Proglacial Lakes Elevate Glacier Surface Velocities in the Himalayan Region

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The Mountain Cryosphere Research Group

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A study on the influence of proglacial lakes on Himalayan glacier dynamics, using remote sensing techniques and a synthetic numerical glacier model.

Currently under review for The Cryosphere:

https://doi.org/10.5194/tc-2021-90

or

Introduction

- Himalayan glaciers provide an important baseline supply of meltwater for downstream areas.

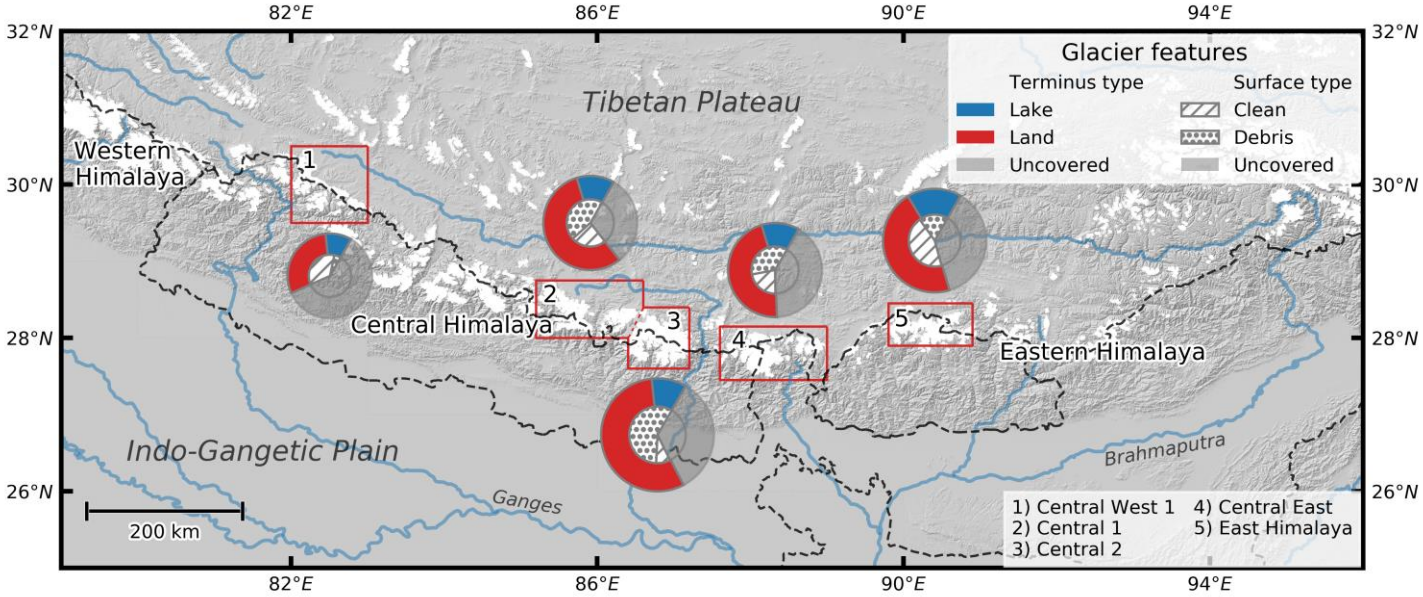
- The development of proglacial lakes has been linked with enhanced glacier mass loss in the Himalayan region.

- Objective: Investigate the attribution of lake-driven changes in the velocity field to dynamic thinning.

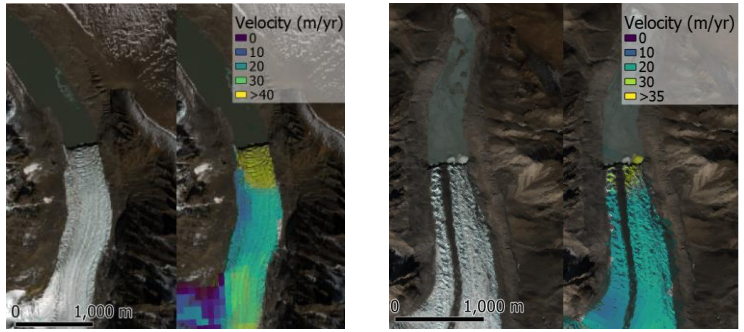
Where lakes formed, glaciers retreated significantly: Lake Garlung Co, Central Himalaya. Photo: J Pronk

Methods

- All glaciers > 3 km^2
- 2017 – 2019 Sentinel-2 imagery (10 m pixel resolution).
- Images matched in the frequency domain.
- End product: 80 m resolution median displacement field.



Map showing the regional subdivisions (red rectangles) with the associated glacier characteristics, including terminus type and surface cover as a fraction of the total sub-regional glacierised area. The uncovered fraction represents the glacierised area from glaciers smaller than 3 km^2 .

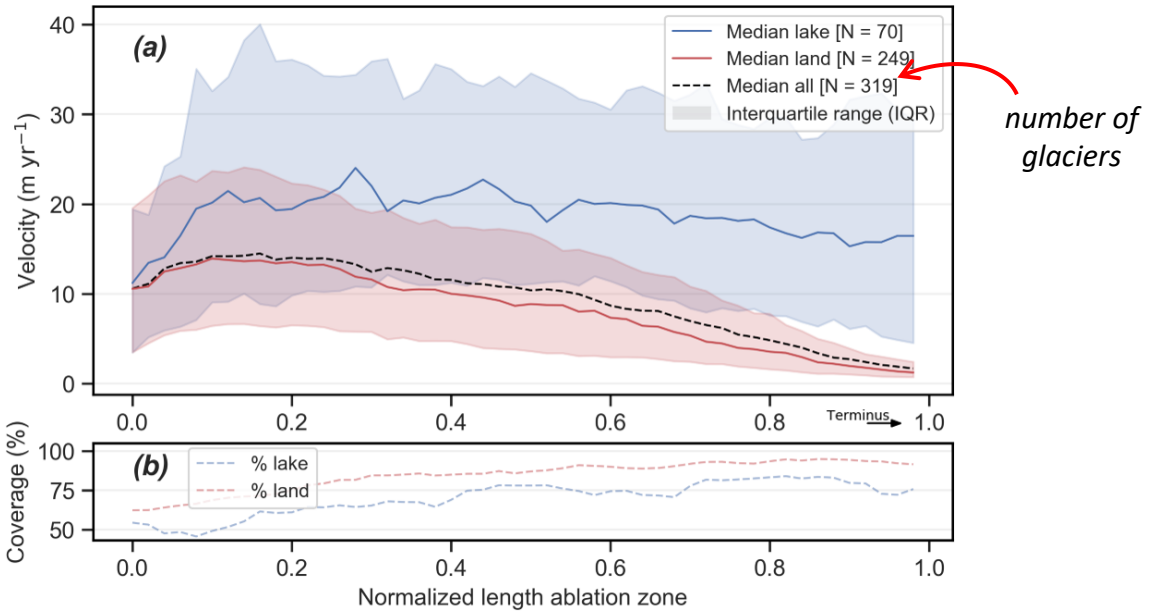


Visual of the 80 m resolution velocity field. Velocity data and RGB images are retrieved from Sentinel-2

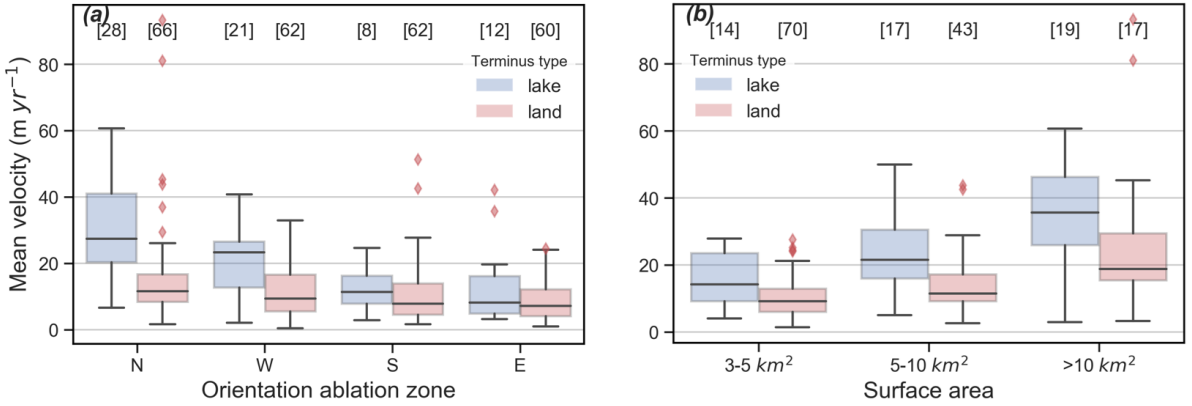
Results

Lake-terminating glacier surface velocities…

- …double those of land-term. glaciers (18.8 vs 8.24 m yr^{-1}) (upper figure).
- …show much more heterogeneity at the terminus (upper figure).
- …are higher regardless glacier size or orientation (lower figure).



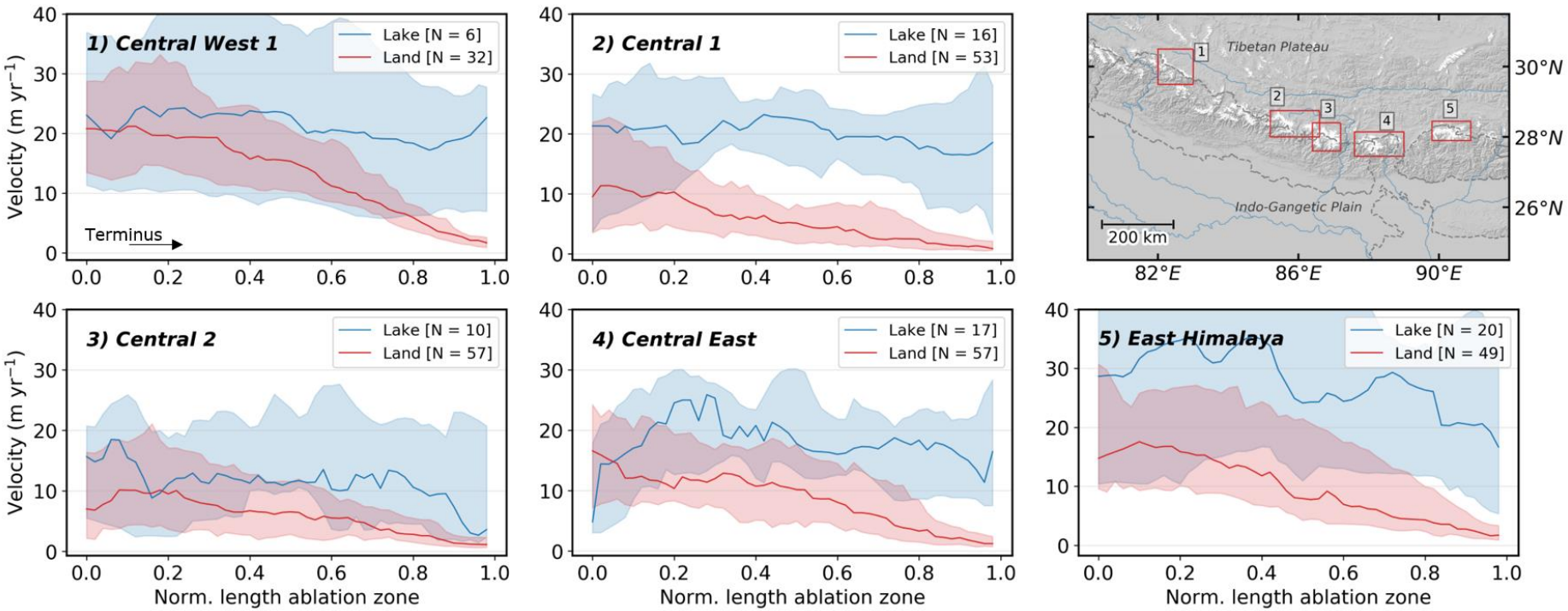
Median centre flow line surface velocity (m yr-1) (a) and coverage (%) of the velocity estimates (b). (a) The spread among the glacier population is represented by the IQR. (b) The coverage is defined by the percentage of valid velocity estimates (CI_{95} < 5 m yr^{-1}) at a given position along the centre flowline.



Boxplot showing the mean velocity contrast between lake-terminating and land-terminating glaciers depending on the orientation of the ablation zone (a) and surface area (b).

Results

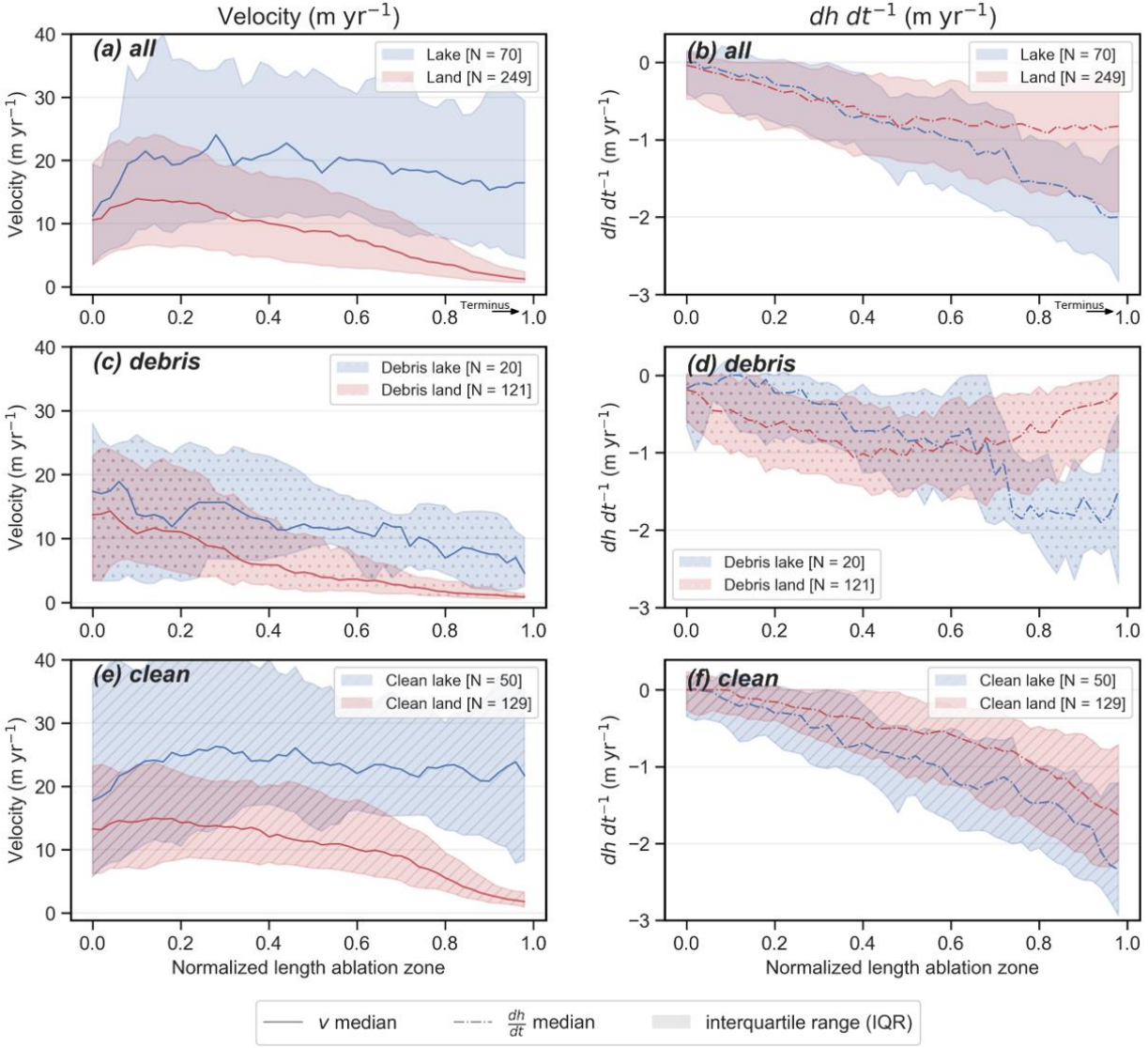
- Lake-terminating glacier surface velocities are higher for all regions (upper figure).



Regional velocity: **Subregional glacier median centre flow line velocity estimates and their location along the CE Himalaya (red rectangles).**

Results

- Differences in lake-land contrast between regions partly due to surface cover.
- Link between contrast in velocity and elevation change -> strong indication for dynamic thinning.



Velocity and elevation change by surface type: Glacier median centre flow line velocity (m yr-1) (a, c, e) and surface elevation change (dh dt-1) estimates (after King et al. (2019)) (b, d, e) for lake-terminating land-terminating glaciers. A further subdivision is made between debris-covered (c, d) and clean-ice glaciers (e, f).

Glacier modelling

The Model:

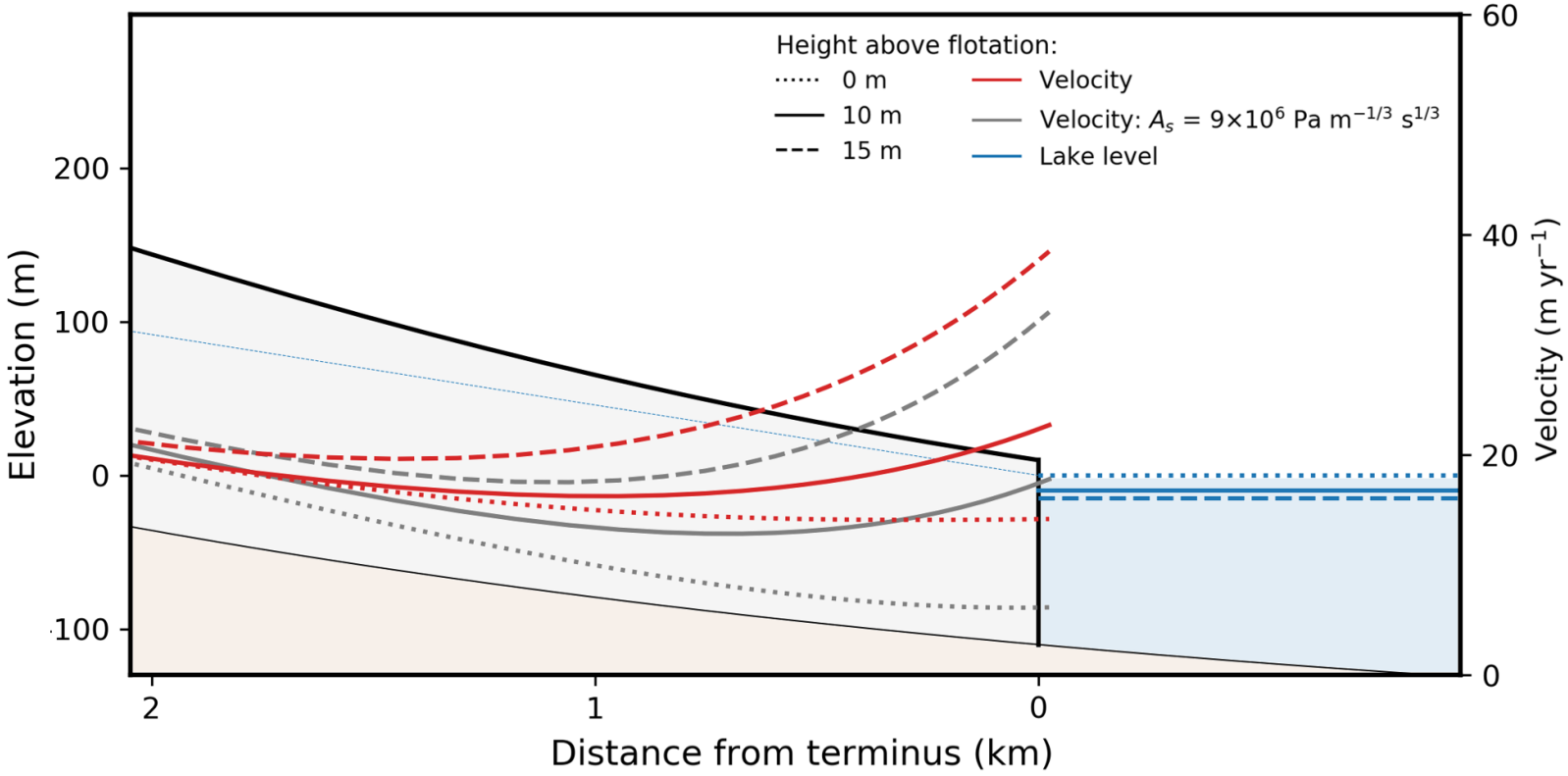
- Synthetic numerical flowline model of a 'typical' Himalayan lake-terminating glacier.

Experimental Design:

- Varying the frontal ice-cliff height (i.e., height above flotation).
- Both fixing and relaxing the basal friction (red & grey line).

Results:

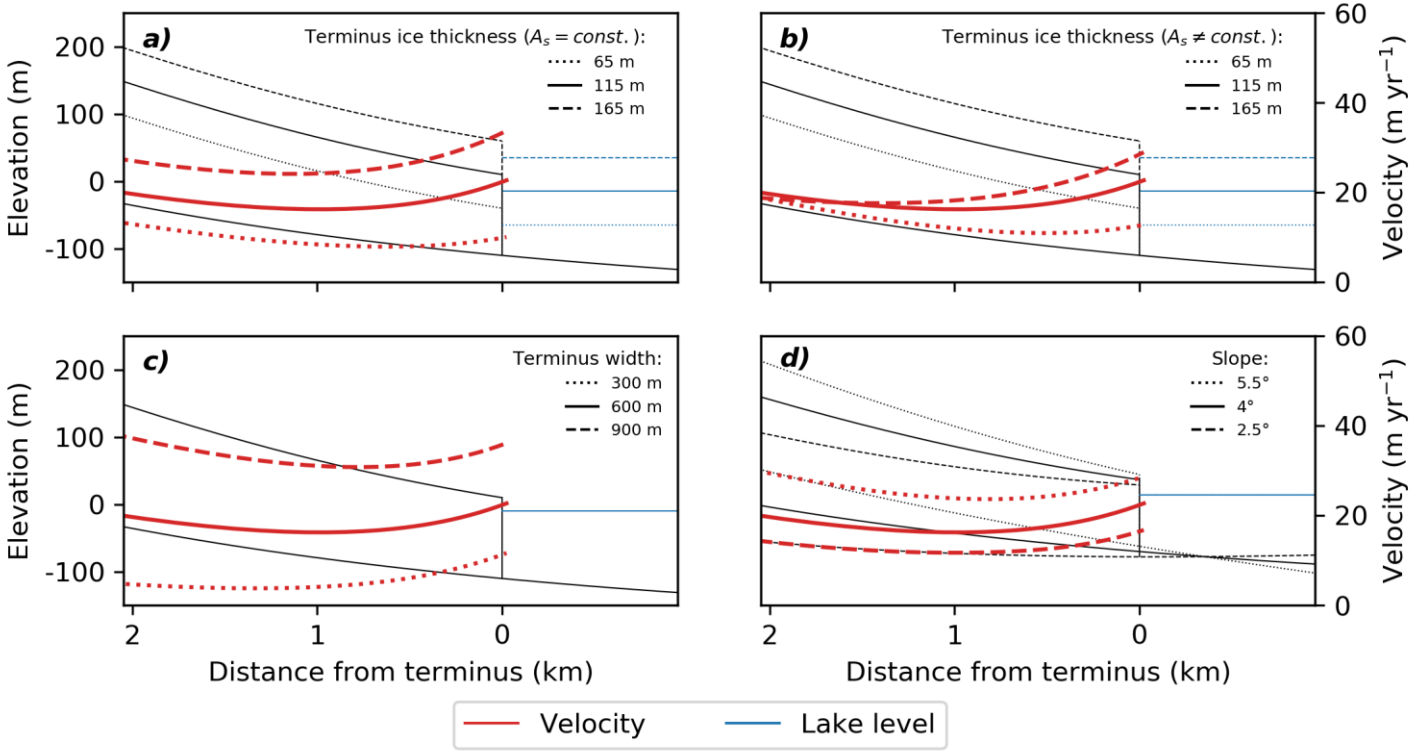
- Frontal boundary condition contributes more to the surface velocity change near the terminus (i.e., dynamic thinning) than basal friction.



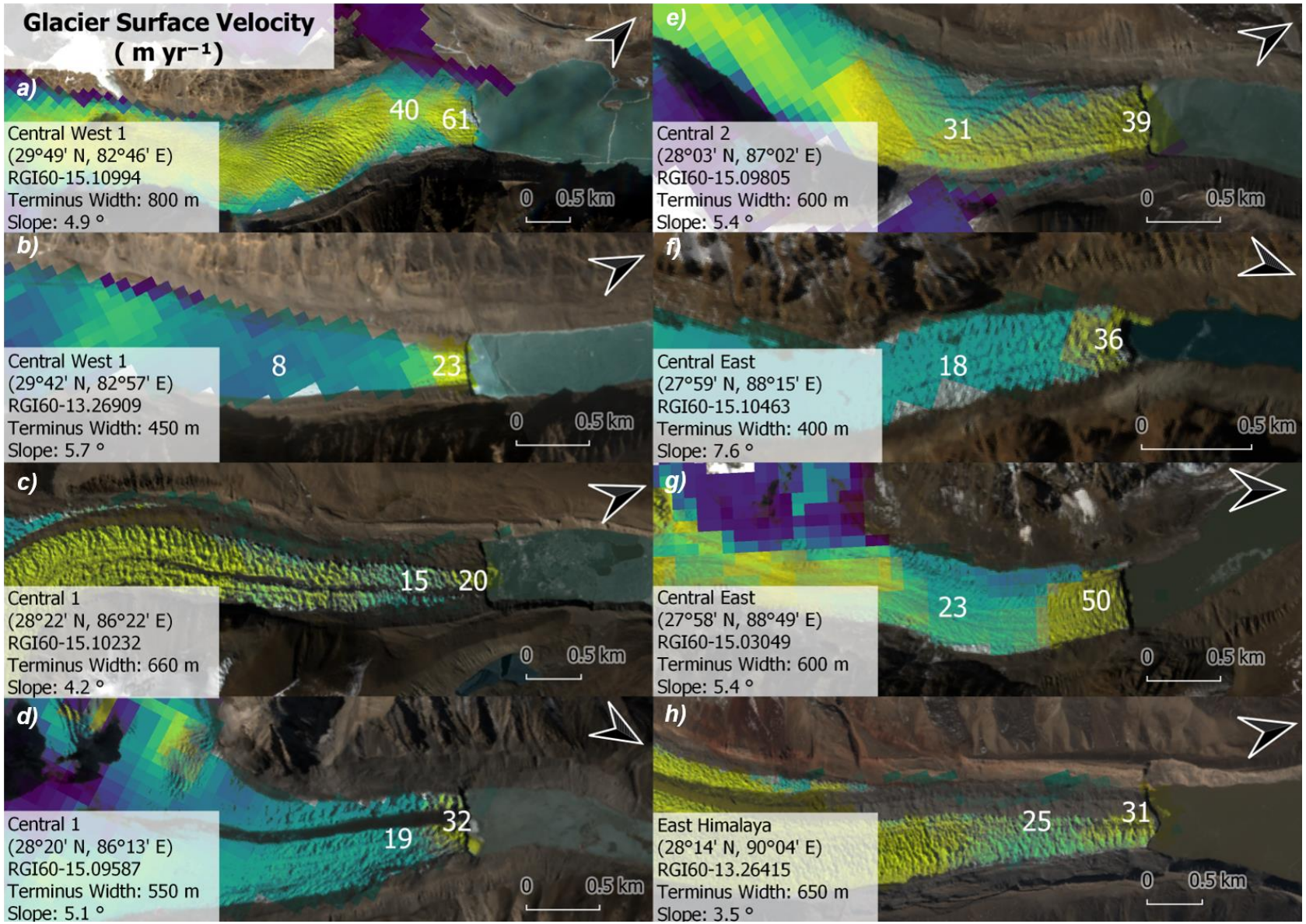
Velocity results from the numerical experiment for three varying frontal ice-cliff heights by varying the lake levels ($\Delta \boldsymbol{D}$), for both effective pressure dependent roughness parameter and a constant roughness parameter (A_s).

Glacier modelling

- Basic sensitivity experiments indicate that the velocity profile is especially sensitive to changes in terminus ice thickness (a & b).
- Ice thickness and frontal configuration still very uncertain and needs further investigation!



Velocity sensitivity experiment to ice thickness (a), ice thickness with varying roughness factor (b), terminus width (c) and slope (d).



Examples of lake-terminating glacier accelerating towards their terminus with glacier attributes within 2 km of the terminus. White numbers represent the glacier surface velocity in m yr-1 . Colour scale of plotted velocity data is indicative and varies among glaciers. Velocity data and RGB images are retrieved from Sentinel-2.

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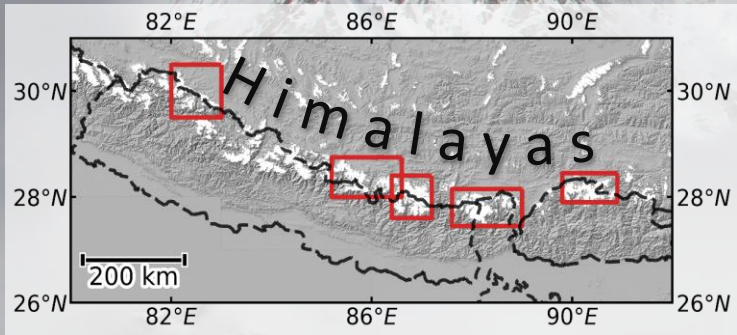
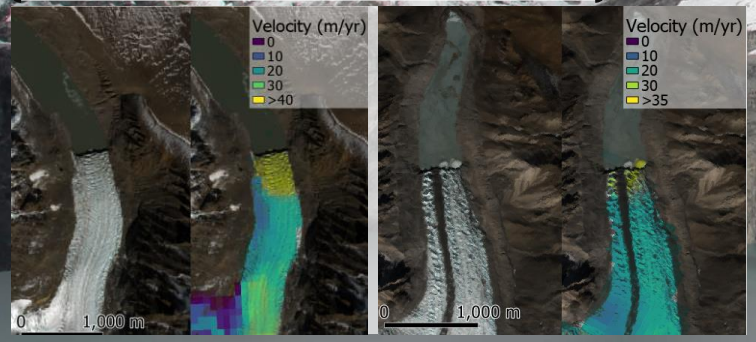
Under review for The Cryosphere!

Study regions

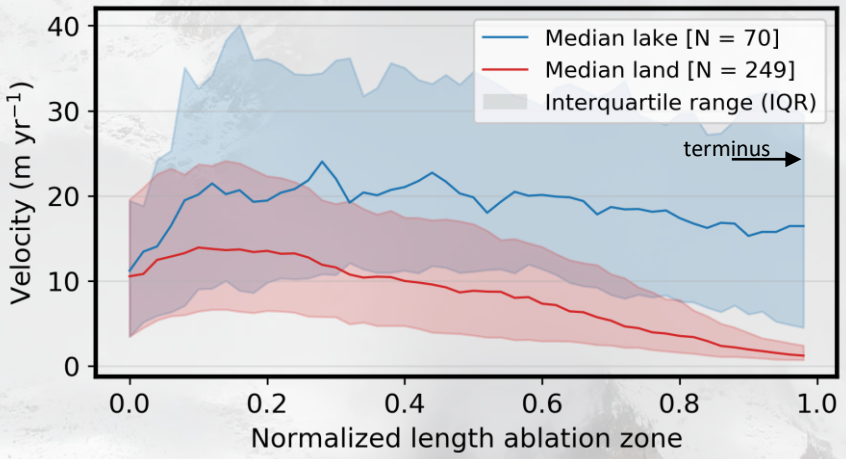


Glacier velocity calculation

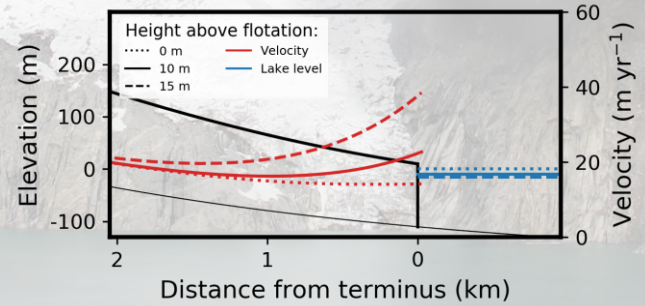
Sentinel-2 | 2017 – 2019



Results



- Higher velocities at lake-terminating glacier termini.
- Half of lake-terminating glaciers accelerate towards their terminus.



Modelling: Frontal boundary condition important in lake-terminating glacier dynamics.

Check out our display materials and lets chat!