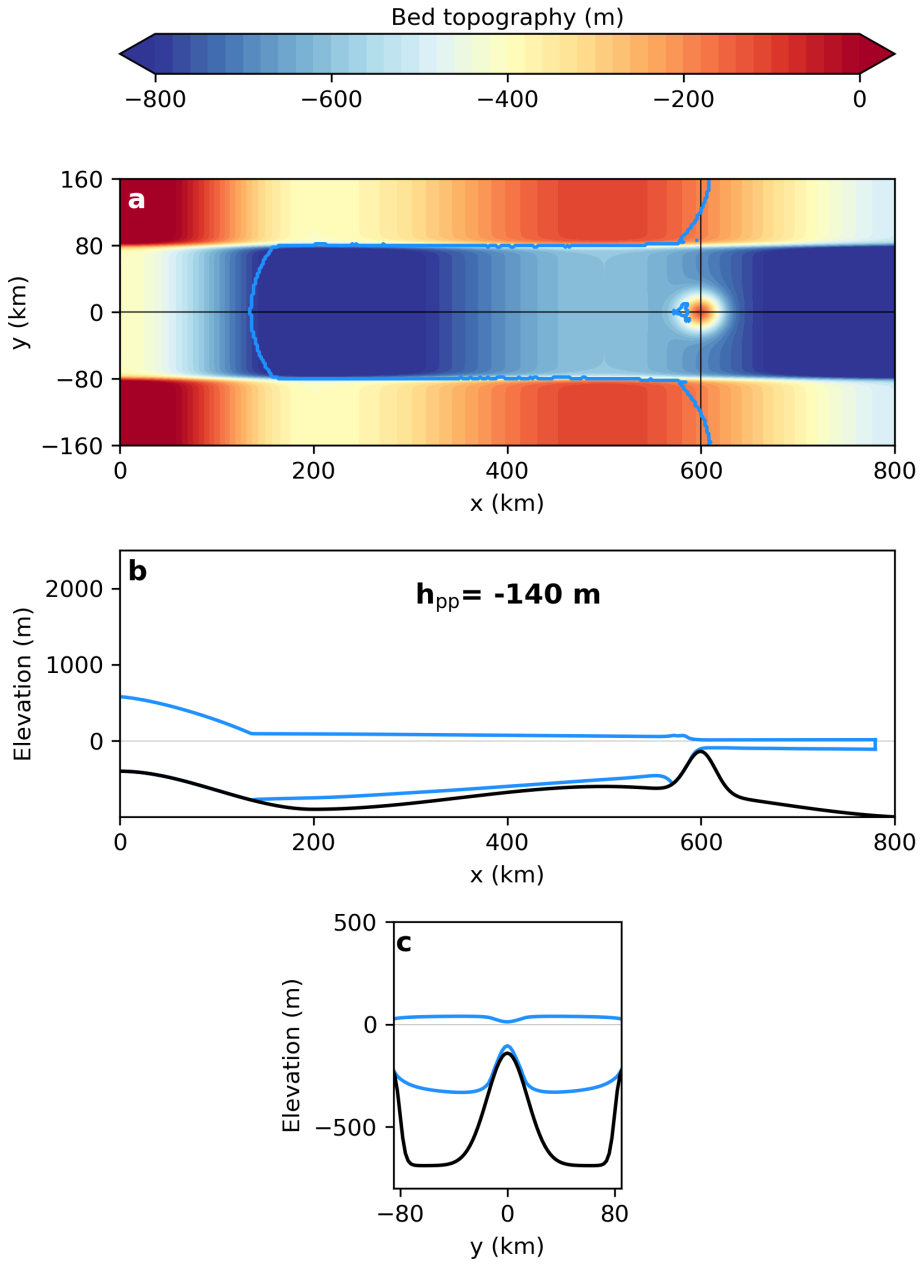

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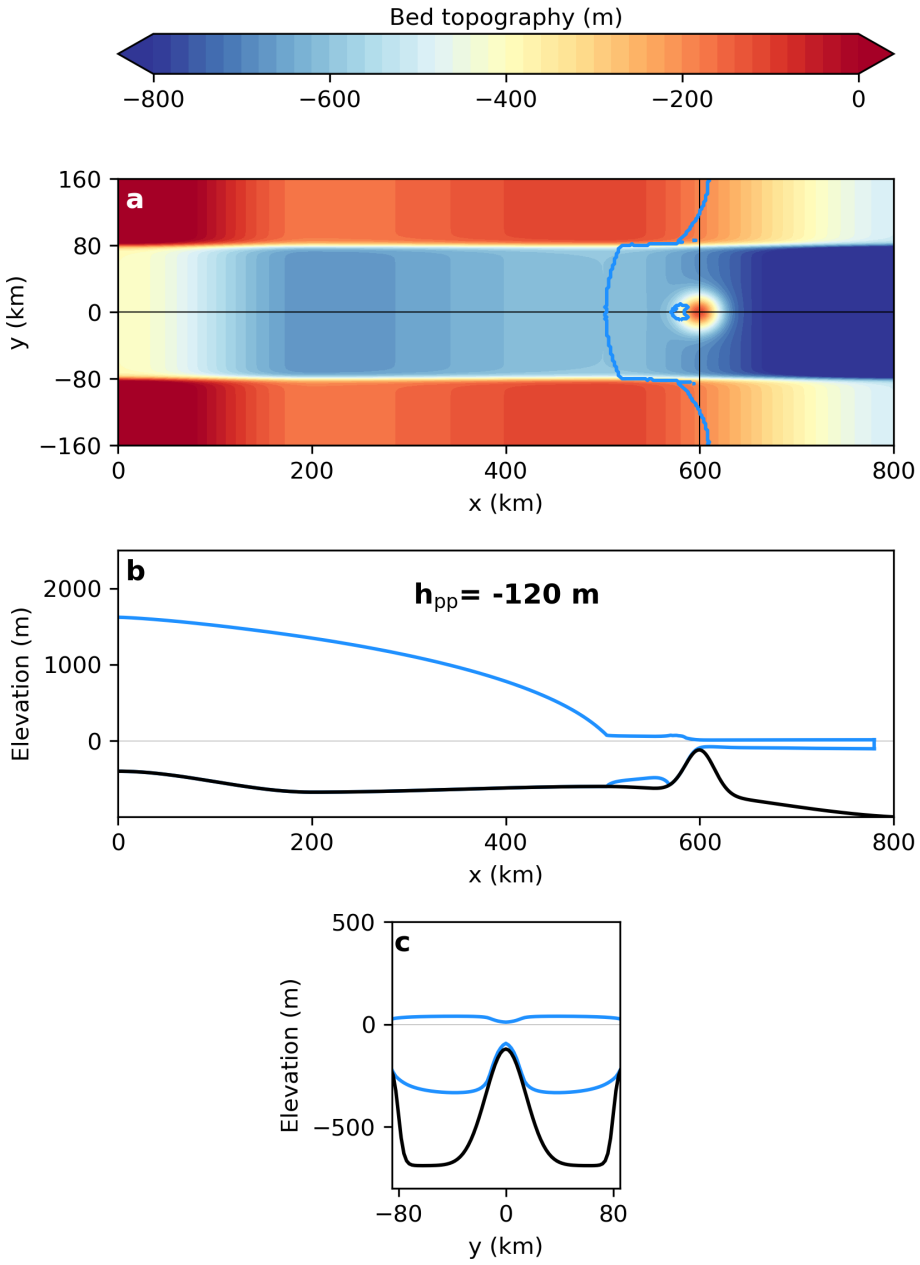
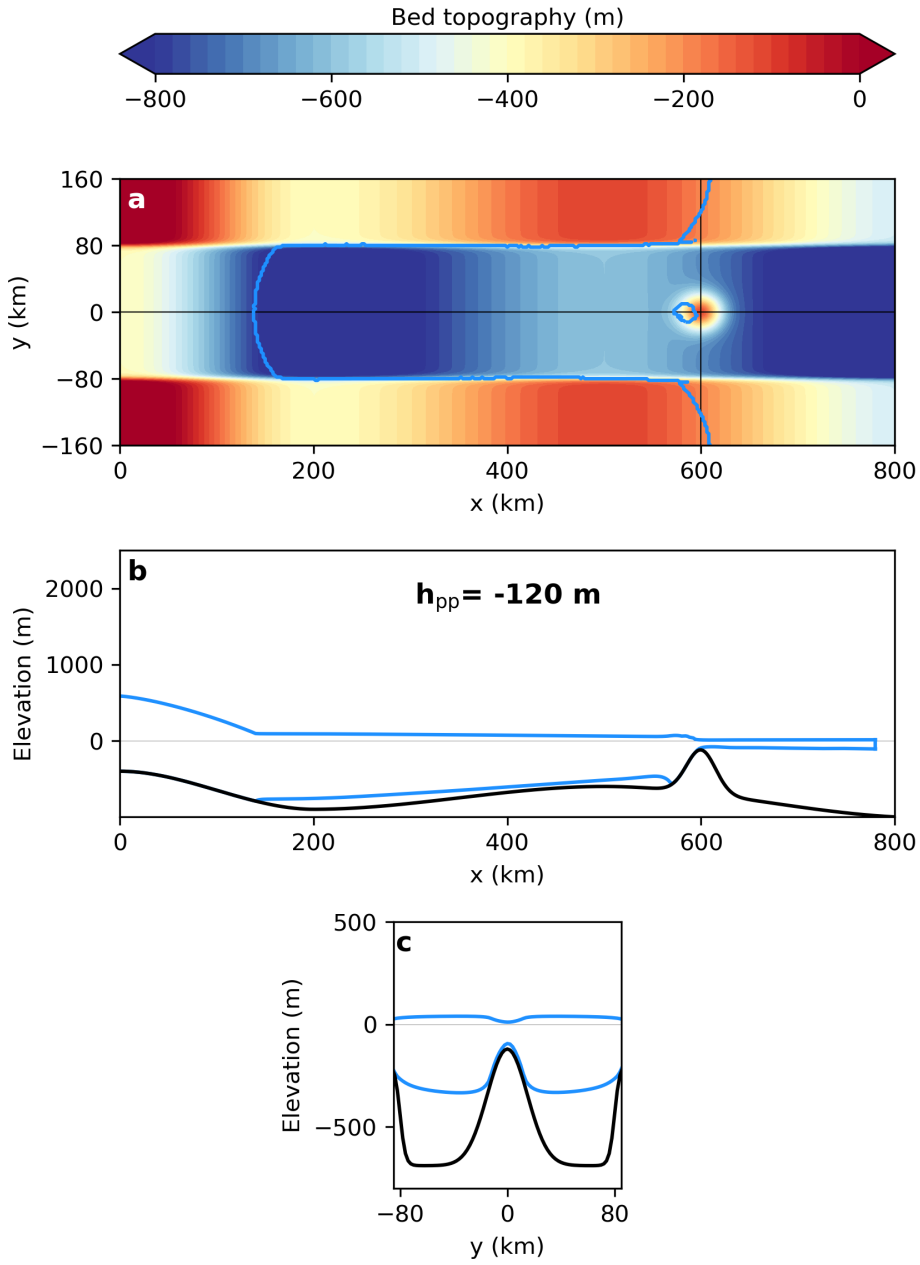


Steep slope (4·*s*)



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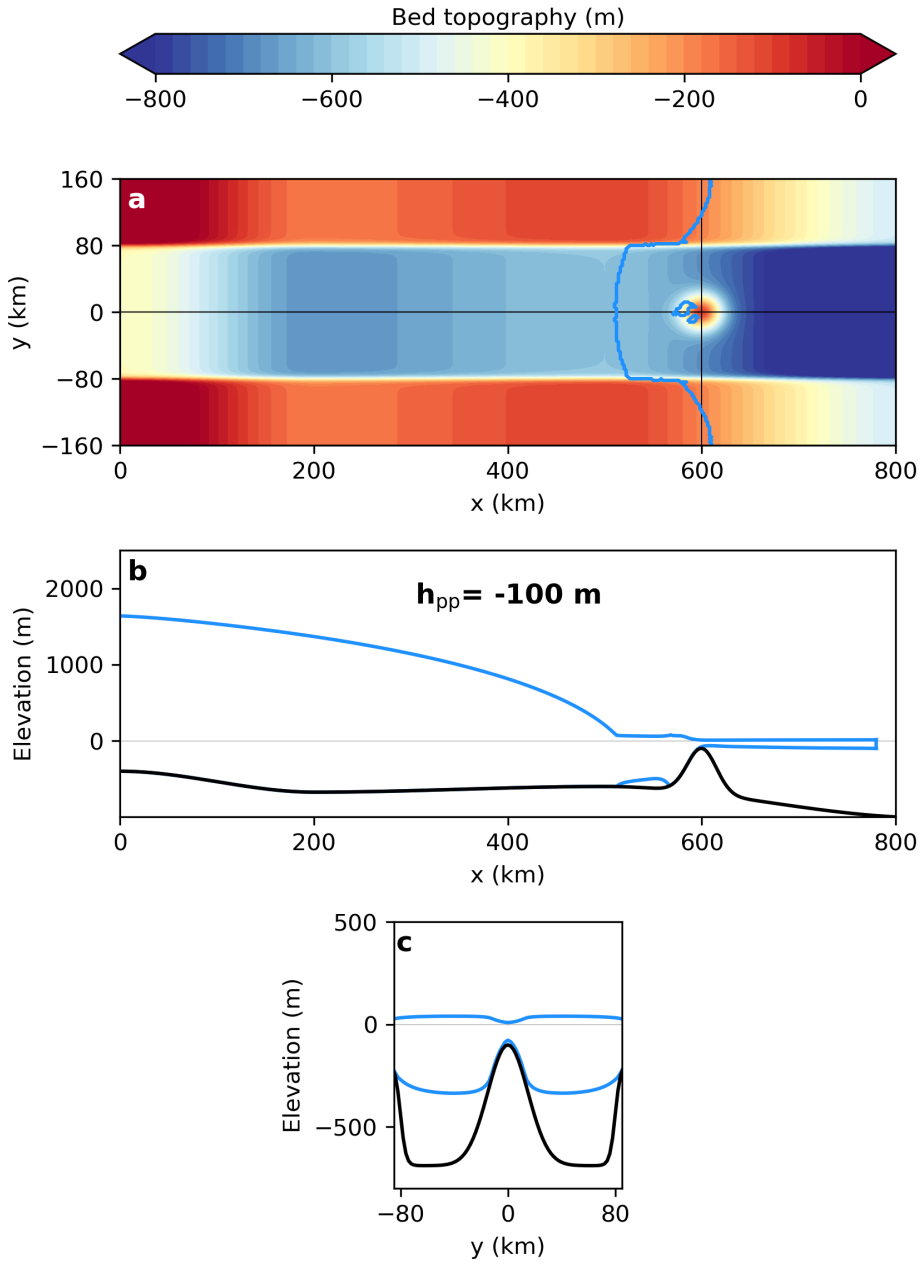
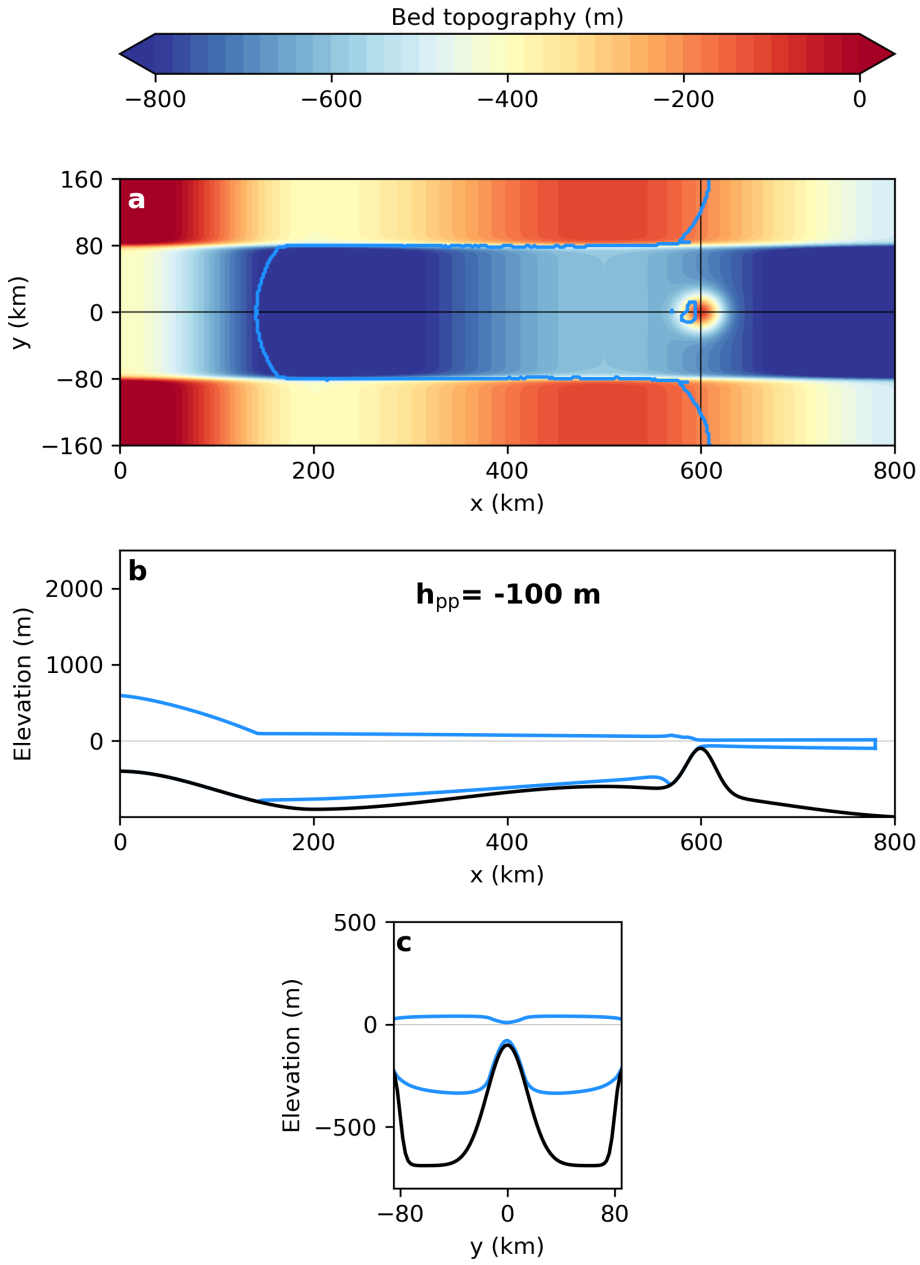


Steep slope (4·*s*)



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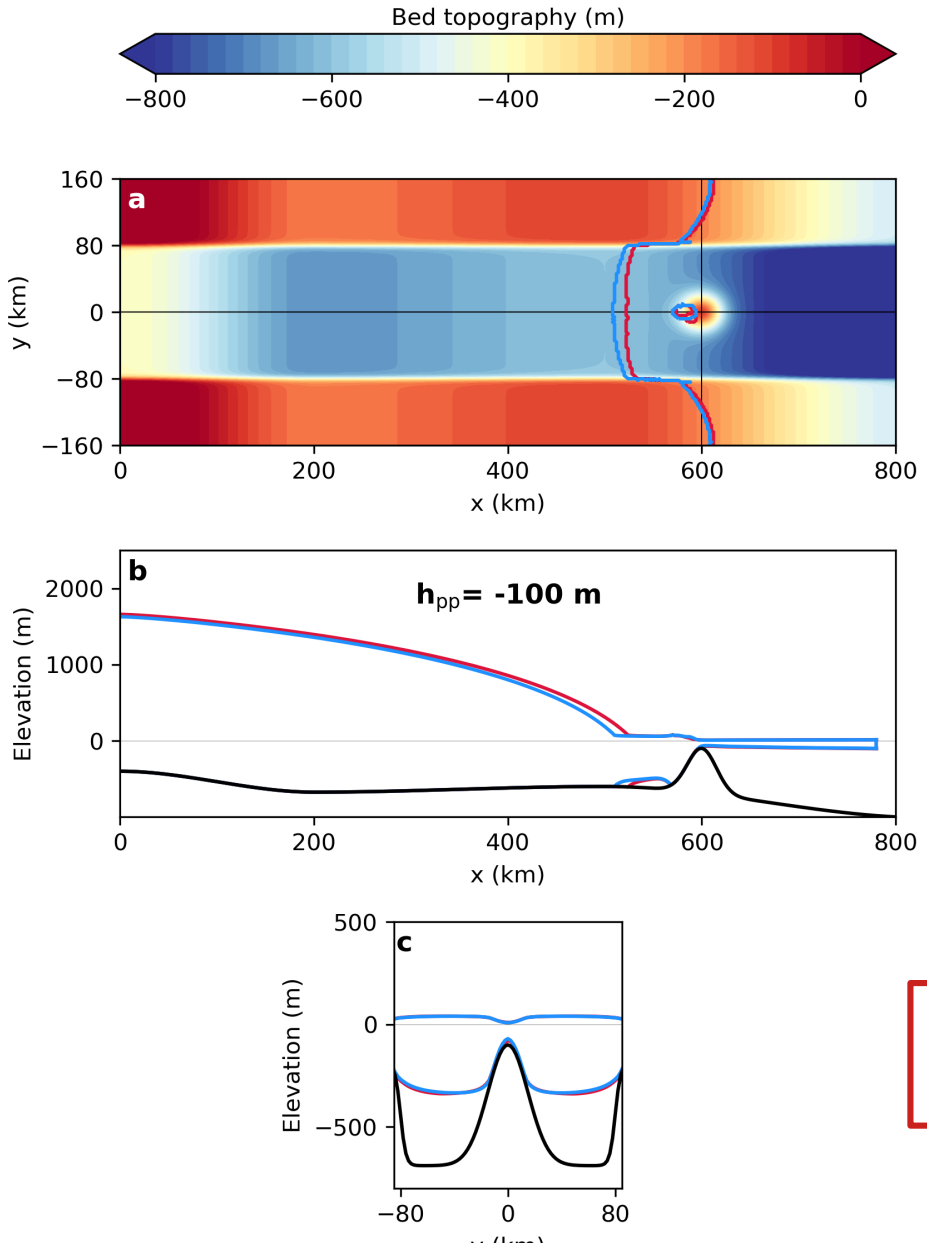

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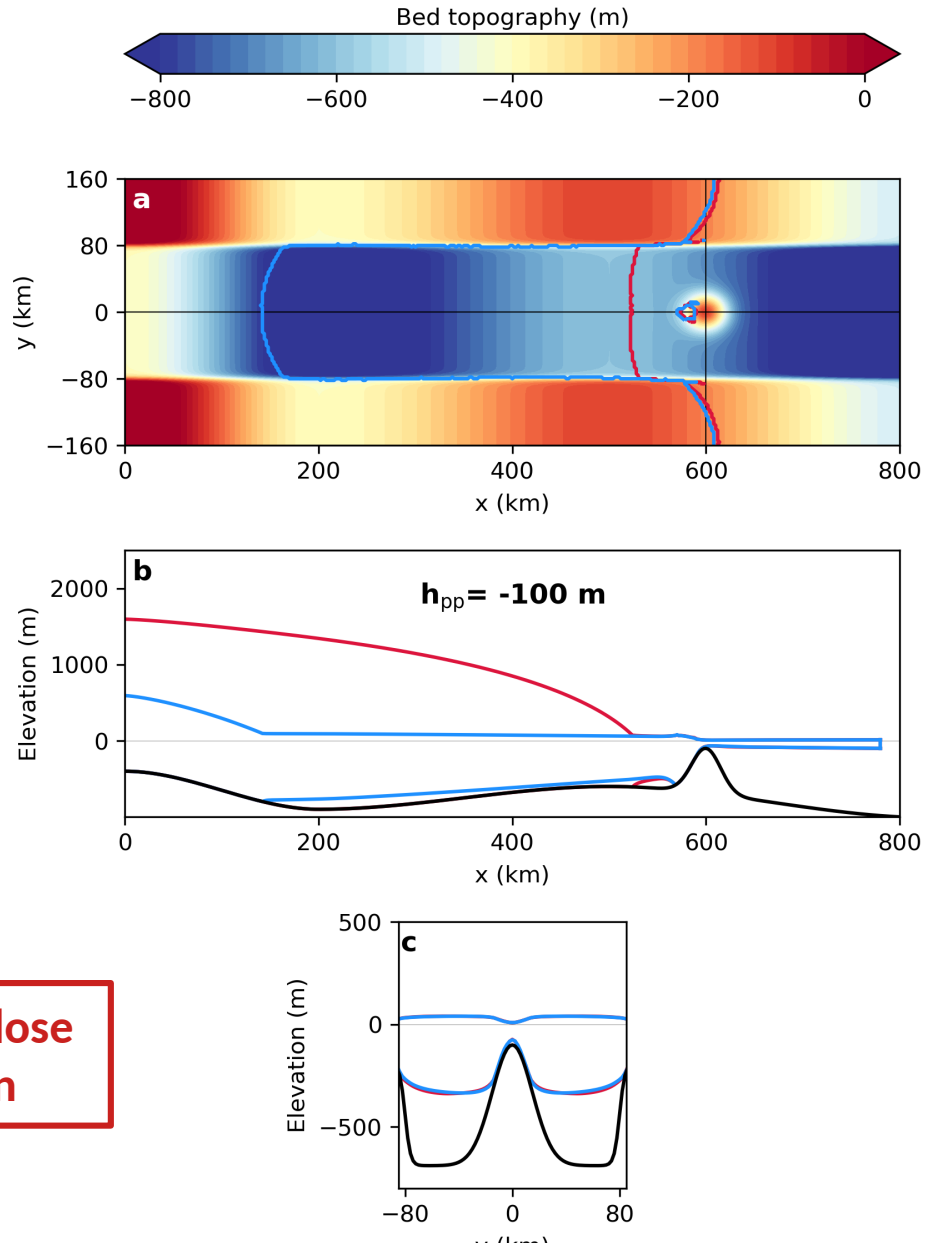
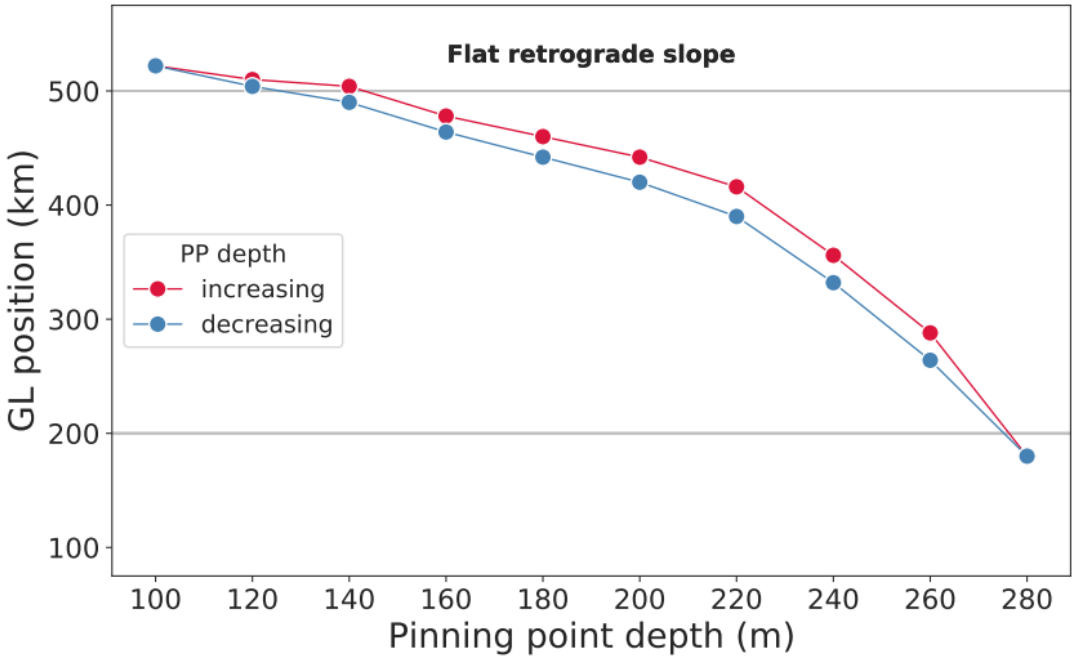


<u>Steep case:</u> glacier remains close to retreated state → locked in

Hysteresis curves

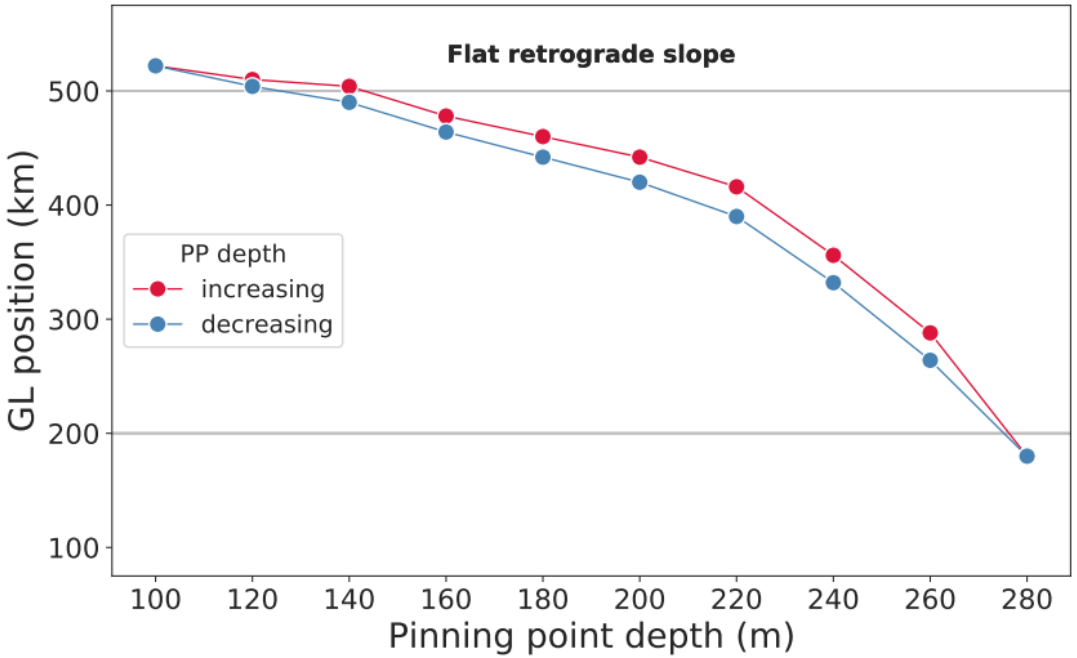
Flat slope (*s*)



Steep slope (4·*s*)

Hysteresis curves

Flat slope (*s*)



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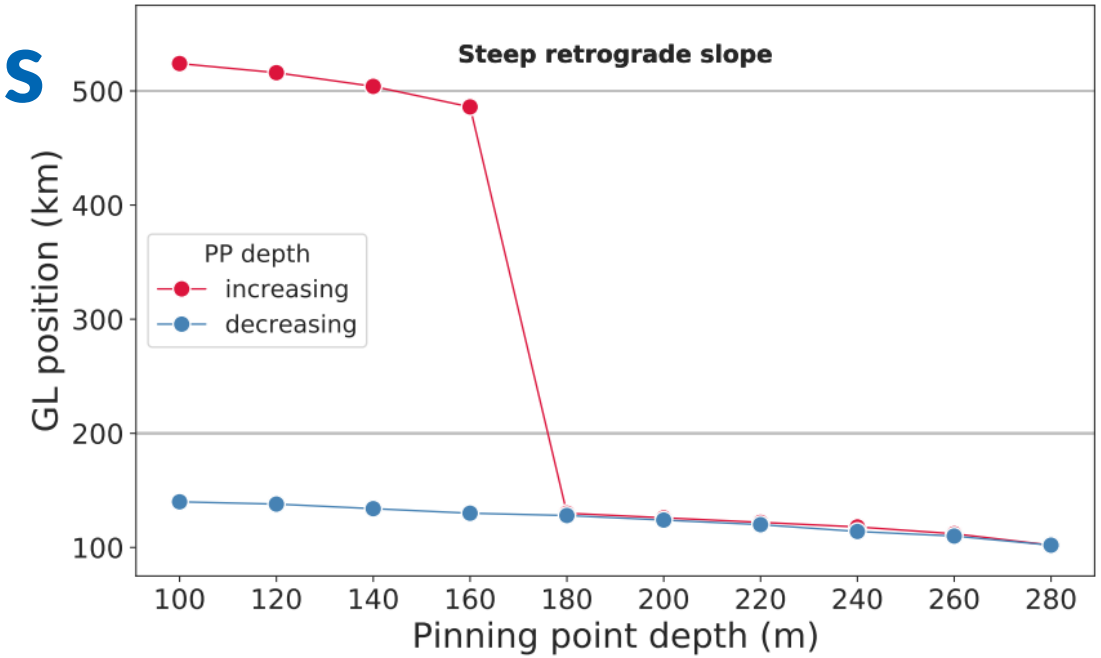

Hysteresis curves

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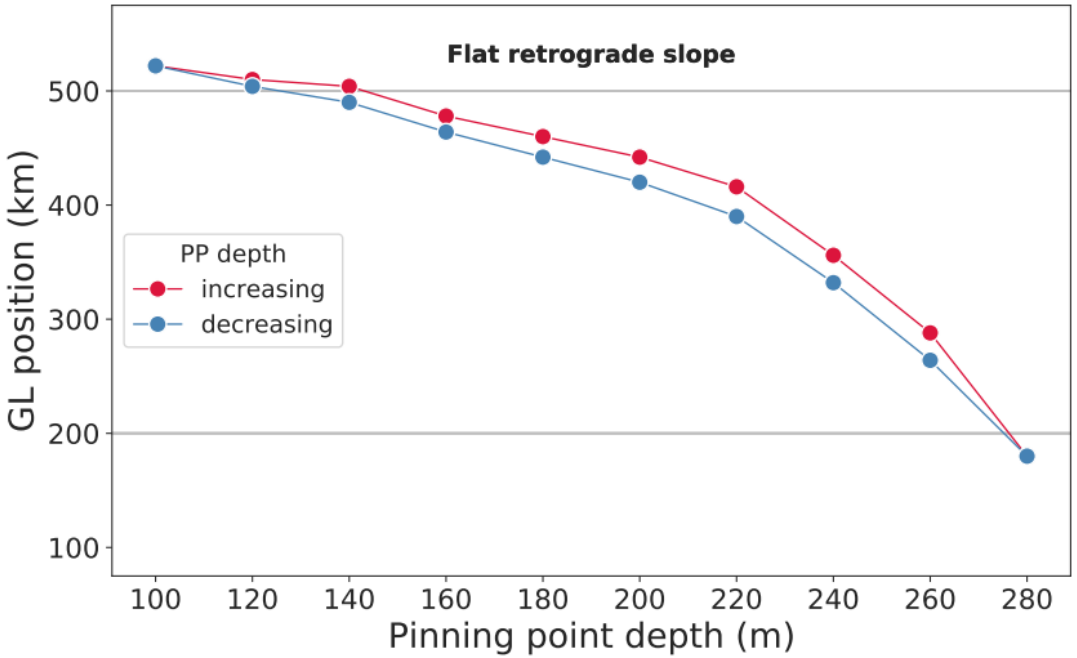

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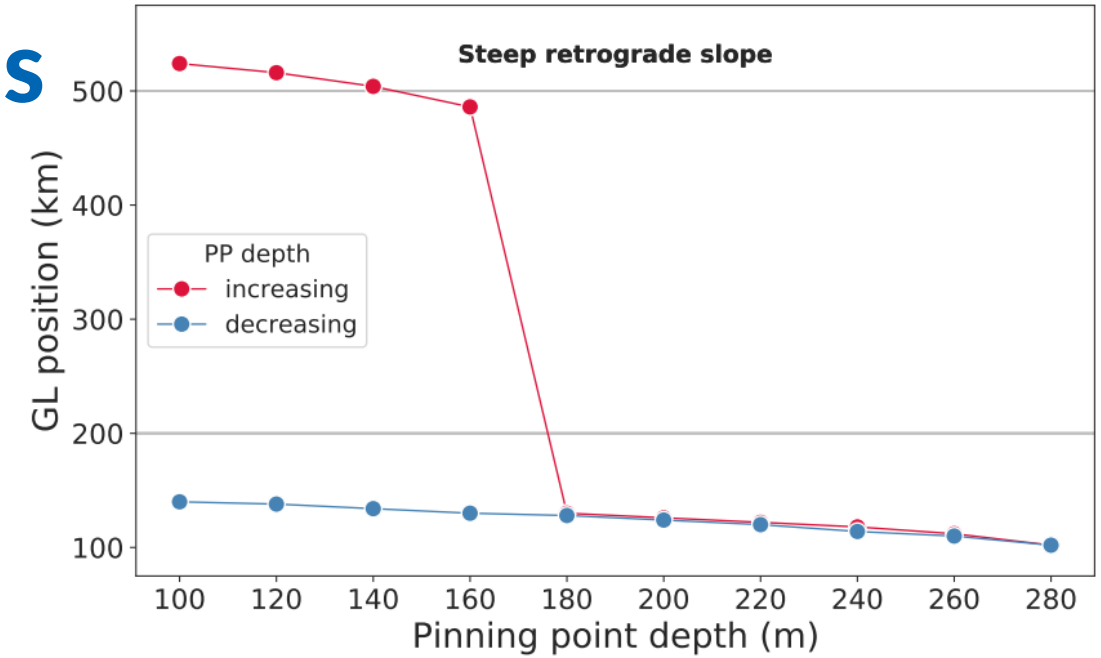
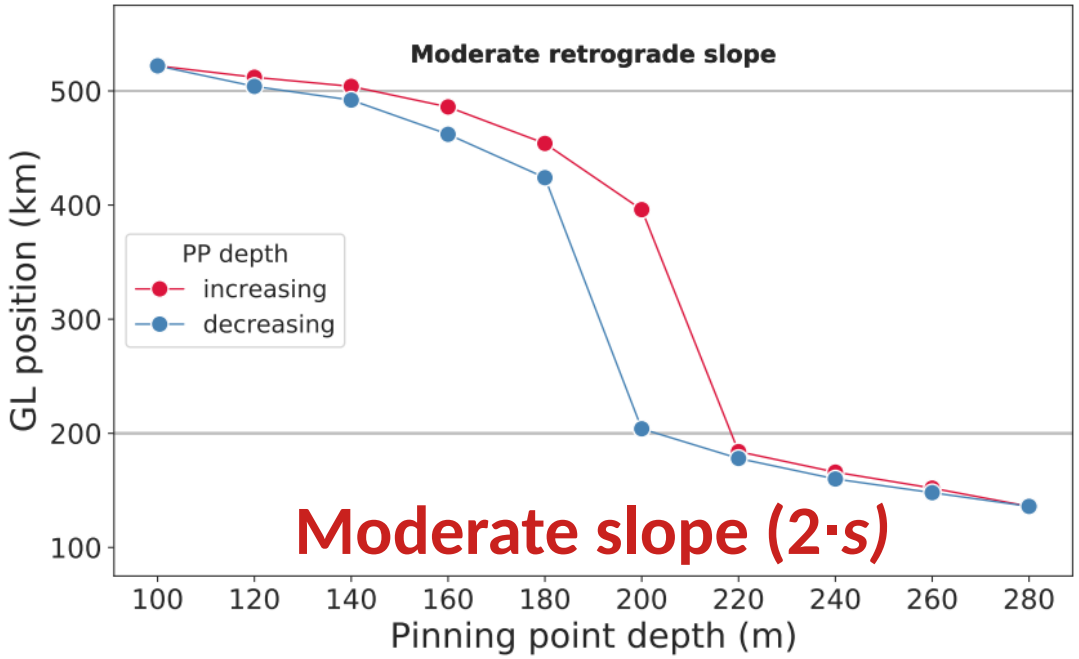


Moderate slope (2·*s*)



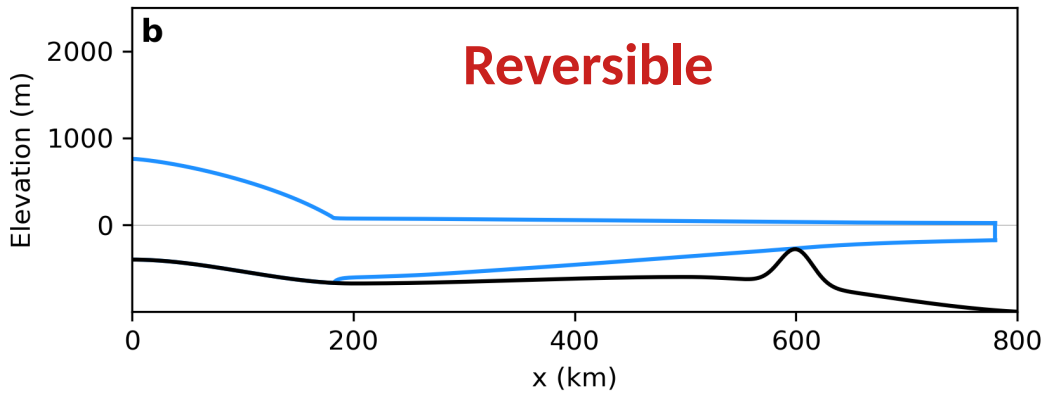
Interpretation (preliminary)

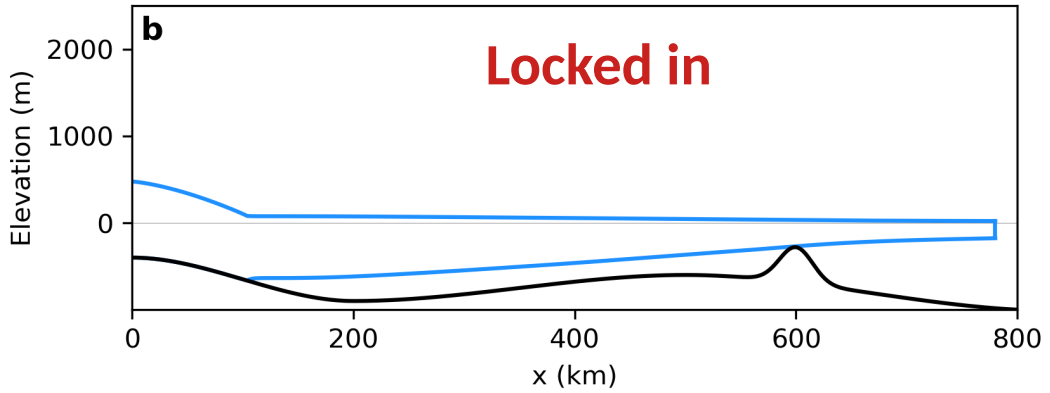
- Deeper bed depression yields retreated (unpinned) glacier that is:

  1) smaller

  AND

  2) on steeper prograde slope





Interpretation (preliminary)

- Deeper bed depression yields retreated (unpinned) glacier that is:

1) smaller

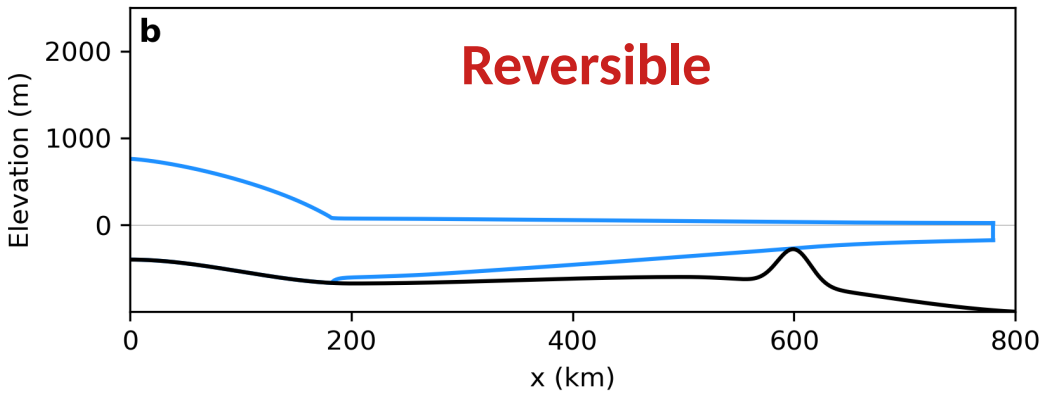
→ gains less accumulation (influx)
→ farther away from PP (buttressing source)

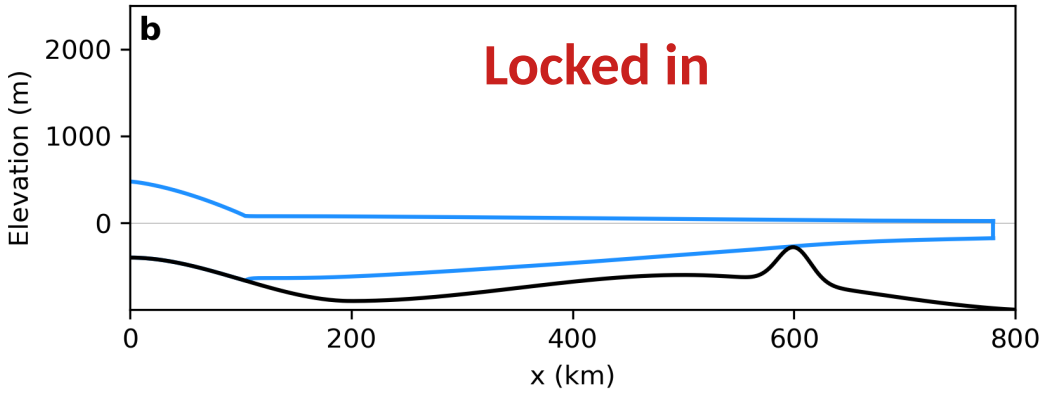
AND

2) on steeper prograde slope

→ larger increase in ice discharge when GL advances

All three factors hamper GL re-advance!





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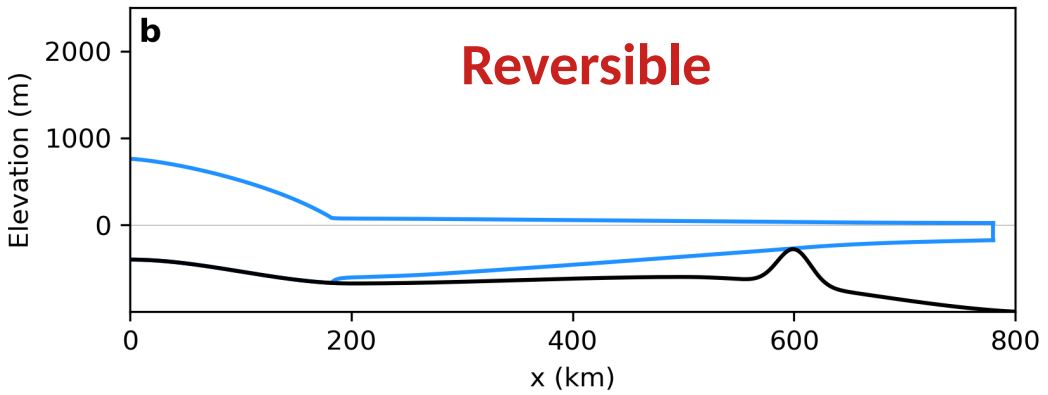
→ farther away from PP (buttressing source)

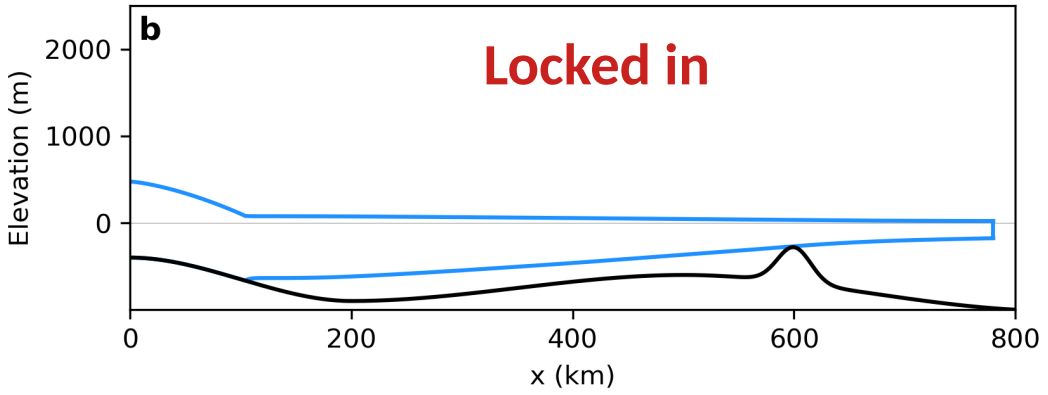
AND

2) on steeper prograde slope

→ larger increase in ice discharge when GL advances

All three factors hamper GL re-advance!

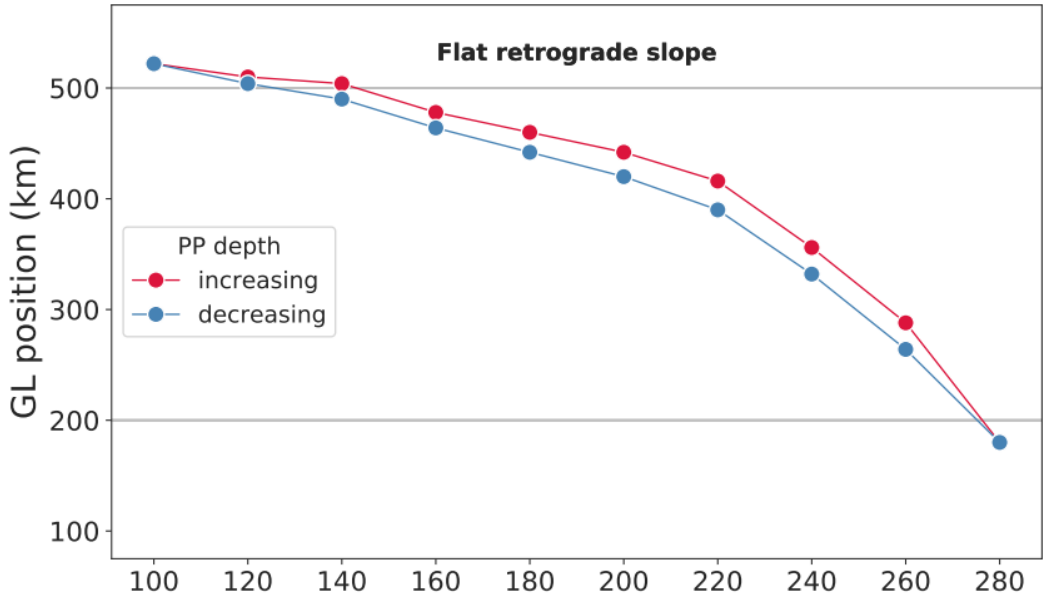


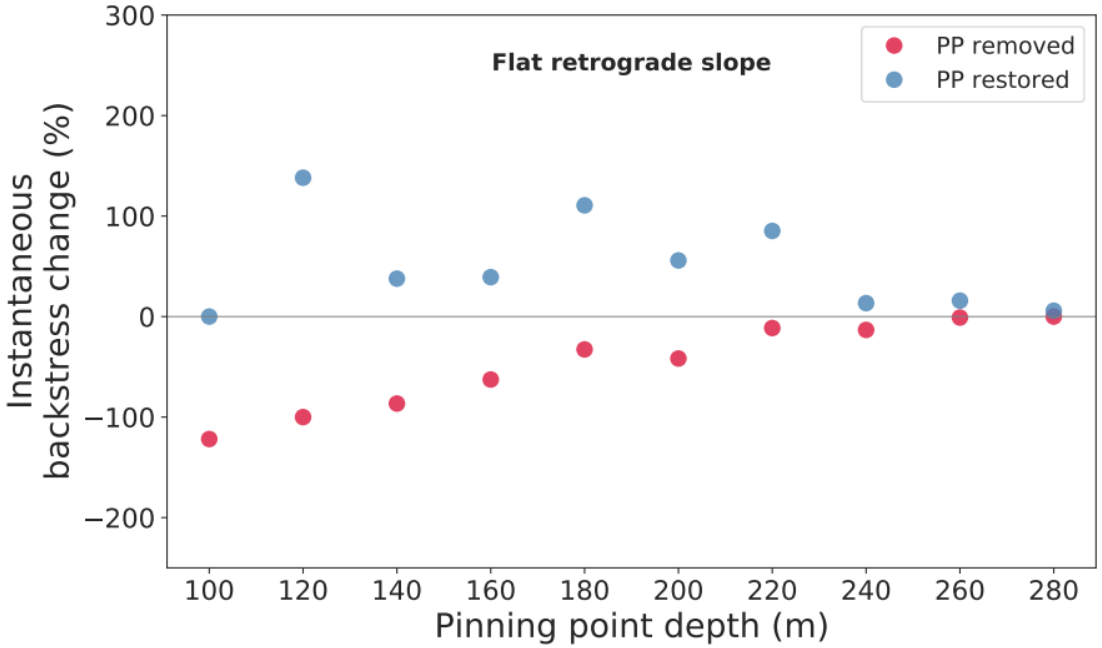


→ **Size of bed depression decisive for reversibility of glacier retreat with possibility of glacier remaining locked into collapsed state**

Buttressing change

Flat slope (*s*)





Steep slope (4·*s*)