Combining surface characteristics and rock-mechanical properties to identify unstable glacier headwalls on a regional scale

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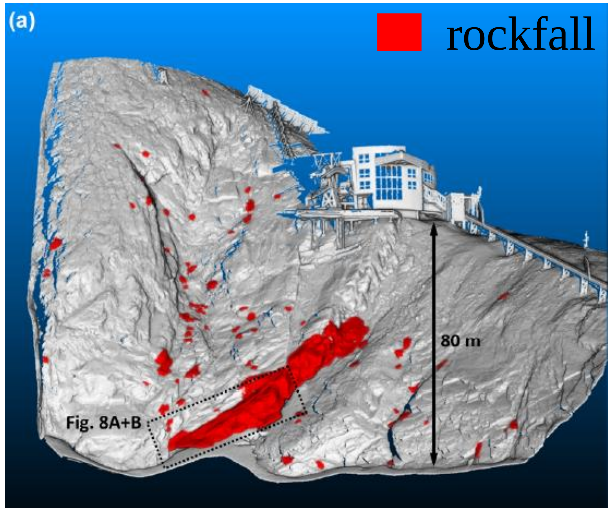
EGU General Assembly 2021

Motivation & Research Questions

Methodology

Results I, II

Conclusions & Outlook



HARTMEYER et al. 2020

Increasing rockfall frequency in **glacier-proximal** areas!

Structural preconditioning!

Potential **increase** of large **rock slides** initiated in recently deglaciating cirque headwalls!

Absence of **regional scale assessments** of preconditioning factors!

Aim:

Identify headwalls in recently deglaciated cirques and valleys with the highest potential for increased slope instability and rock fall

Research Questions:

- How to identify glacier headwalls based on morphological features and how to implement their geological structure on a regional scale?
- Can we identify potentially unstable headwalls on a regional scale?

Main tasks:

- Semi-automatic identification of headwalls
- Integration of rock structure

Anticipate future slope instability in glaciated areas!

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I. Headwalls

OBIA (eCognition)

Segmentation
Input variables: slope, aspect, TPI

Classification
Input variables: slope, elevation

Validation
Manual headwall mapping

II. Rock structure

GIS (ArcMap)

Topography
aspect, slope

Foliation
direction, dip

Δ-index
(GRELLE et al. 2011)

dip-slope relation
(CRUDEN 2003)

All terrain rock structure

Merge

Cataclinal headwalls

Anaclinal headwalls

I. eCognition was used for **semi-automatic headwall detection**. Segmentation is derived from DEM derivatives like *slope*, *aspect* and a *TPI-based landform classification*. Headwall segments are classified based on *slope* and *elevation* thresholds that have been identified and validated using manual headwall mapping.

II. Foliation information extracted from regional geological maps was compared to local geological surveys in order to specify type of foliation. Bedrock structure was interpolated based on a *non-continuous azimuth distribution approach* (NADIA). By combining *topographic* and *geological data* we derived a **geotechnical classification scheme** from cataclinal to anaclinal slopes with various dip-slope relations.

Integrate material properties on regional scale studies!

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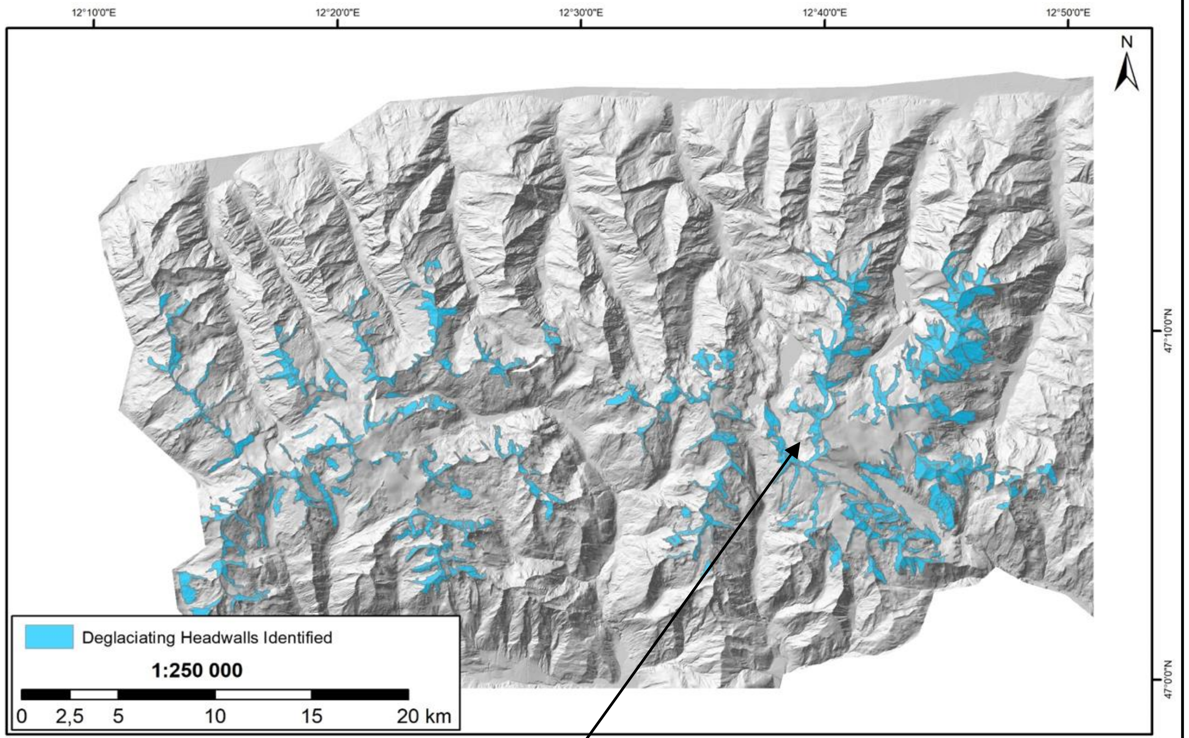

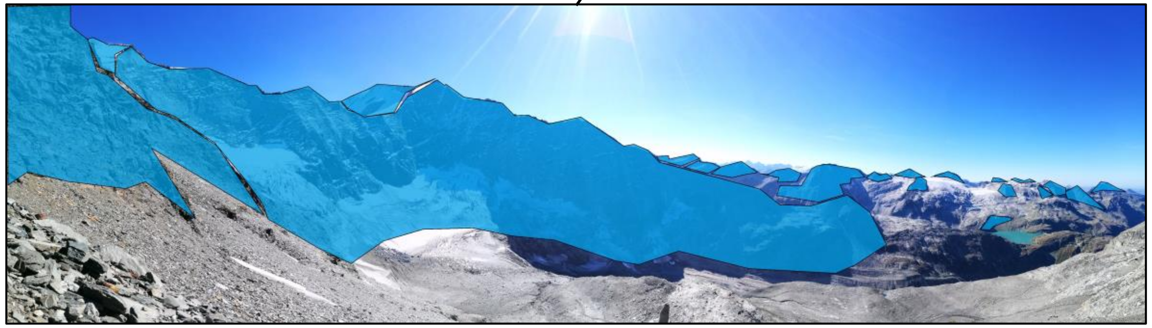

Semi-automatic headwall detection

- semi-automated headwall detection largely reproduces local observations
- overestimation of 61% of total headwall area compared to manually mapped headwalls
- undetected area is considered to be negligible
- overestimation mainly arises from inclusion of high-altitude profile straight slopes, matching the classification requirements without obvious glacial imprints such as schrundlines

Glacier headwalls can be identified using OBIA!

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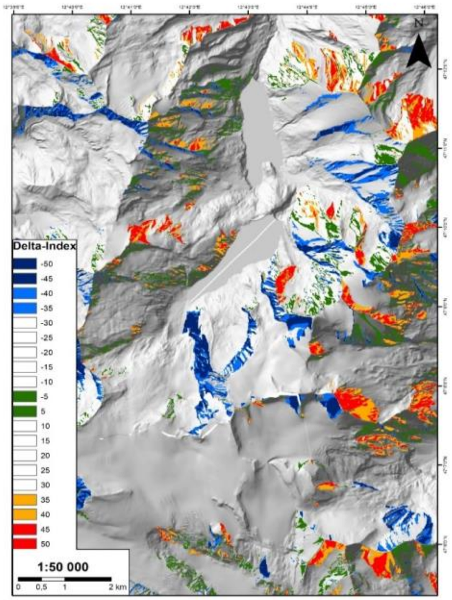
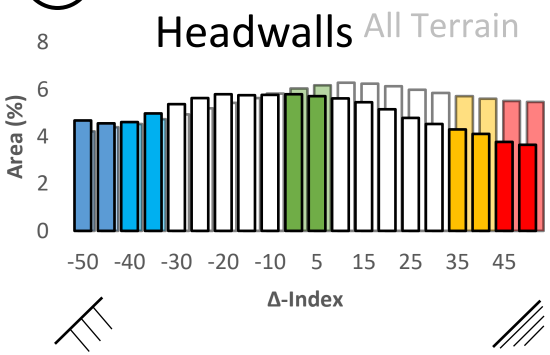
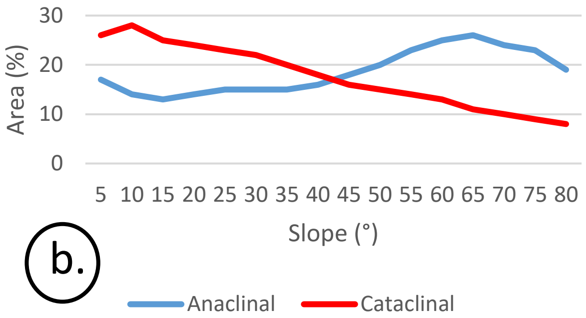


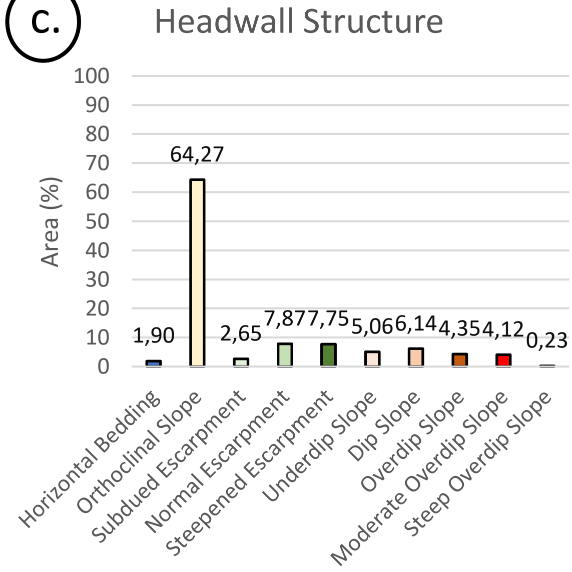
a.





b.

c.



Integration of rock structure

a. dominance of cataclinal slopes in the entire landscape

b. at steeper terrain, including glacier headwalls, anaclinal slopes prevail

c. unstable situations such as overdip slopes are rare and predominantly found in the lower sections of glacier headwalls marked by schrundlines

d. (steep permafrost rock walls were found to be almost exclusively anaclinal, which might be considered as site-specific)

Rock structure was successfully integrated and reveals potentially unstable slopes such as overdips!

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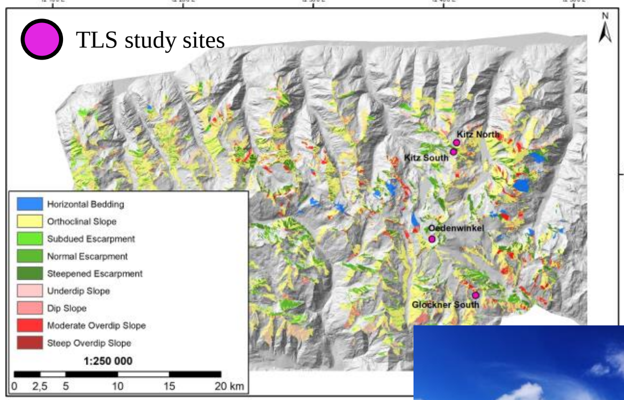
In conclusion:

- Overall aim: Anticipate future slope instability in glaciated areas
- Methodological challenge: Integrate material properties on regional scale studies
- Accomplishments:
  - Headwalls can be identified using OBIA
  - Rock structure was successfully integrated and reveals potentially unstable slopes such as overdips
- Shortcomings:
  - Overestimation of headwall identification
  - 10m DEM resolution probably too low
  - Mapped foliation dip classes too wide

To do:



TLS monitoring of **rock slope failures** to evaluate regional scale findings

Monitor **destabilising processes** in a recently deglaciating, cataclinal headwall (OpAL Kitzsteinhorn)

Refine modeled **preconditioning**, decipher **destabilising processes** and monitor actual **rock slope failure**!