Landslide dam susceptibility in the Austrian Alps inferred from modelled landslides, potential valley damming and lake formation

EGU 2020 presentation

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May 05, 2020

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What are landslide dams?

Landslide dams

Landslides deposited in the river bed, damming the river flow and forming a (temporal) lake.

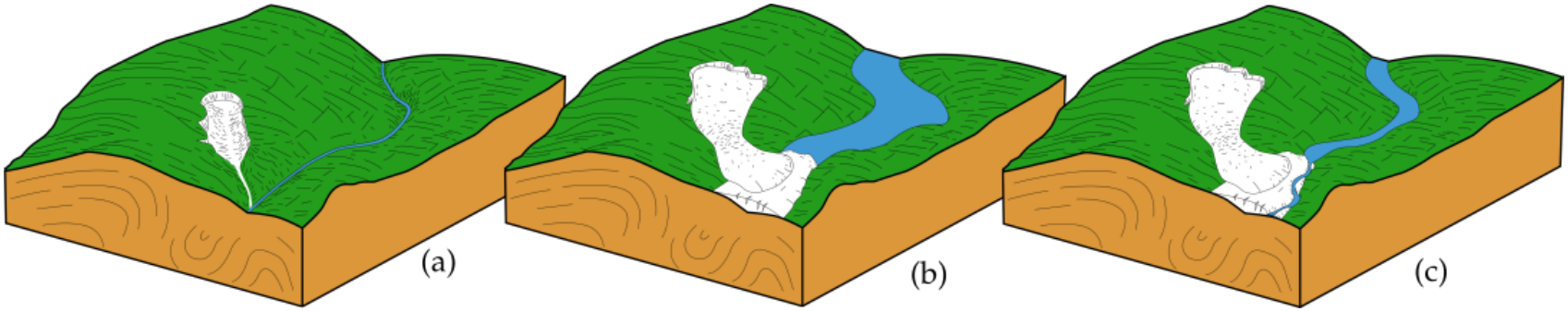

Figure 1: Landslide of Creux-du-Van dams the Val-de-Travers. (a) Landslide begins. (b) Landslide dams the river, sedimentation. (c) Dam break or overtopping. [From Matthey, 1971.]

[0] Matthey, F. (1971). Contribution à l'étude de l'évolution tardi-et postglaciaire de la végétation dans le Jura central. H. Huber.

What are landslide dams?

Landslide dams

Landslides deposited in the river bed, damming the river flow and forming a (temporal) lake.

Figure 2: A view of the Leader dam in New Zealand, triggered by the 14 November 2016 Kaikoura earthquake. The dam has been incised by the river. 03.01.2019

Modeling approach

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Modeling approach
Input data

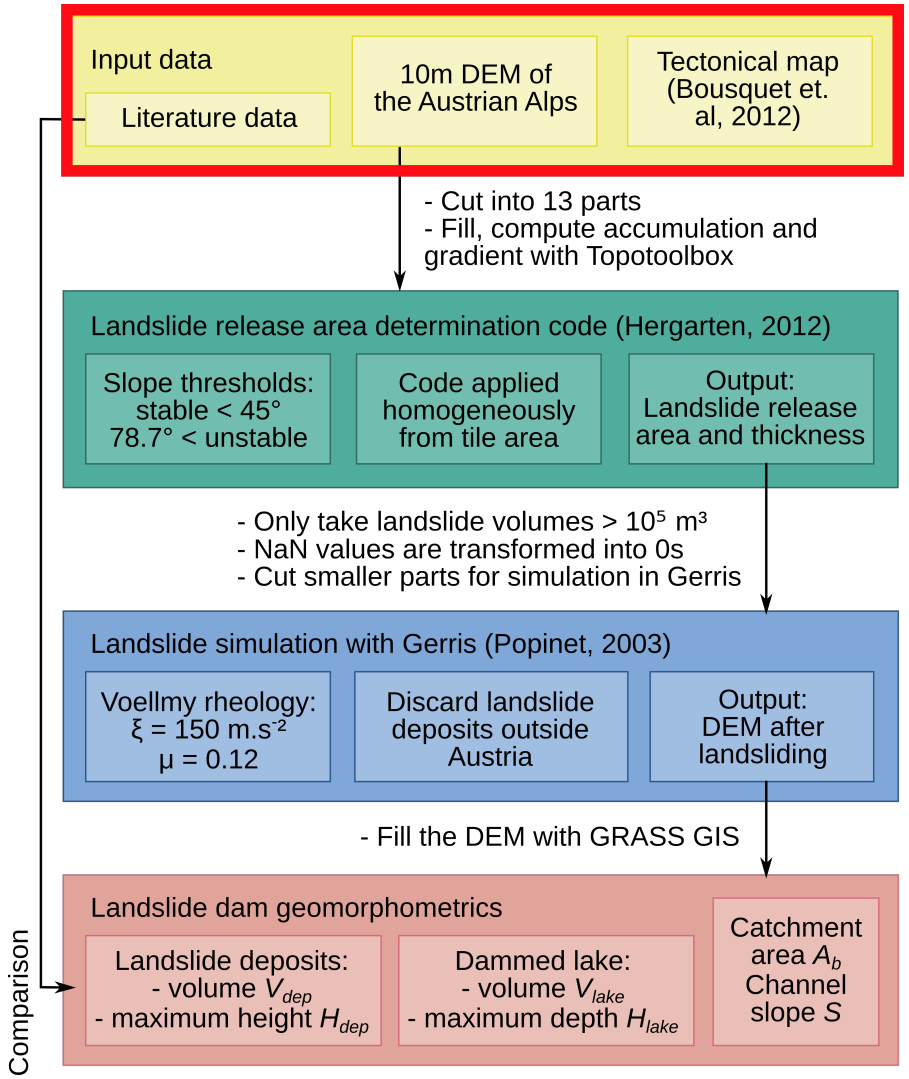

Figure 3: Workflow

Simple input data.

Our landslide model relies on topographical data only.

Modeling approach
Determination of landslide release areas

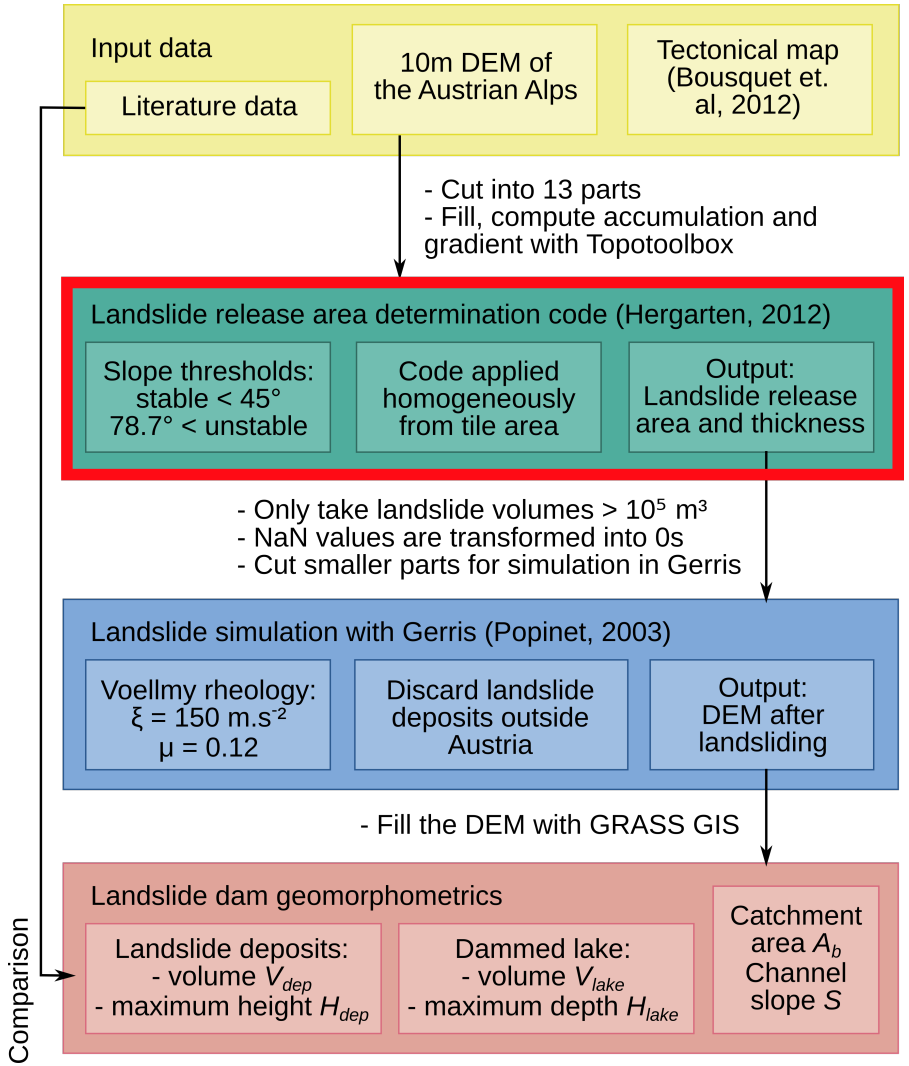

Figure 3: Workflow

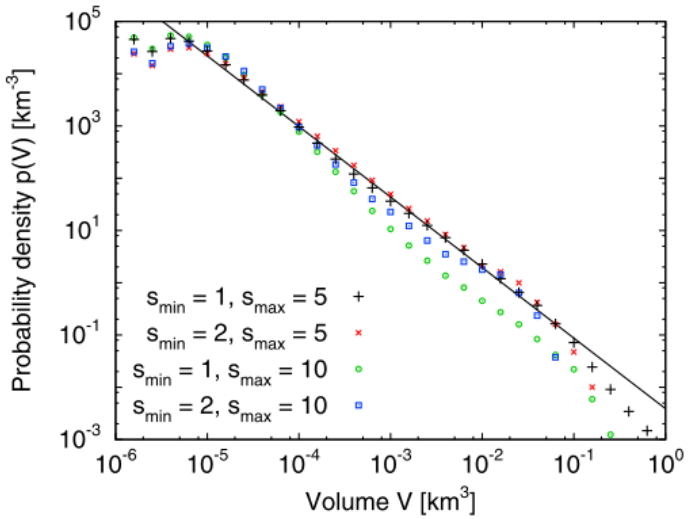

Figure 4: The probability density of the landslides corresponds to a power-law distribution [from Hergarten, 2012].

Hergarten, S.: Topography-based modeling of large rockfalls and application to hazard assessment, Geophysical Research Letters, 39.

Methodology
Landslide simulation

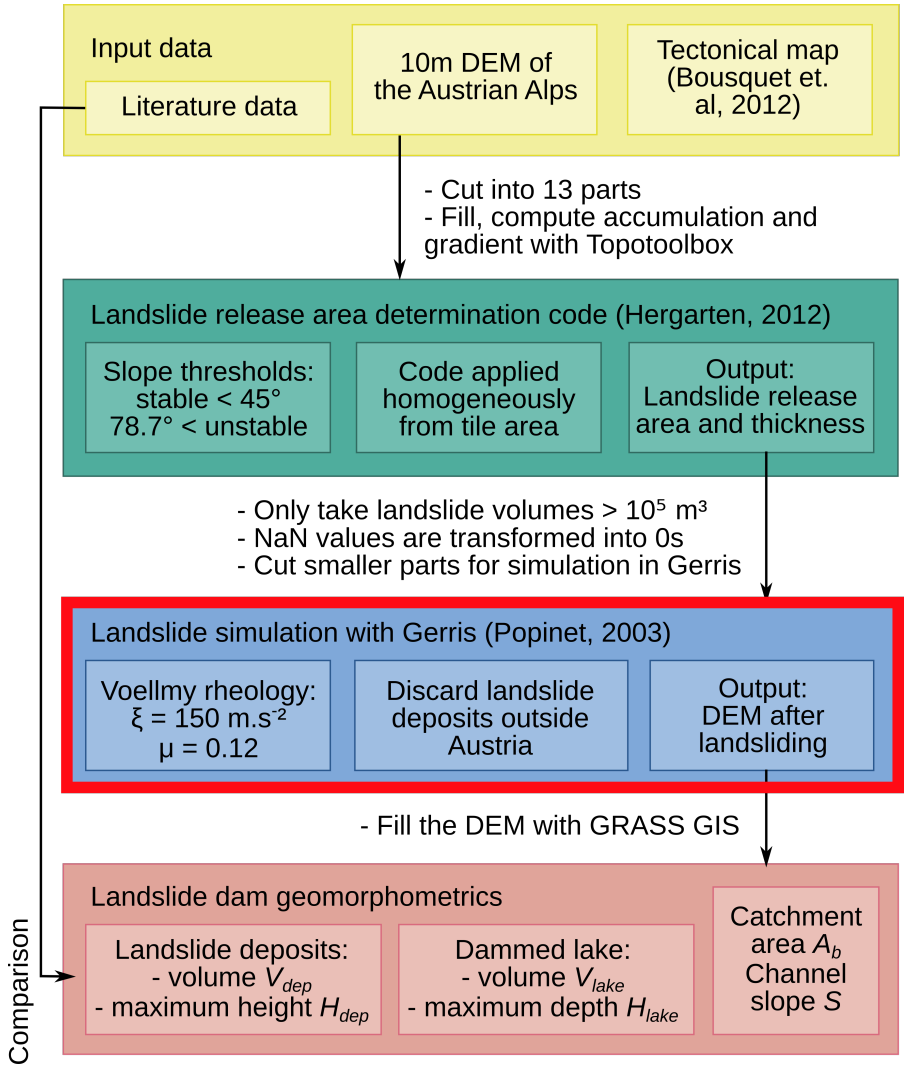

Figure 3: Workflow

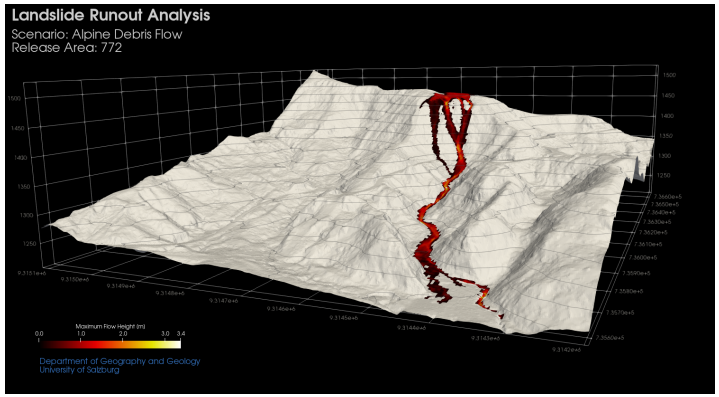

Figure 5: Landslide modeled with Gerris (Popinet, 2003), a depth-averaged flow solver.

Popinet, S.. Gerris. A tree-based adaptive solver for the incompressible Euler equations in complex geometries, Journal of Computational Physics, 190, 572–600, 2003.

Methodology
Geomorphometric parameters

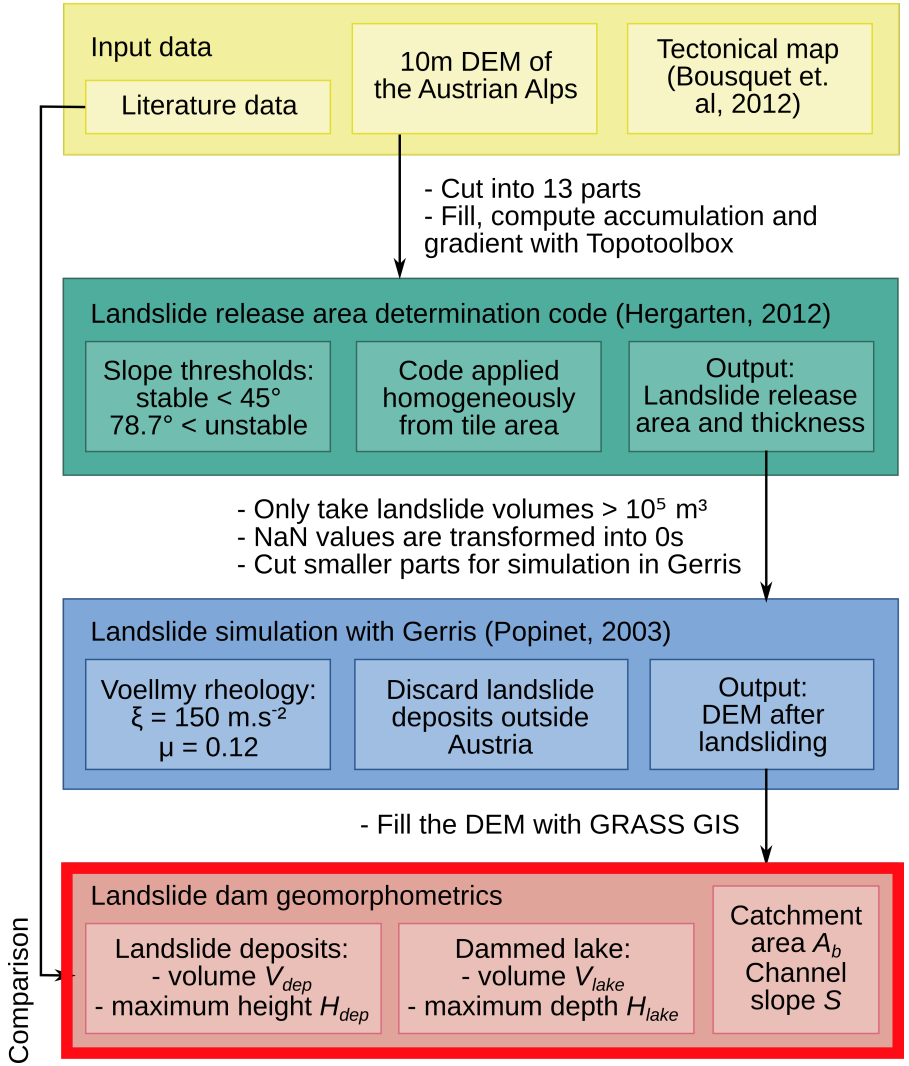

Figure 3: Workflow

100 landslide dams as preliminary results.
1000 intended.

Common geomorphometric parameters:

- Landslide volume
- Lake volume
- Dam volume & height
  → Definition not straightforward

First results

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First results - Comparison with literature
Landslide and lake volumes

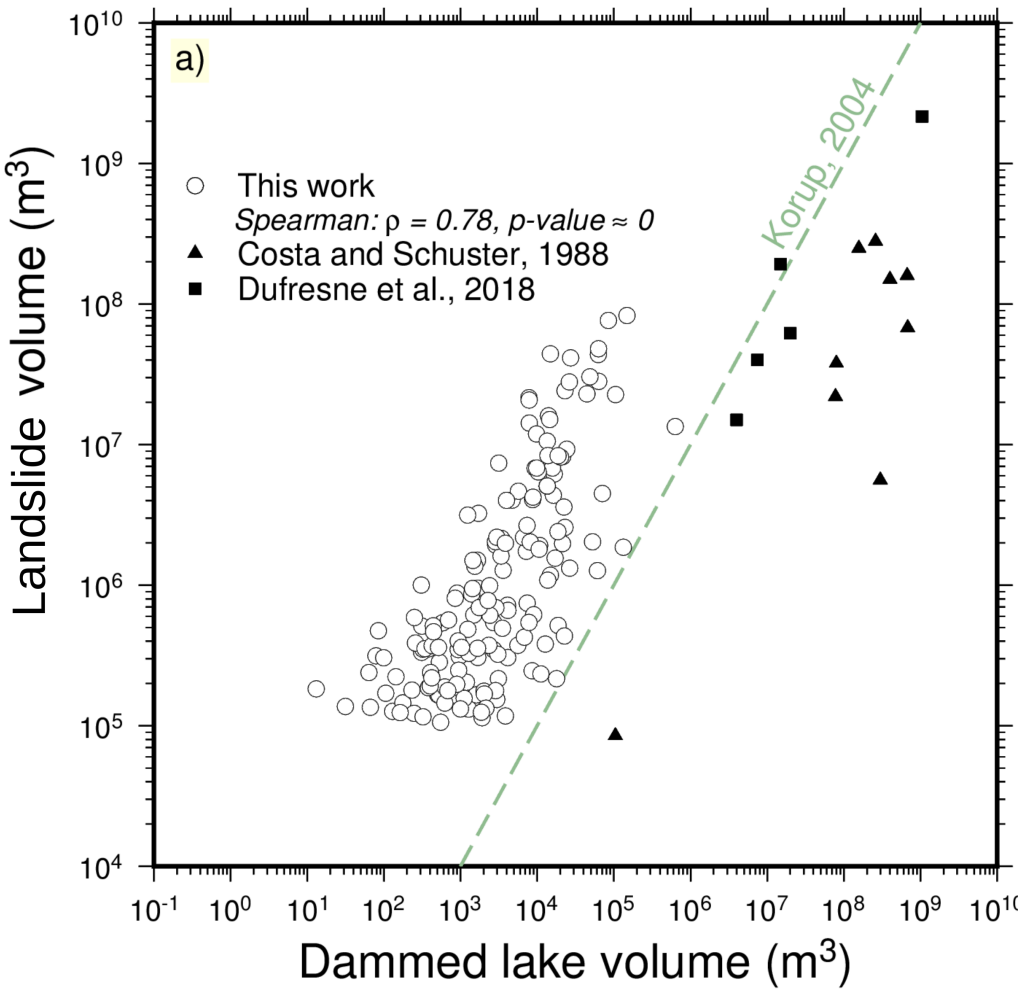

Figure 6: Our landslide dammed lake values.

Observations :

- Linear correlation between landslide and lake volume
- Values are shifted to the left in comparison with literature data

→ Investigate the shift in our values by looking at the dam height (which is not directly measurable).

First results - Comparison with literature
Proxies for dam height H_{dam}

H_{dam}: Dam height
H_{lake}: Maximum depth of the lake
H_{dep}: Maximum height of the landslide deposits.

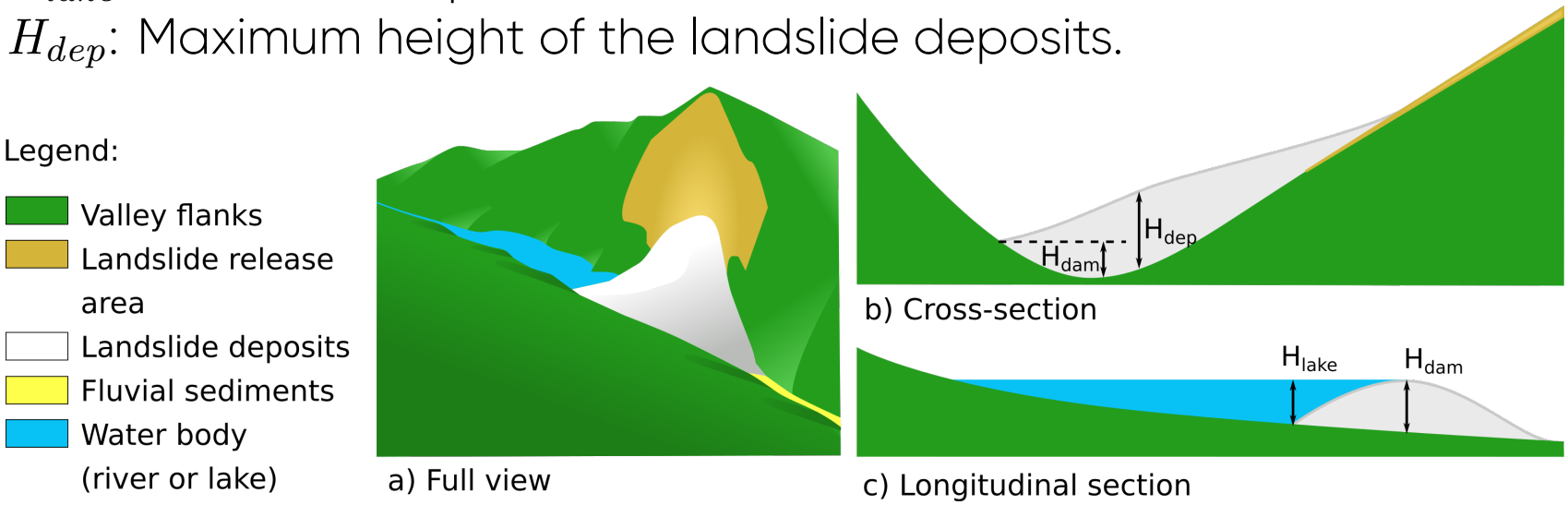

Figure 7: Measurement of heights in cross and longitudinal sections.

Heights relationship:

$$H_{lake} \leq H_{dam} \leq H_{dep} \quad (1)$$

First results - Comparison with literature

Relation of H_{dep} and H_{lake} with $V_{landslide}$ and V_{lake}

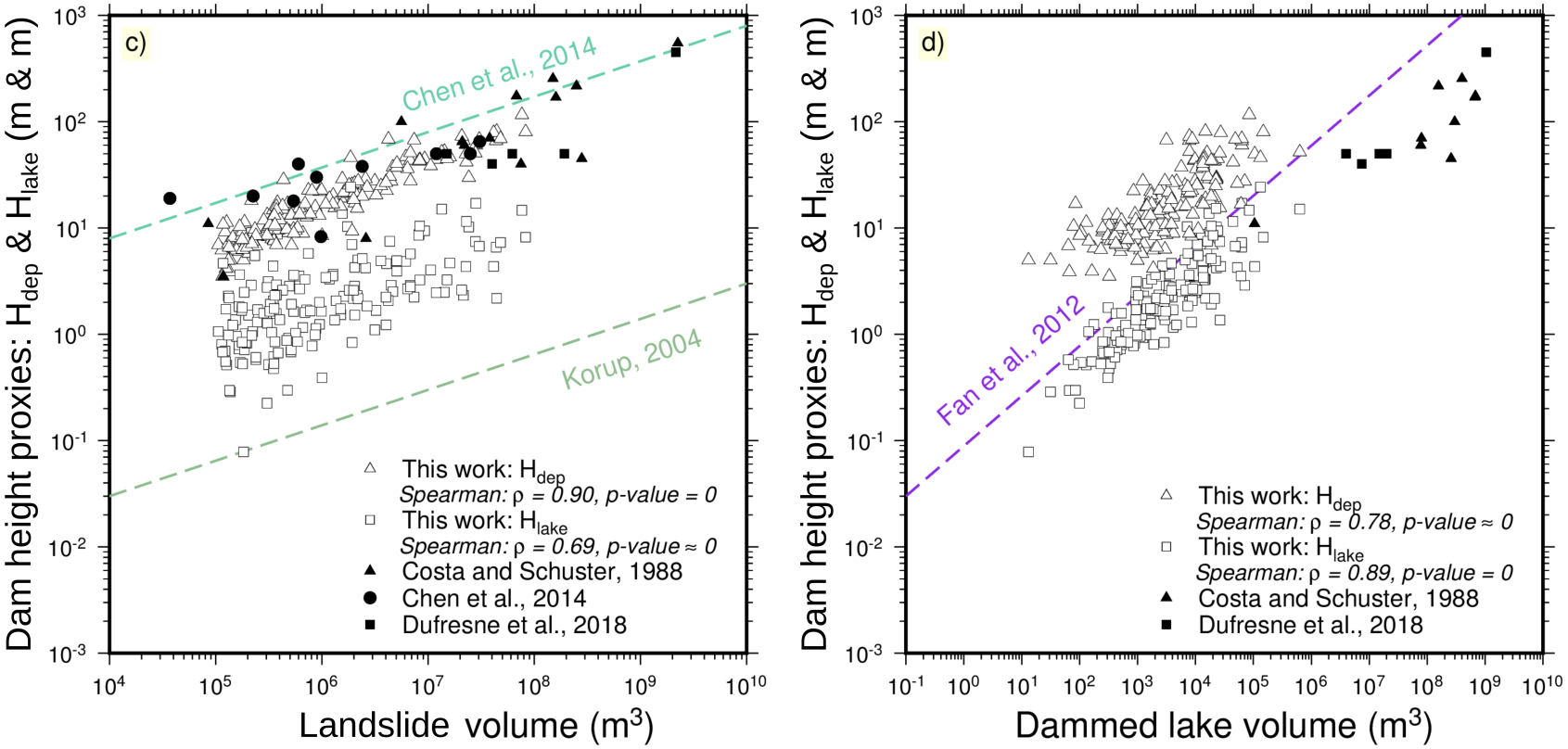

Figure 8: Decomposition of the relation with the dam height proxies: the landslide deposits height H_{dep} and the lake depth H_{lake}.

H_{lake} and H_{dep} values are clearly separated...

First results - Comparison with literature

Relation of H_{dep} and H_{lake} with $V_{landslide}$ and V_{lake}

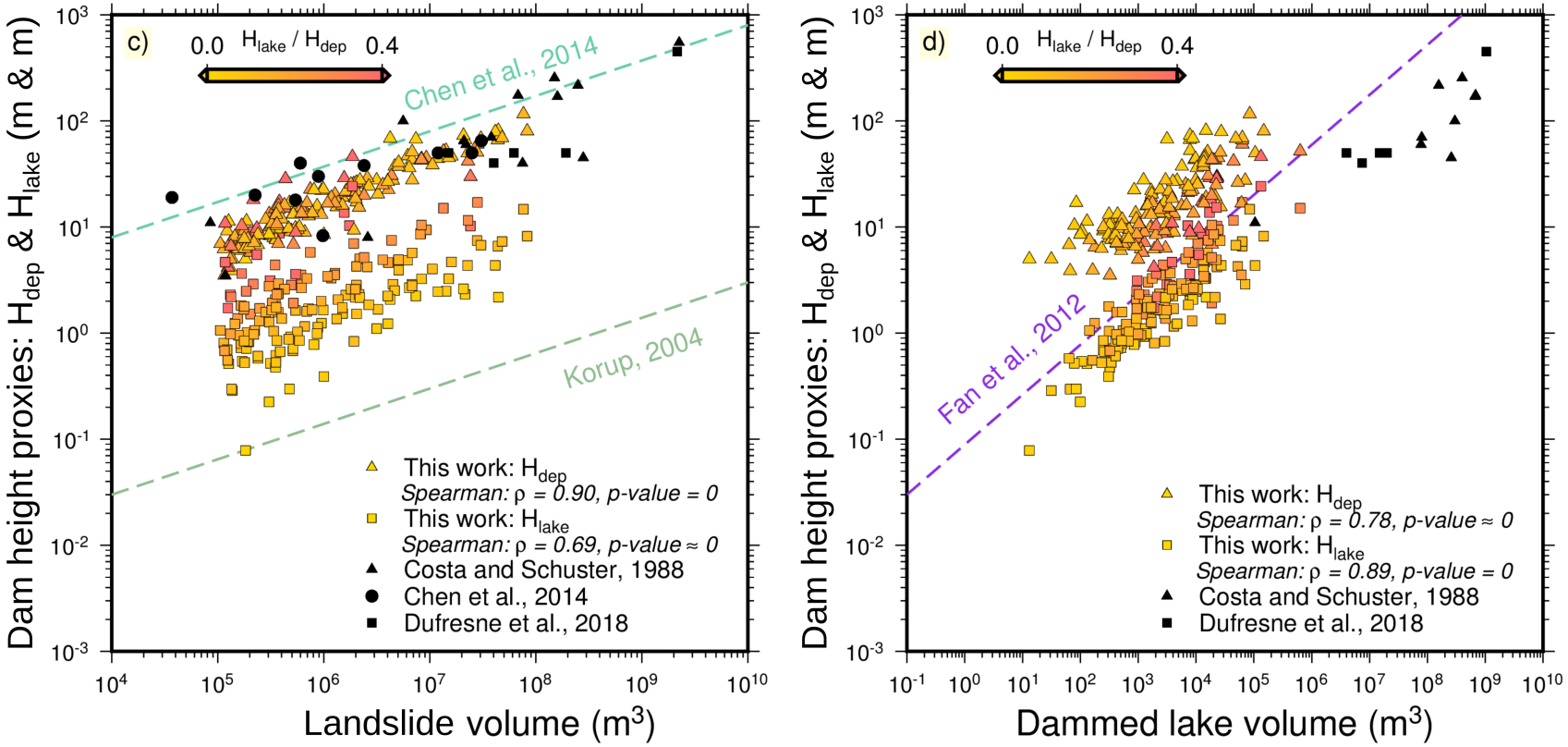

Figure 9: Decomposition of the relation with the dam height proxies: the landslide deposits height H_{dep} and the lake depth H_{lake}.

...and values with high H_{lake}/H_{dep} tend close to the literature.

First results - Comparison with literature
Landslide and lake volumes

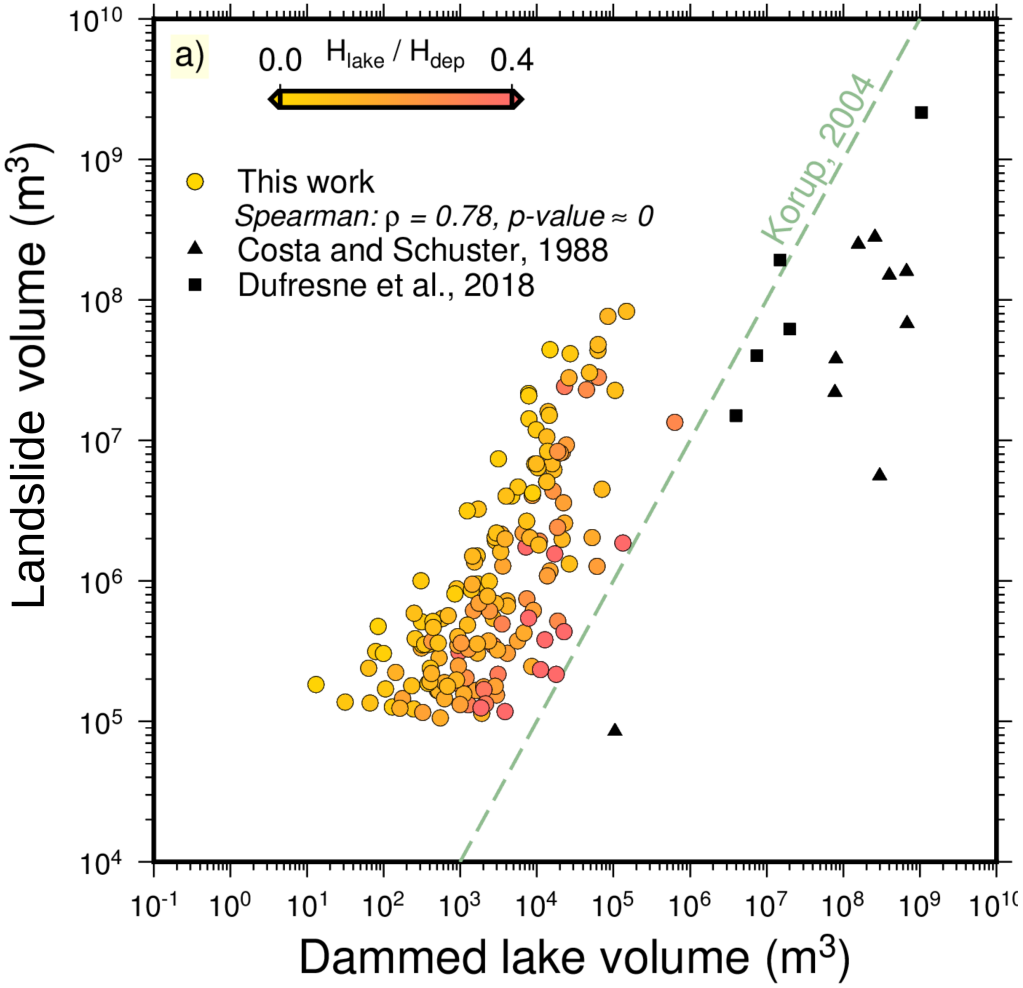

Figure 10: Our landslide dammed lake values.

Observations :

- Linear correlation between landslide and lake volume
- Values are shifted to the left in comparison with literature data
- Gradient of the H_{lake}/H_{dep} ratio.
- Values closer to literature when H_{lake}/H_{dep} is closer to 1.

First results - Comparison with literature
Conclusions

1. H_{dep} fits $V_{landslide}$ very well, like H_{lake} with V_{lake}.
2. Landslide dam literature tend to record the most exceptional landslide dams. We modeled damming and non-damming landslides. We get similar results when H_{lake}/H_{dep} ratio ≈ 1.

There is a need for:

- 3D geomorphometric parameters of landslide dams.
- well-defined on-field procedure for the assessment of the landslide dam geomorphometric parameters (e.g. dam height).

Link to tectonic units

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Link to tectonic units
Area, landslide numbers & densities

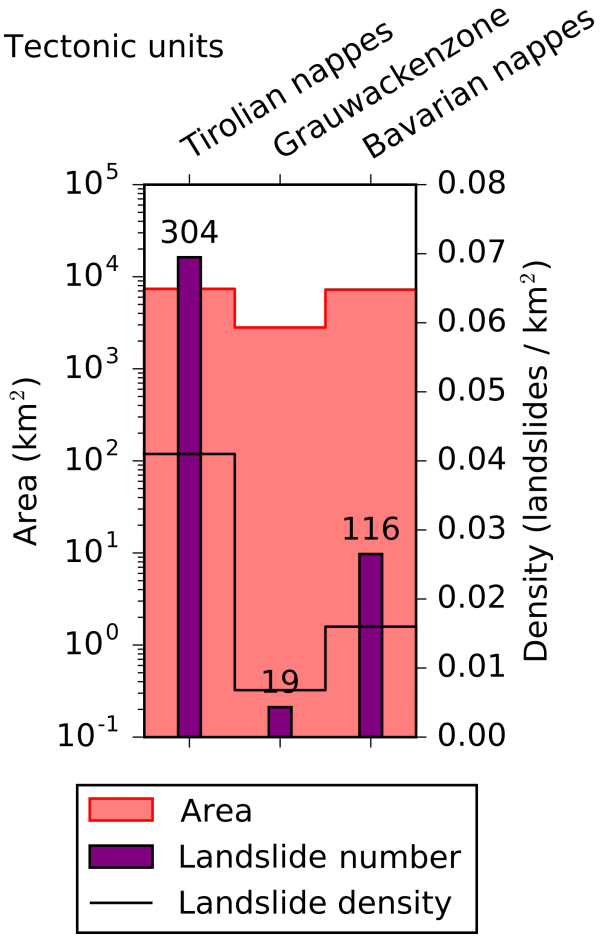


Figure 11: Area, landslide number and density for 3 tectonic units.

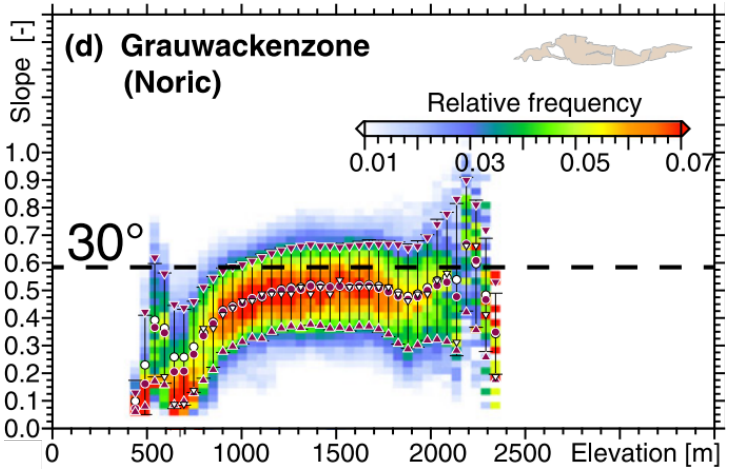


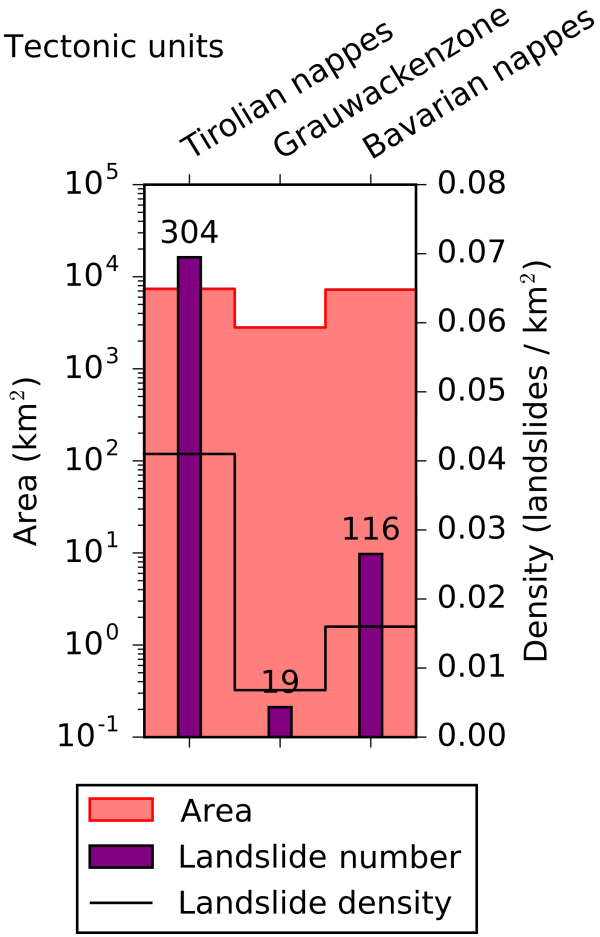
Figure 12: Slope vs elevation [From Robl et al., 2015].

Grauwackenzone: Low landslide density

Gentle slopes → lower than the stability threshold (e.g. 45°)

Robl, J., Prasicek, G., Hergarten, S., and Stüwe, K.. Alpine topography in the light of tectonic uplift and glaciation, Global and Planetary Change, 127, 34–49, 2015.

Link to tectonic units
Area, landslide numbers & densities



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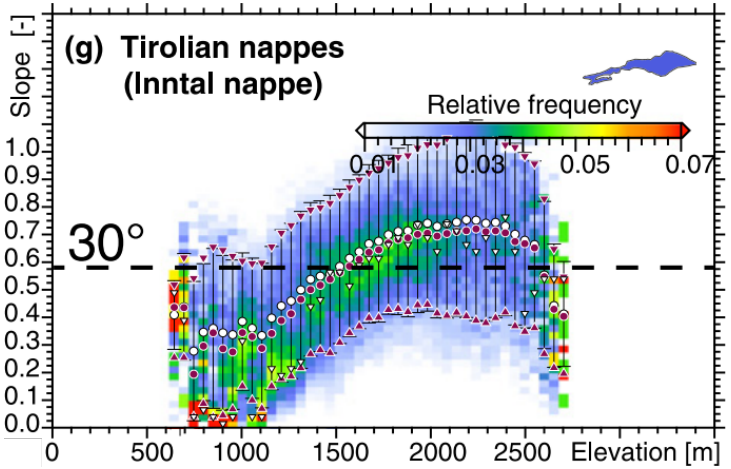


Figure 13: Slope vs elevation [From Robl et al., 2015].

Tirolian Nappes: High landslide density

Steep slopes → higher than the unstability threshold (e.g. 78.7°)

Robl, J., Prasicek, G., Hergarten, S., and Stüwe, K.. Alpine topography in the light of tectonic uplift and glaciation, Global and Planetary Change, 127, 34–49, 2015.

Link to tectonic units
Landslide & lake volumes, height ratios

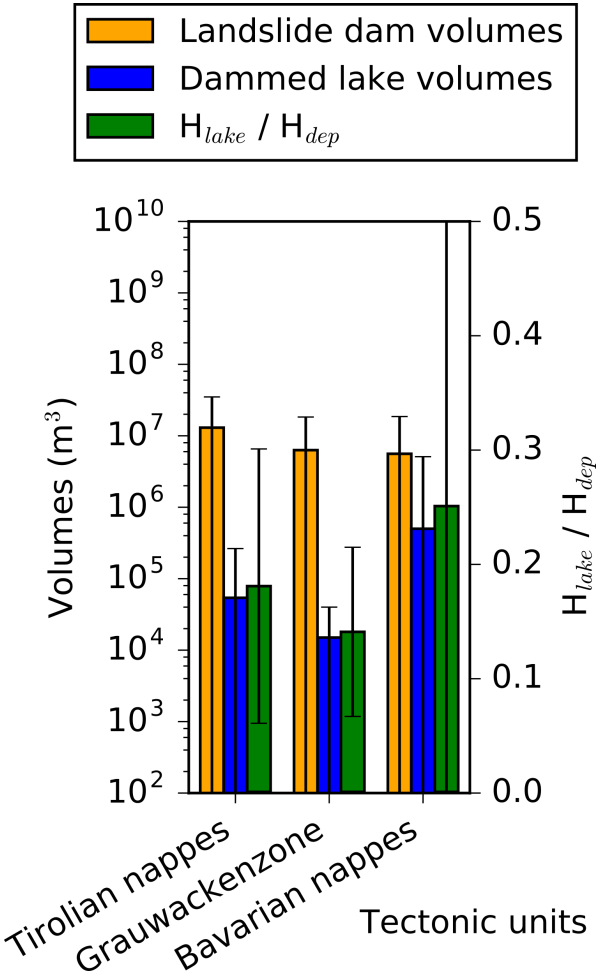
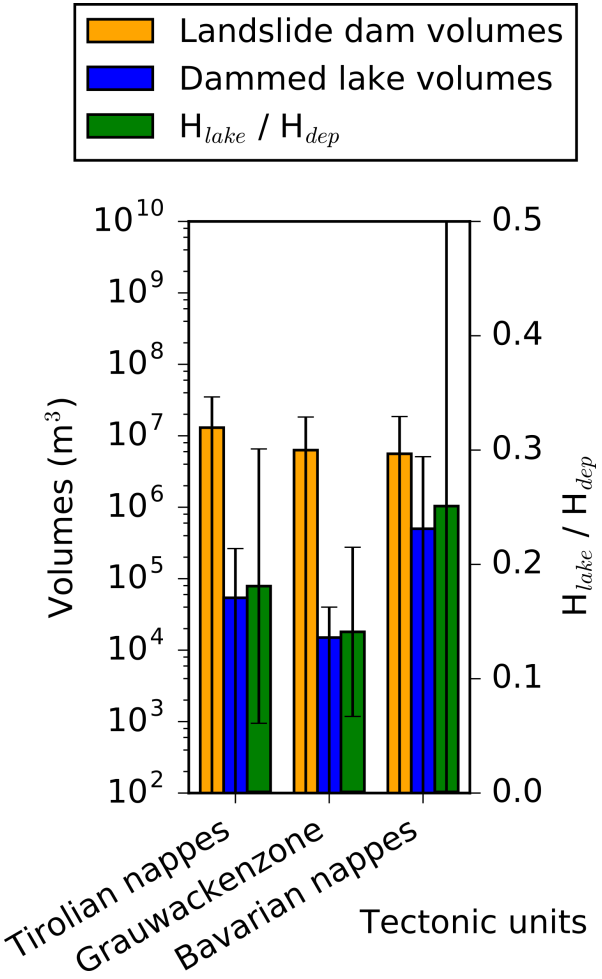


Figure 14: Mean deposits and lake volumes, ratio H_{lake}/H_{dep}.

Observations:

- H_{lake}/H_{dep} ratio mostly correlated to lake volume
- H_{lake}/H_{dep} ratio and lake volume varies depending on tectonic unit, for similar landslide volumes
- Probable influence of topography

Link to tectonic units
Landslide & lake volumes, height ratios



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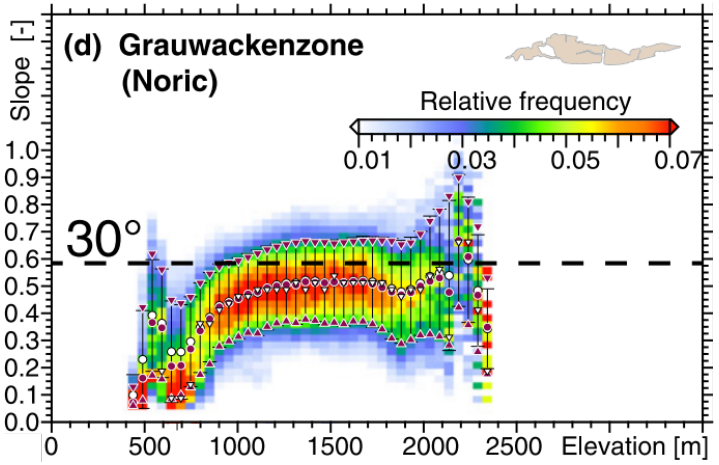


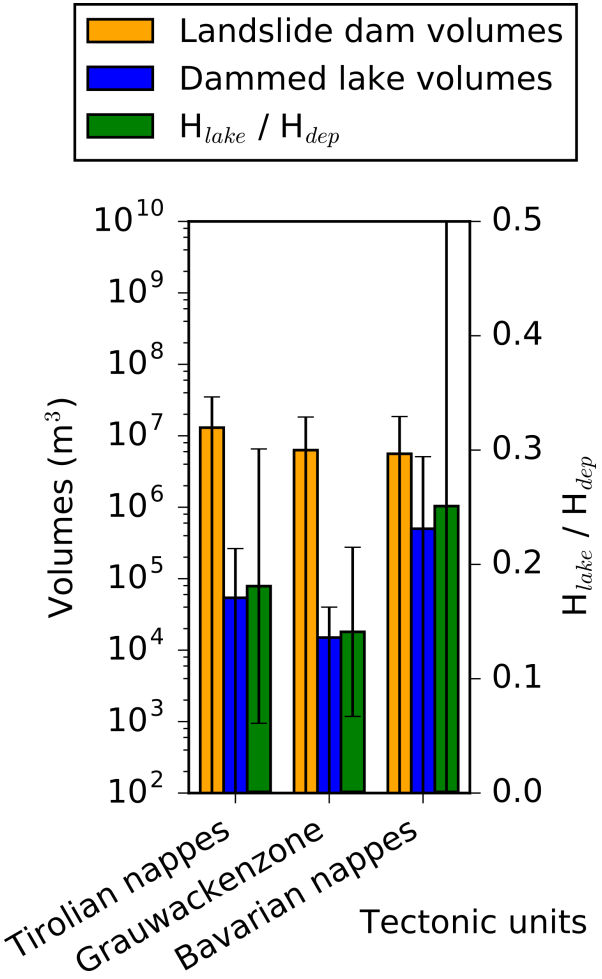
Figure 15: Slope vs elevation [From Robl et al., 2015].

Grauwackenzone: Low H_{lake}/H_{dep} ratio

Gently dipping valley flanks $\rightarrow$ Landslide masses deposit close to valley flanks

Large valley floors $\rightarrow$ Harder to dam

Link to tectonic units
Landslide & lake volumes, height ratios



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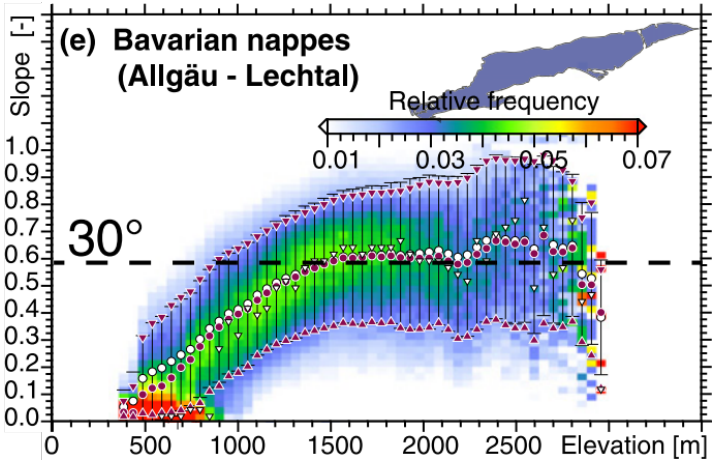

Figure 16: Slope vs elevation [From Robl et al., 2015].

Bavarian Nappes: High H_{lake}/H_{dep} ratio

Steep valley flanks → Landslide masses reach the river bed

V-type of valleys → Easier to dam

Conclusion

- There is a correlation between landslide and lake volumes.
- The modeled landslide dams with high H_{lake}/H_{dep} ratio are closer to literature values.
- Tectonic units present different H_{lake}/H_{dep} ratios and lake volumes for similar landslide volumes.

Future possible work:

- Investigate the variability of the H_{lake}/H_{dep} ratio, and look for a relation with the slope, the topography.
- Try measuring the H_{lake} and H_{dep} of a substantial amount of real-world landslide dammed lakes.

Looking for a post-doc in 2021

Let's chat!

NH3.1: Tuesday May 5, from 14:00 to 18:00

This research has been supported by the Austrian Academy of Sciences (ÖAW) through the project RiCoLa (Detection and analysis of landslide-induced river course changes and lake formation).

RiCoLa

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