Climatic controls on mountain glacier basal thermal regimes dictate spatial patterns of glacial erosion

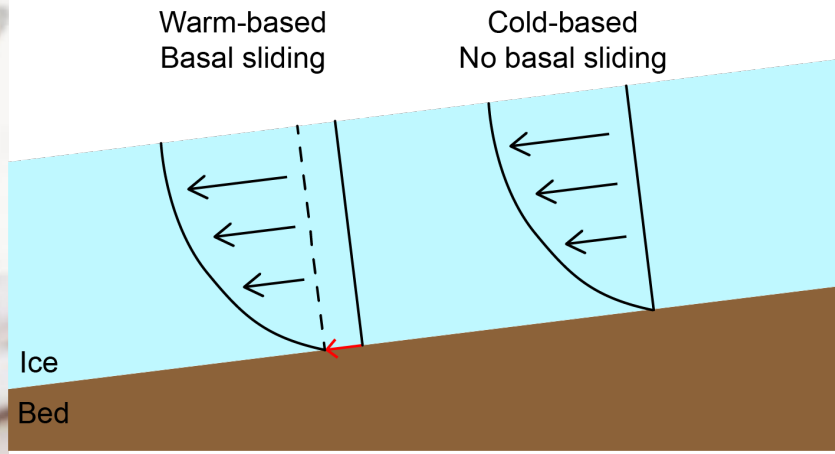
Jingtao Lai[1, 2] and Alison Anders[1]

[1]Department of Geology, University of Illinois at Urbana-Champaign
[2]Now at the GFZ German Research Centre for Geosciences

Basic ice cream dynamics

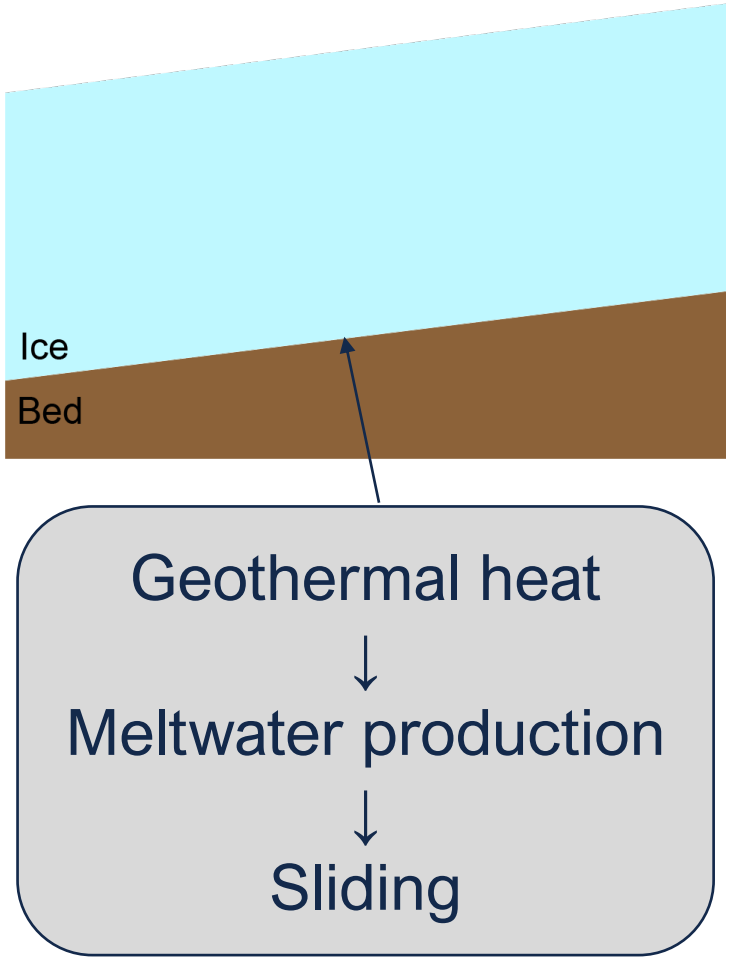


- Cold-based
  - Frozen to the bed, no sliding, no erosion
- Warm-based
  - Melting at the bed, active sliding, erosion

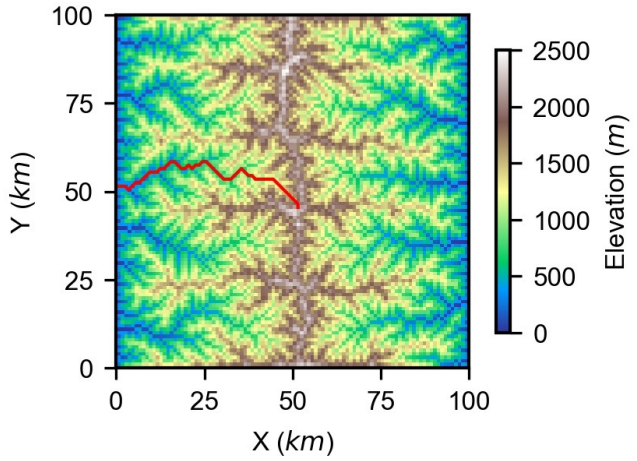


Geothermal heat can change basal thermal regimes

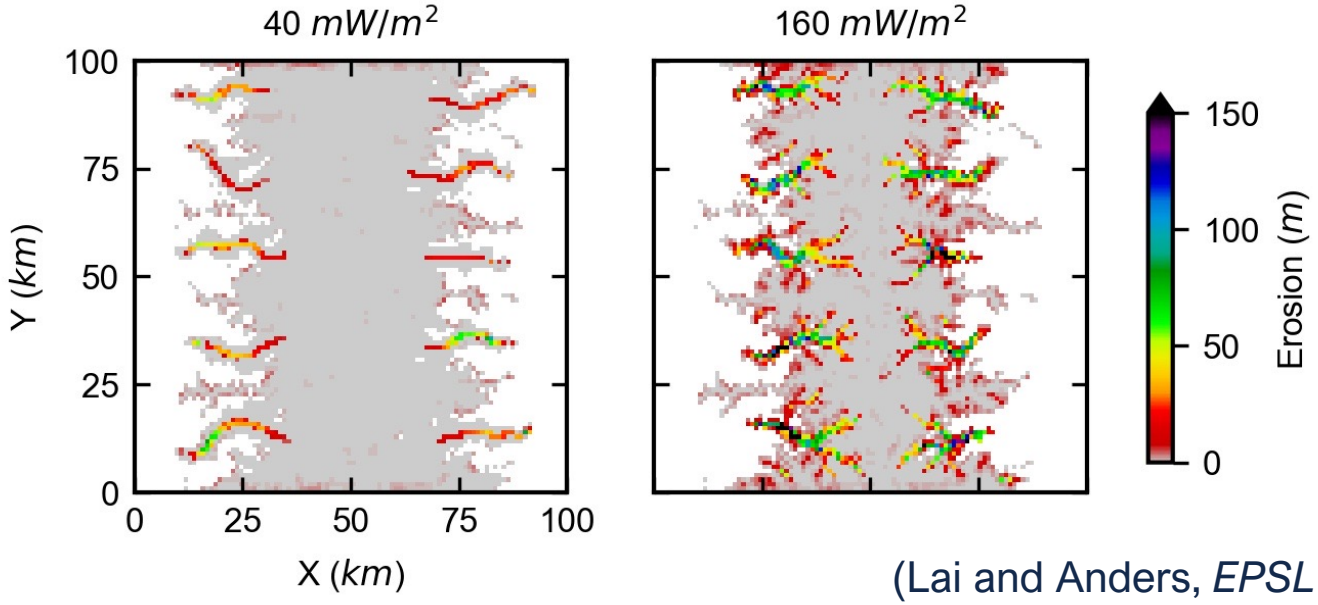


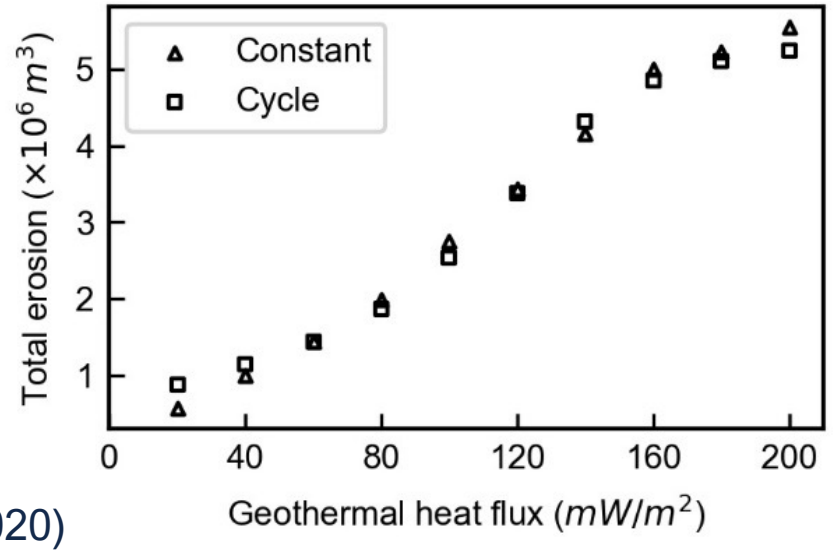


Previous work – geothermal heat and glacial erosion



- As geothermal heat flux increases –
  - larger area of significant glacial erosion
  - the rate of erosion increases
- The total amount of erosion increases as a function of geothermal heat flux

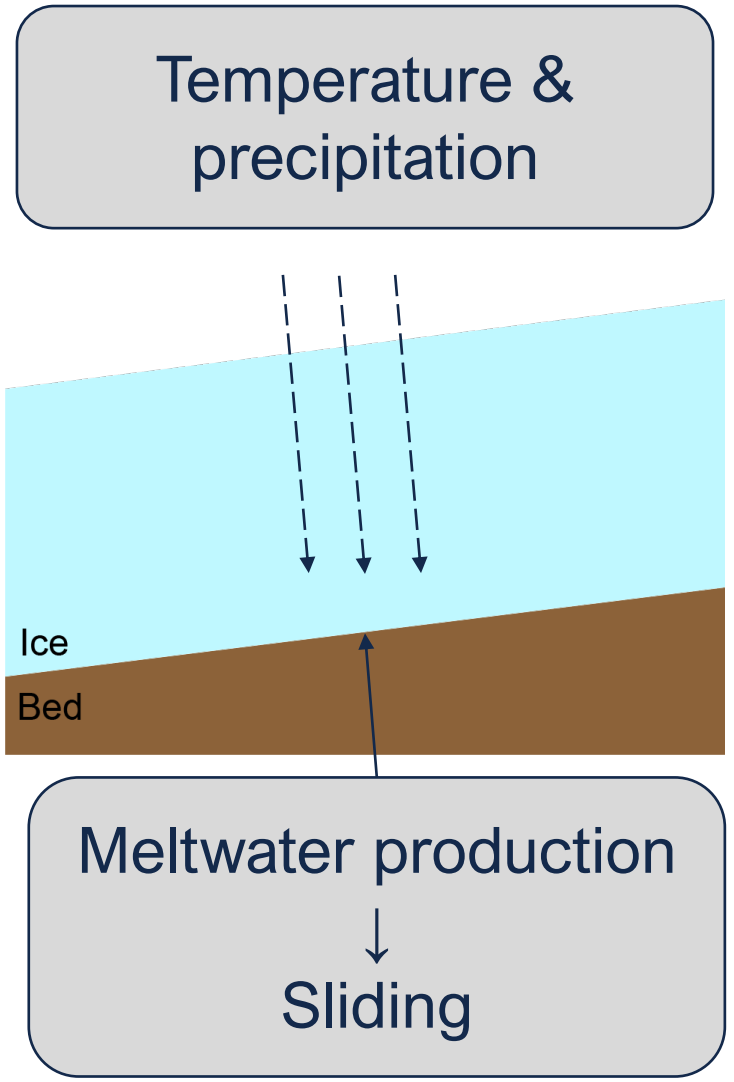




(Lai and Anders, *EPSL*, 2020)

Climate can change basal thermal regimes

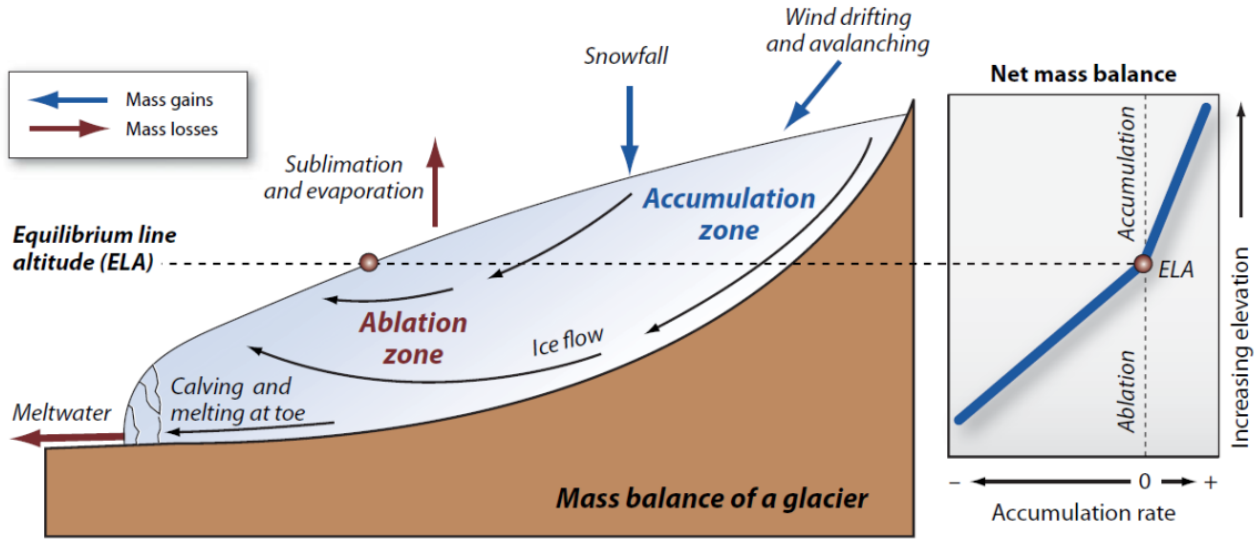




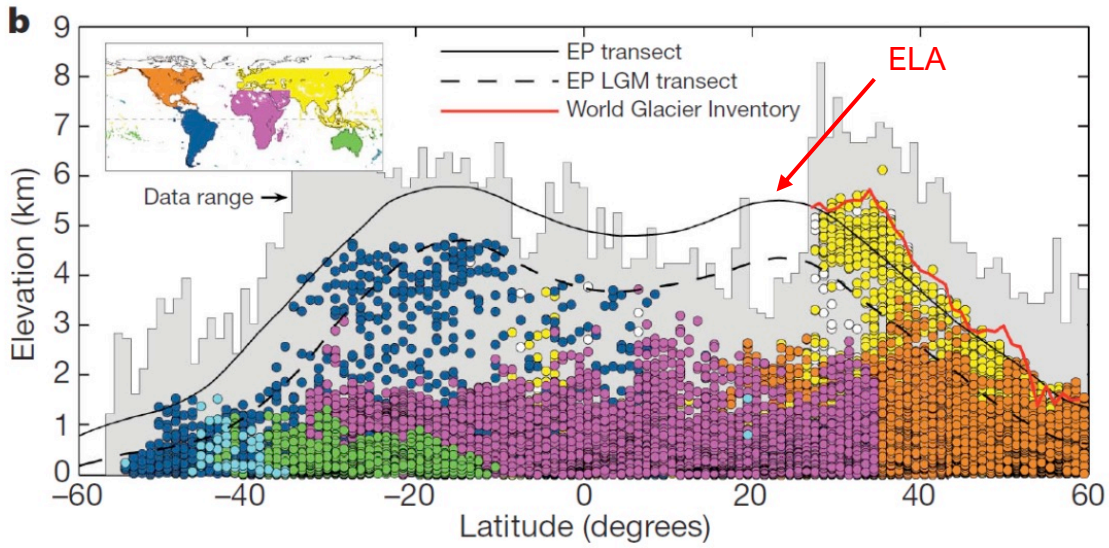
Equilibrium line altitudes (ELA)

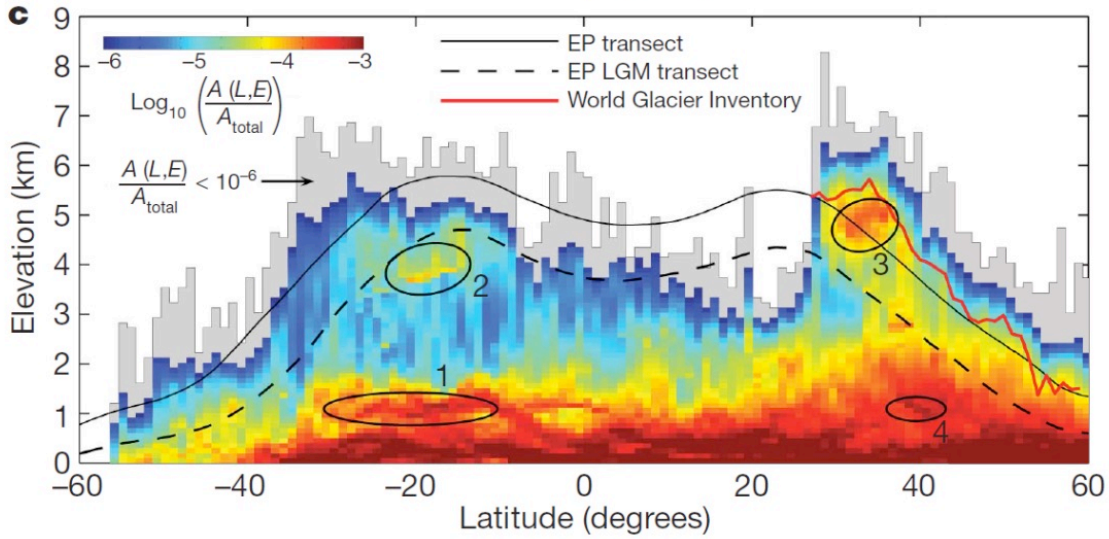
Previous thoughts –

- Glaciers focus their erosion at or above the ELA.
- Climate influences the patterns of erosion by altering the ELA.



(Key concepts in geomorphology)



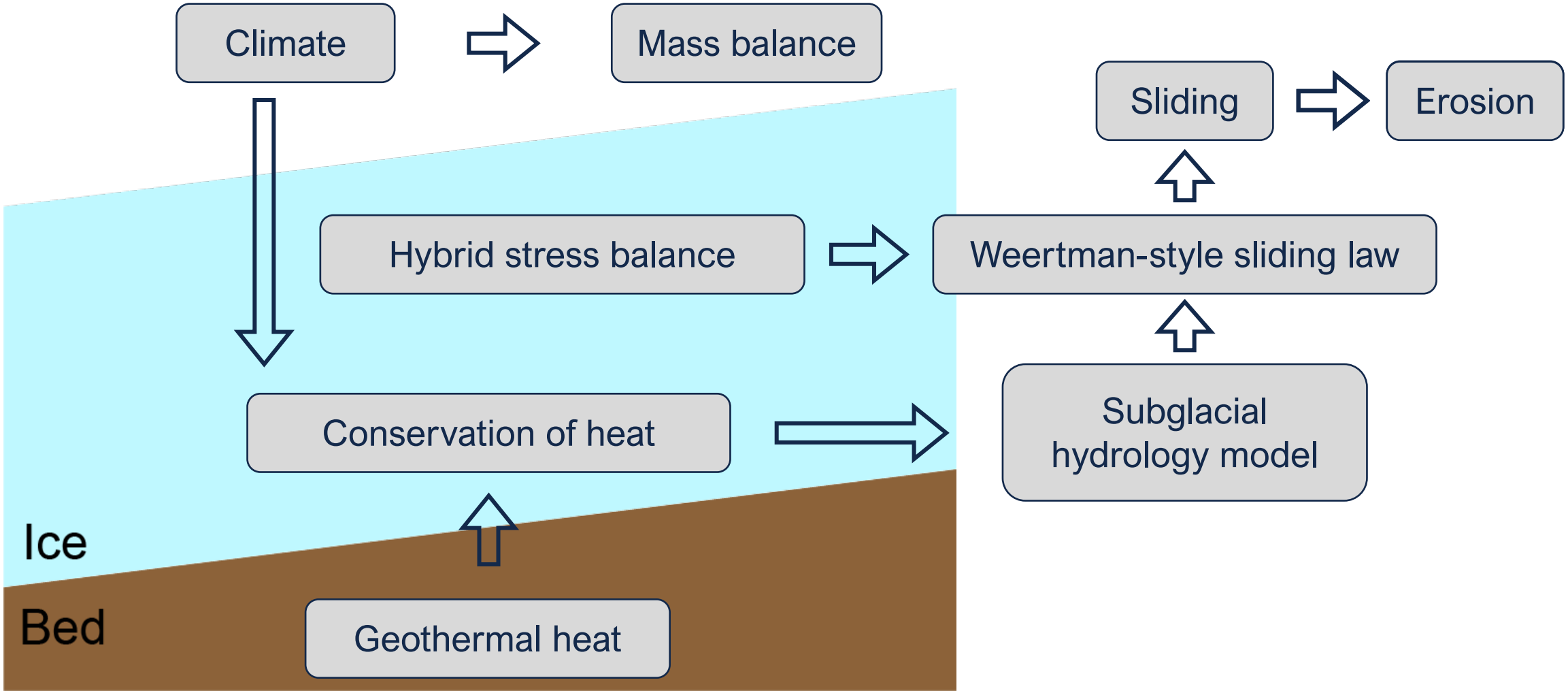


(Egholm et al., 2009)

PISM – Parallel Ice Sheet Model

PISM
Parallel Ice Sheet Model

www.pism-docs.org



Glacial erosion model

- Erosion rate is a function of sliding velocity:

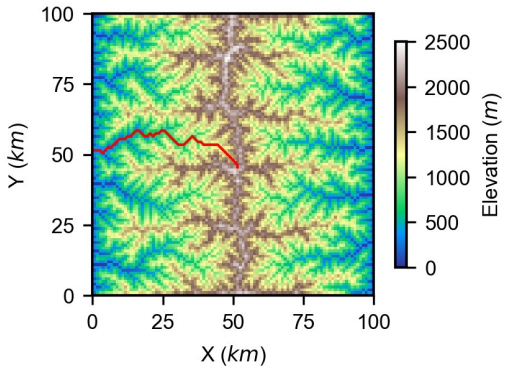
$$E_g = K_g |\boldsymbol{u}_s|^l$$

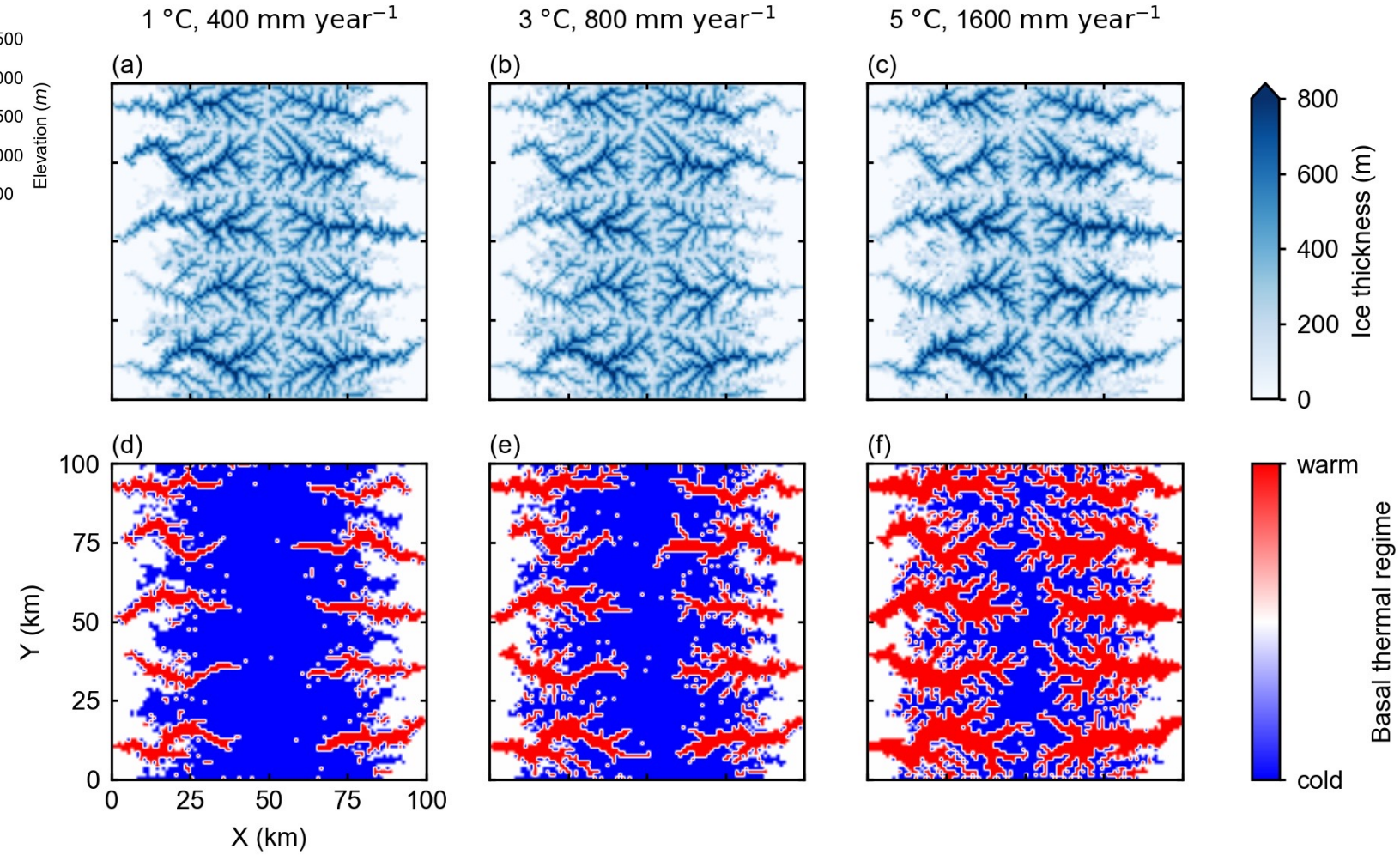
- This is a model for glacial abrasion (wearing of a bedrock surface by rock fragments transported at the glacier base), but also captures the qualitative pattern of glacial quarrying (removal of larger rock fragments along some cracks).





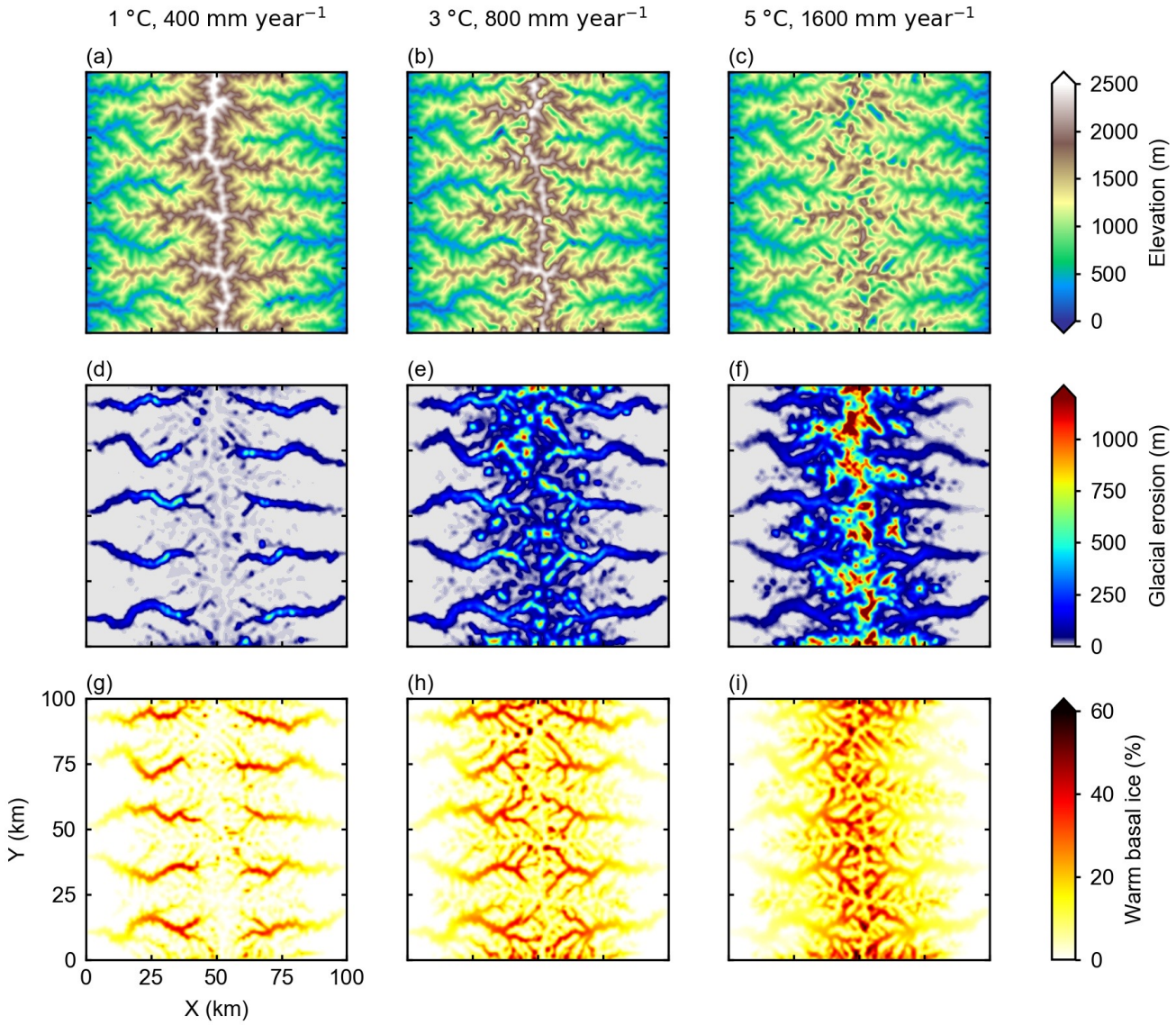
Climatic controls on basal thermal regime





- Different climates can produce glaciers with similar ELAs, but different basal thermal regimes.

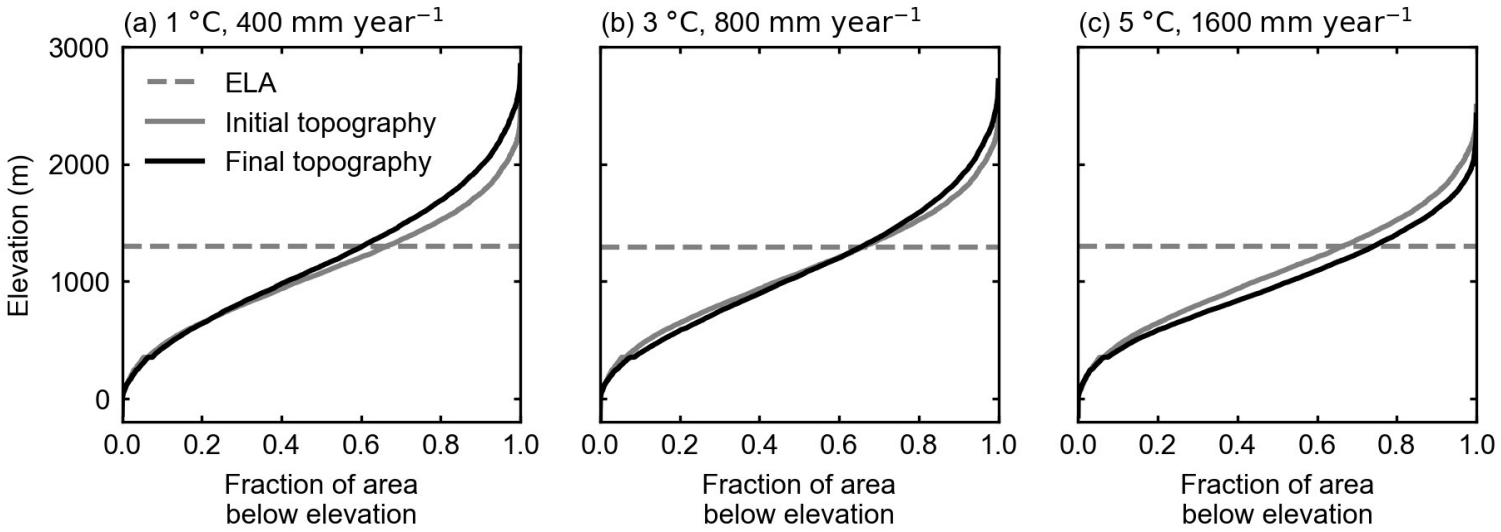
Erosion patterns follow basal thermal regime

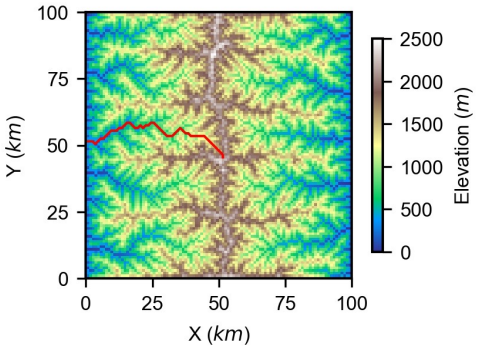


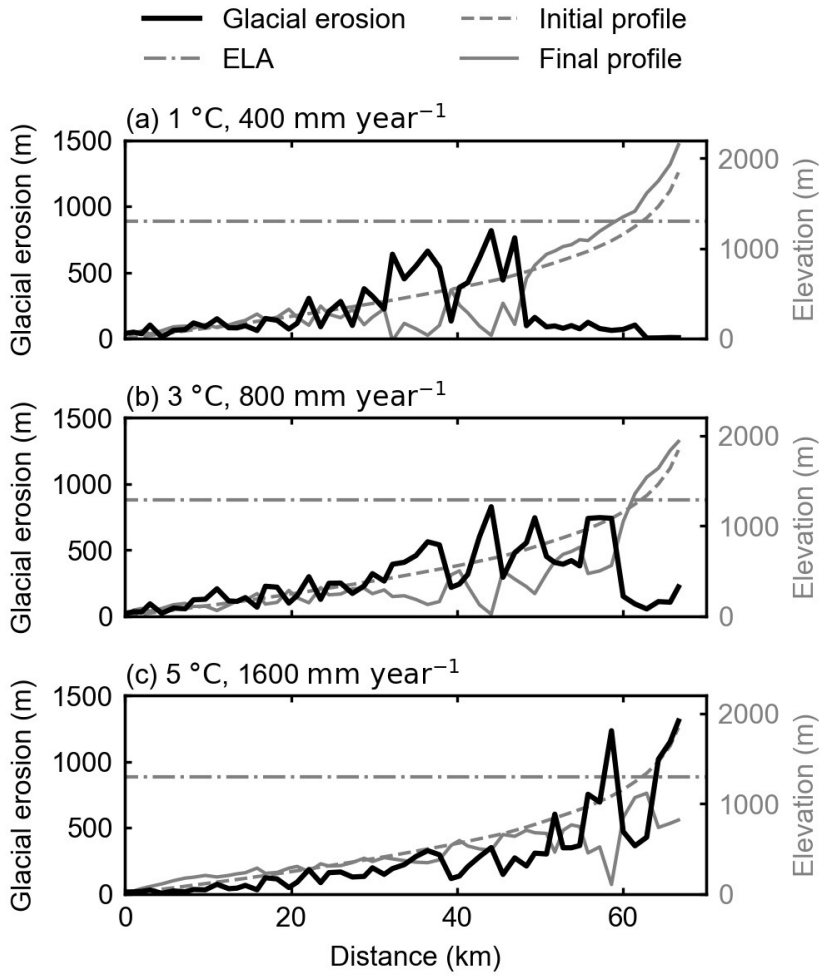
- A cold and dry climate causes limited erosion at high elevations.
- A warm and wet climate focuses erosion at high elevations.

Erosion patterns do not follow the ELA

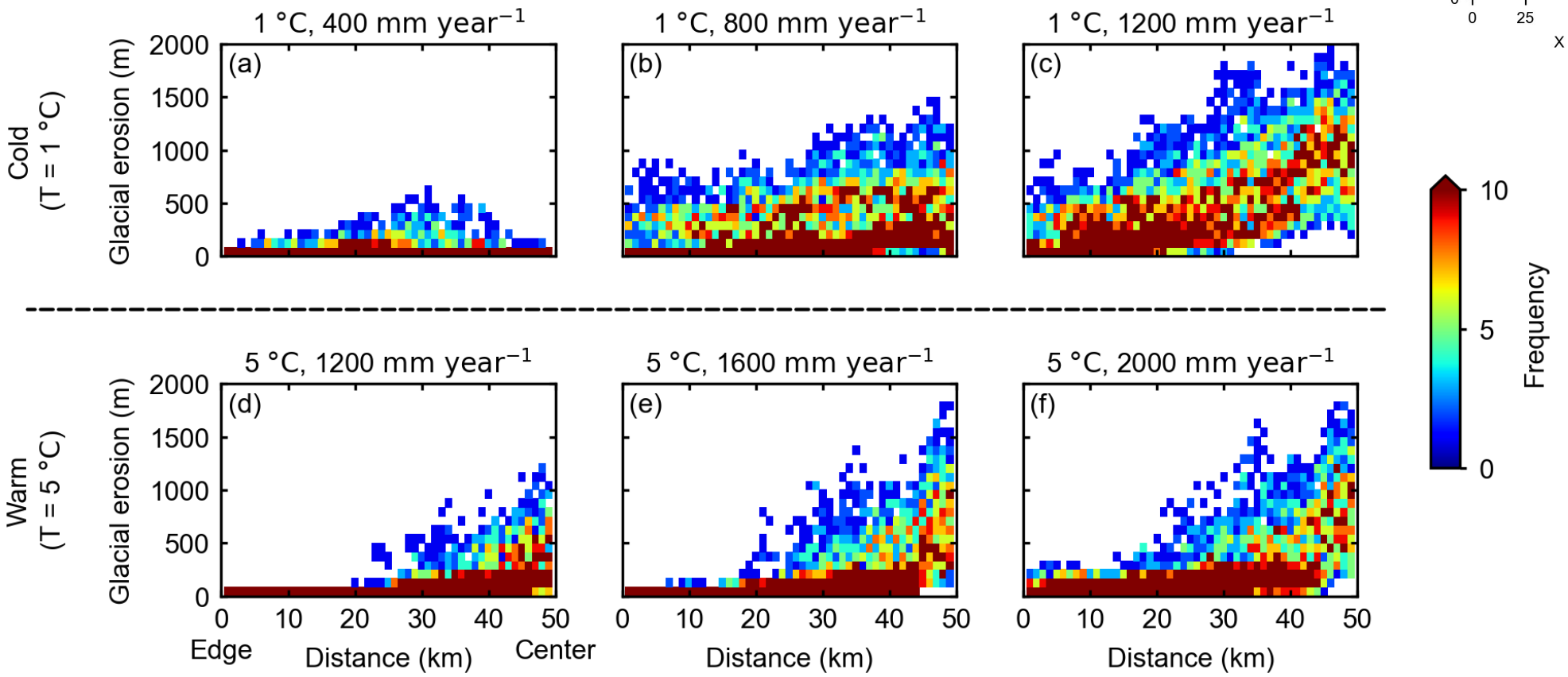
- Same ELAs, but different glacial erosion patterns.

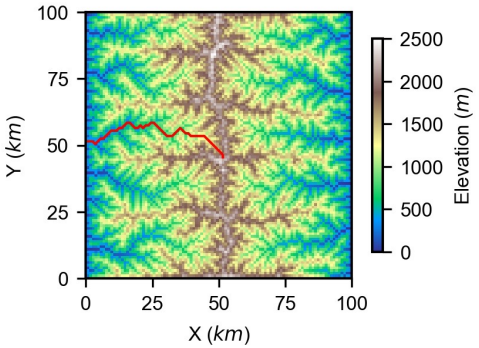






Influence of precipitation



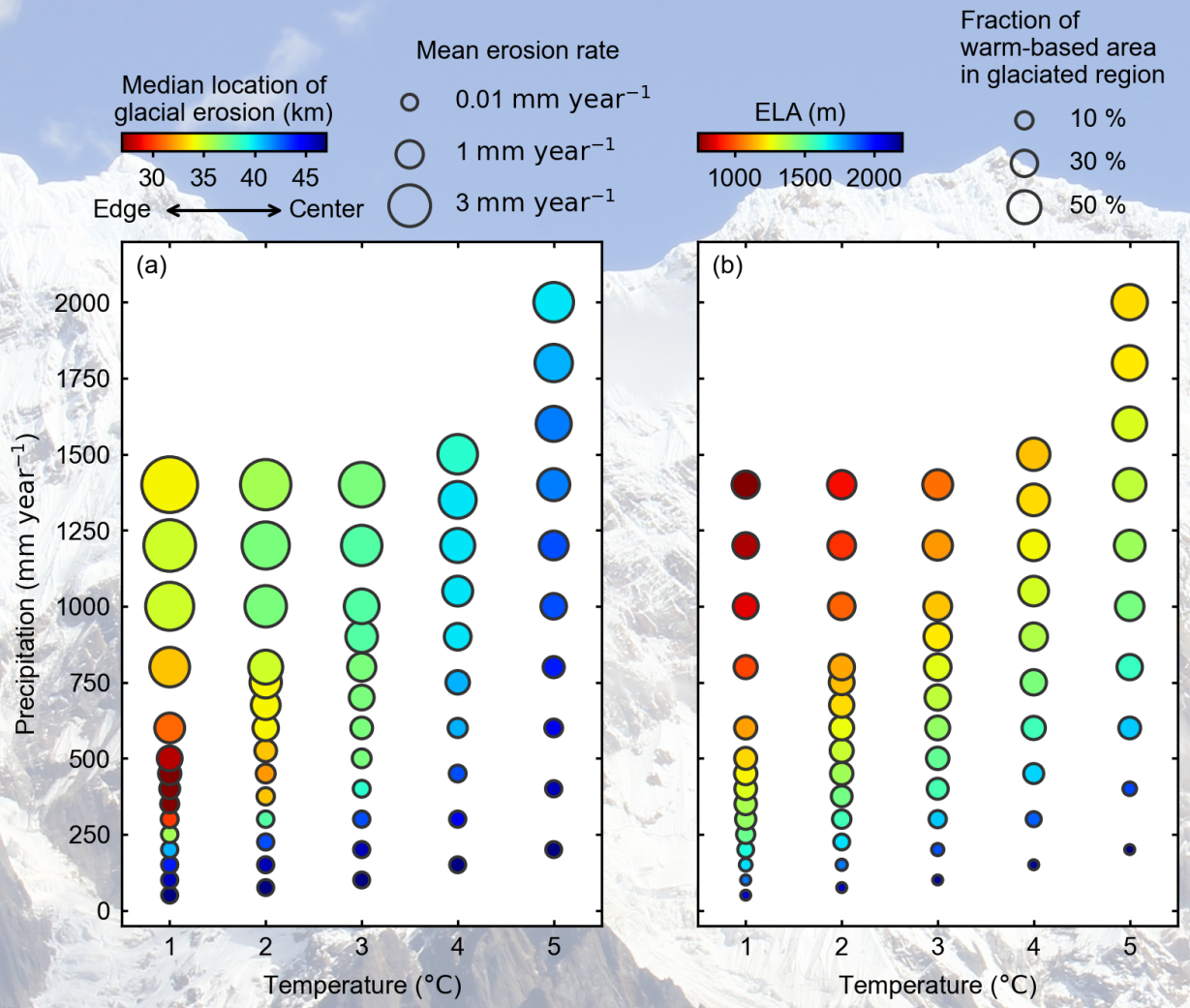


- In cold climates, increasing precipitation causes warm-based conditions at high elevations.

Take-away

- Cold temperatures tend to create cold-based areas at high elevations, leading to limited glacial erosion.
- High precipitation rates extend warm-based areas by increasing ice thickness, resulting in large areas with significant erosion.
- There is no direct correlation between the equilibrium line altitudes (ELAs) and the spatial patterns of glacial erosion.

Climatic controls on mountain glacier basal thermal regimes dictate spatial patterns of glacial erosion



Thank you!

For more information, check out our preprint on Esurf (esurf-2021-26), or contact me!

Jingtao Lai
lai@gfz-potsdam.de

