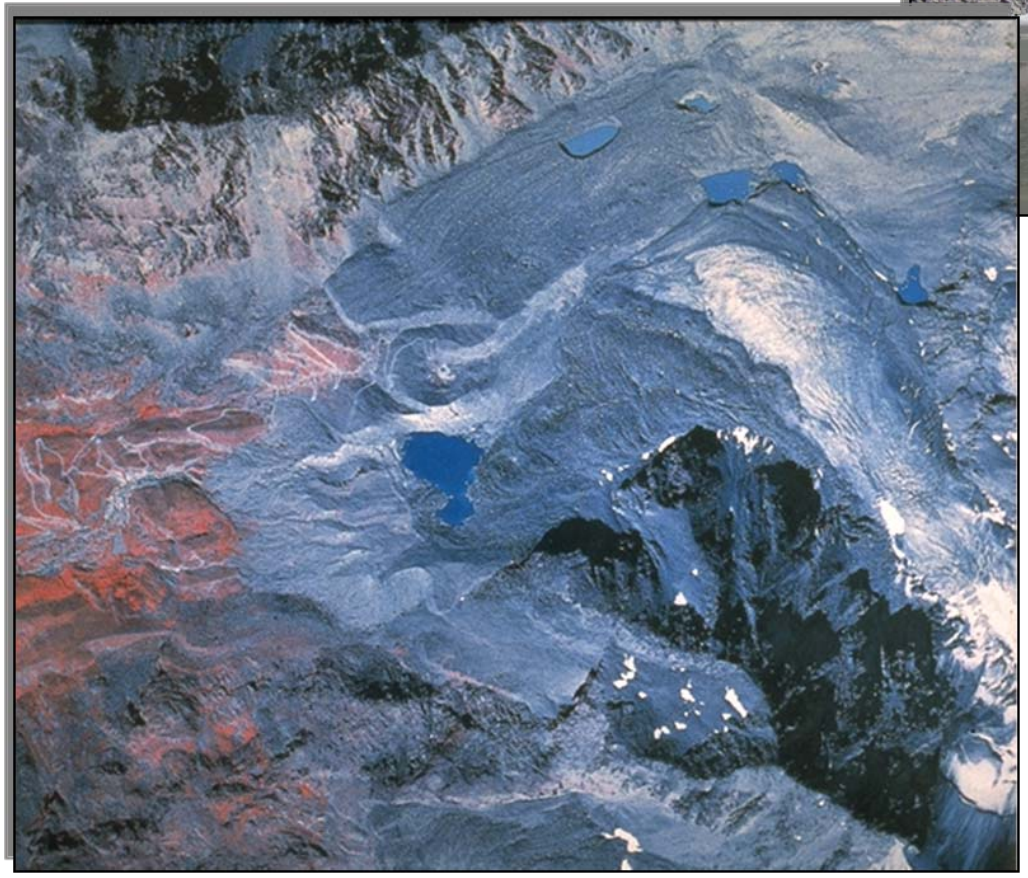
Hazards from glaciers, permafrost and lakes in high-mountain regions:

Processes and interactions



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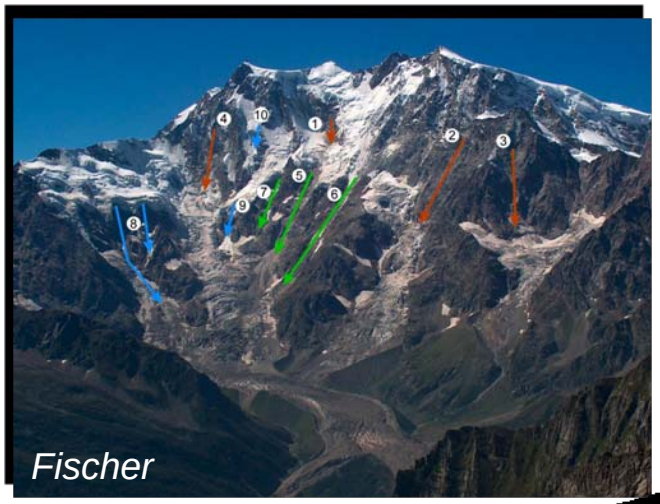
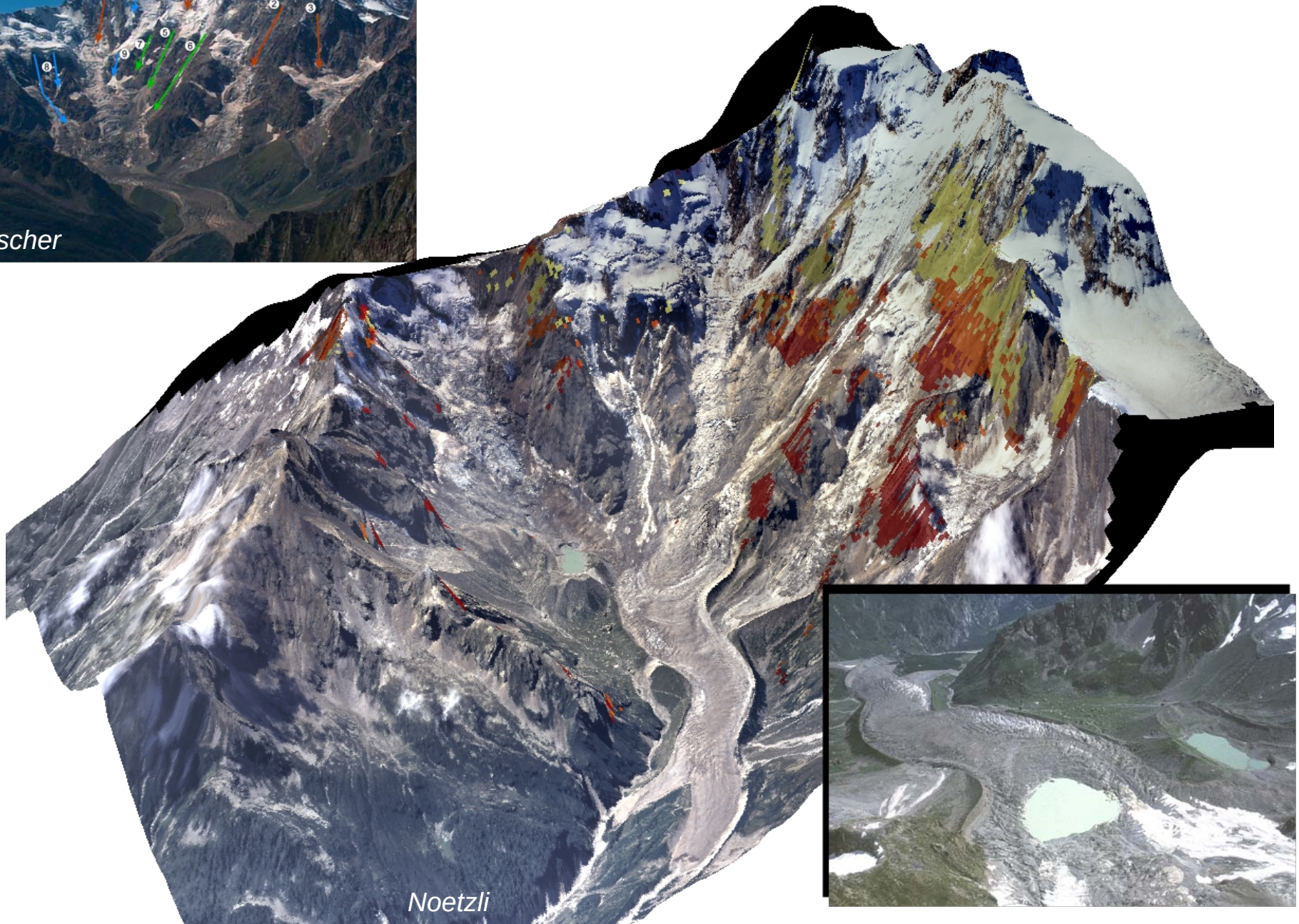
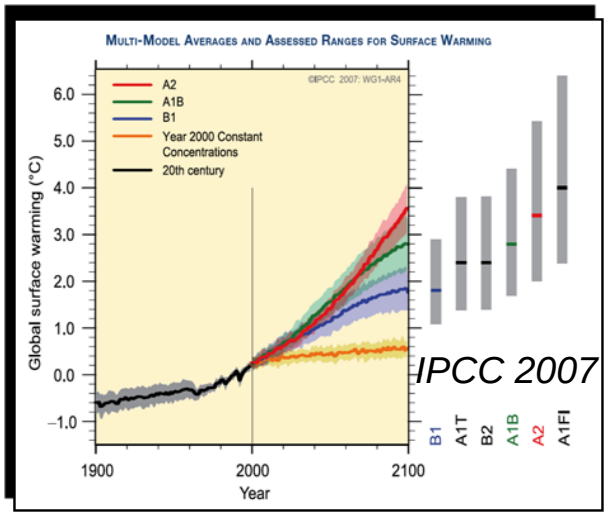
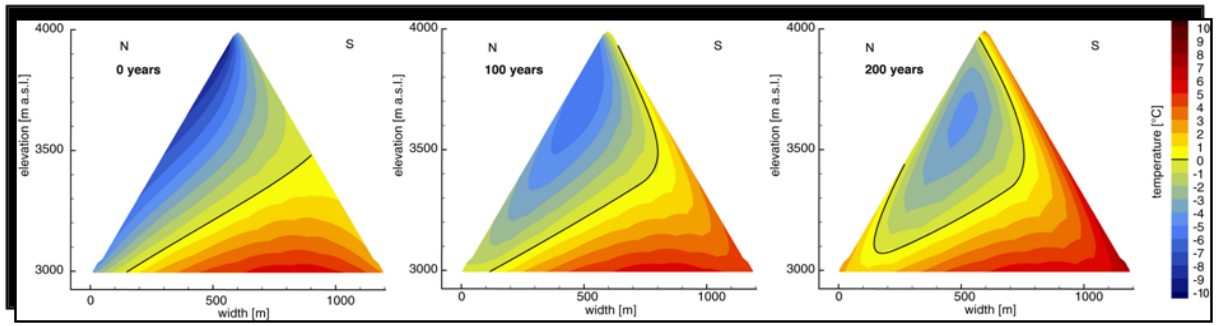




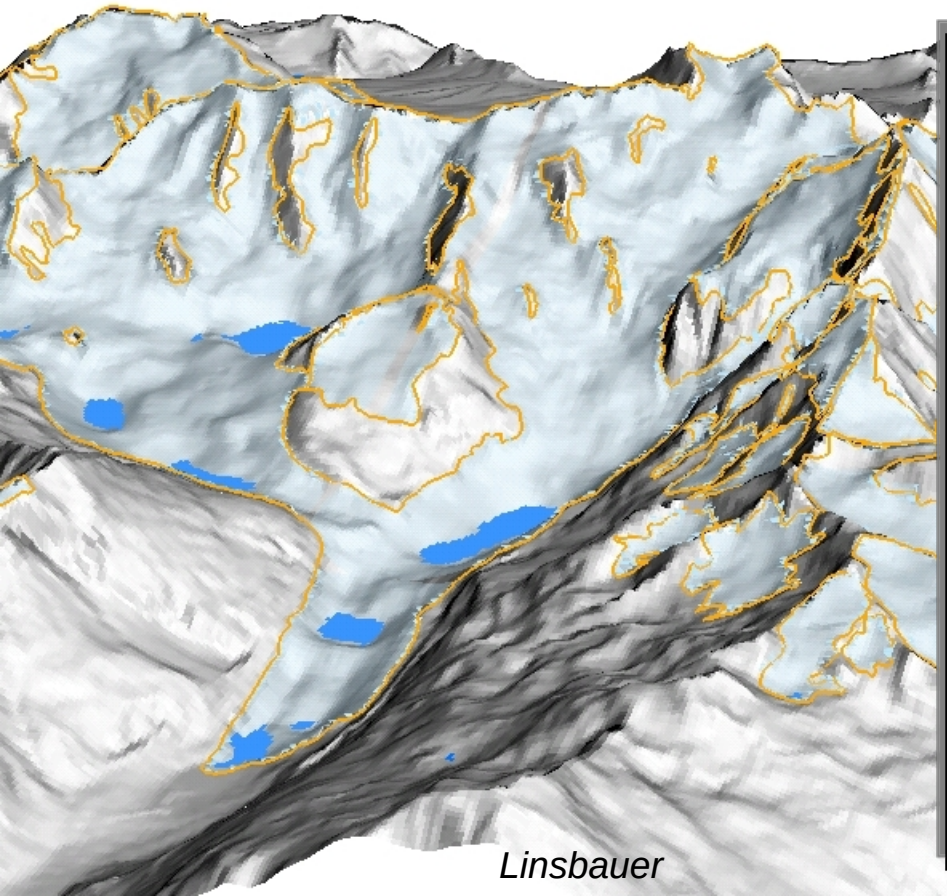


IPCC 2007

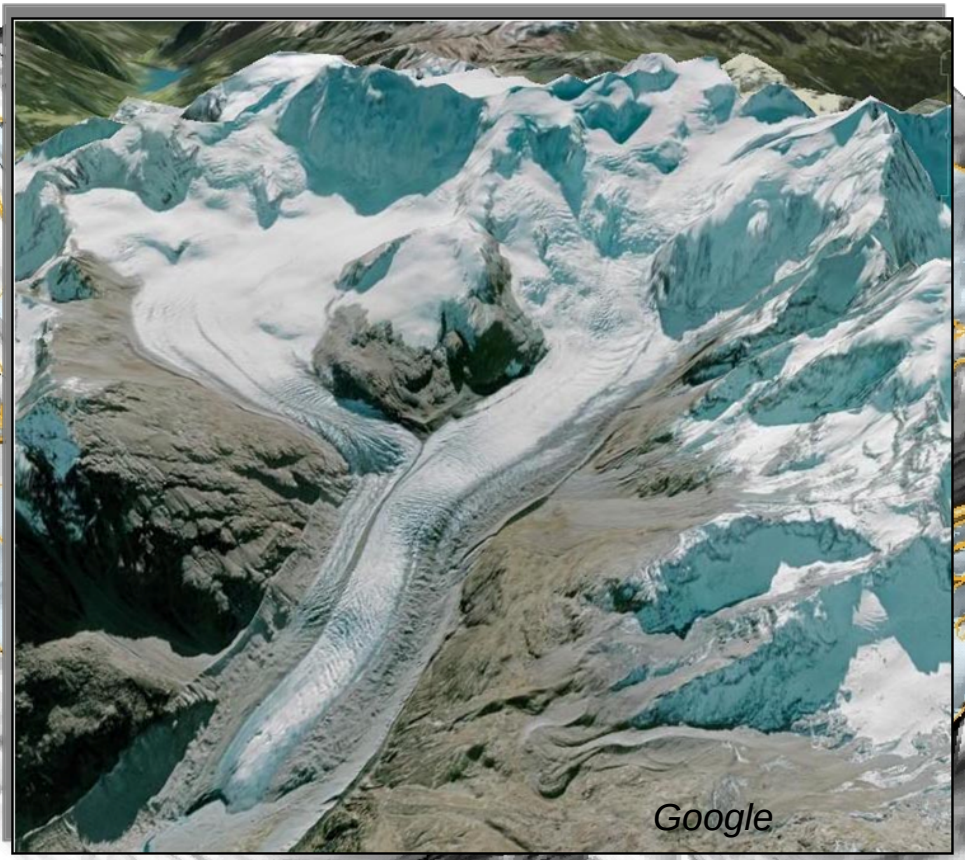


Noetzli

Bernina



Linsbauer



Google

Assessing hazards in high-mountain areas

Phenomena

length changes

glacier floods

ice avalanches

rock avalanches

debris flows

combined events!

Goals

overview

priorities

responsibilities

risk acceptance

observing system

- Systematic overview
- Illustrative cases
- Principal challenges

focus on lakes

special emphasis on rock avalanches

Systematic overview

1. Lake types
2. Dam characteristics
3. Outburst mechanisms
4. Downvalley processes
5. Process chains

1. Lake types

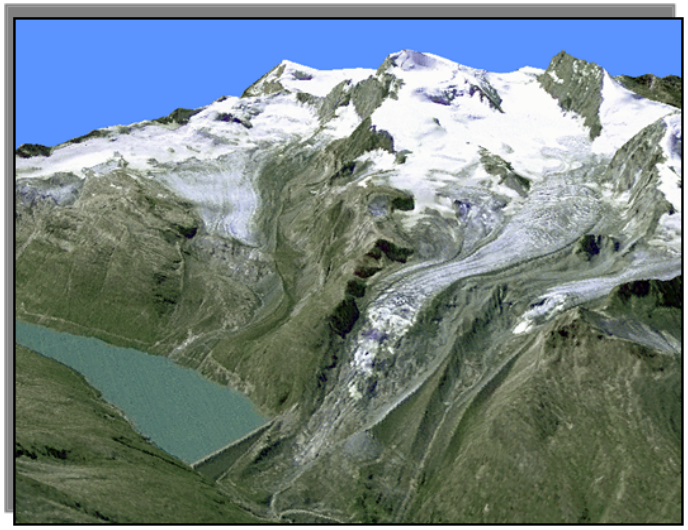
proglacial

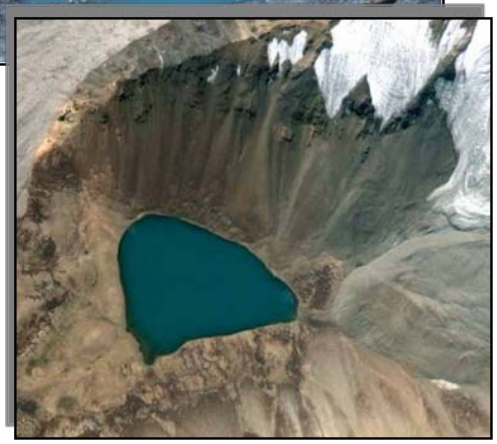
supraglacial

en/subglacial

(artificial)

ice-marginal





periglacial

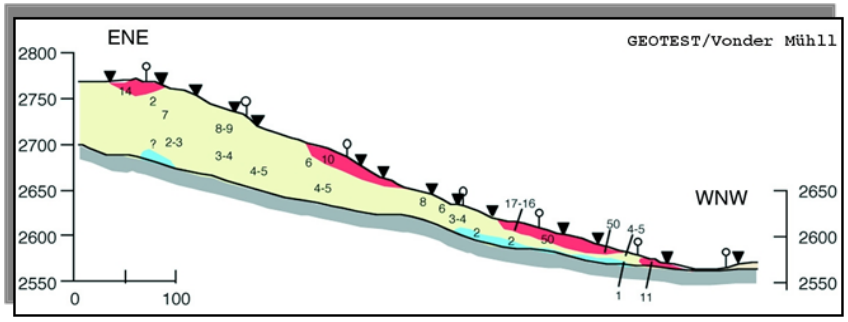
2. Dam characteristics

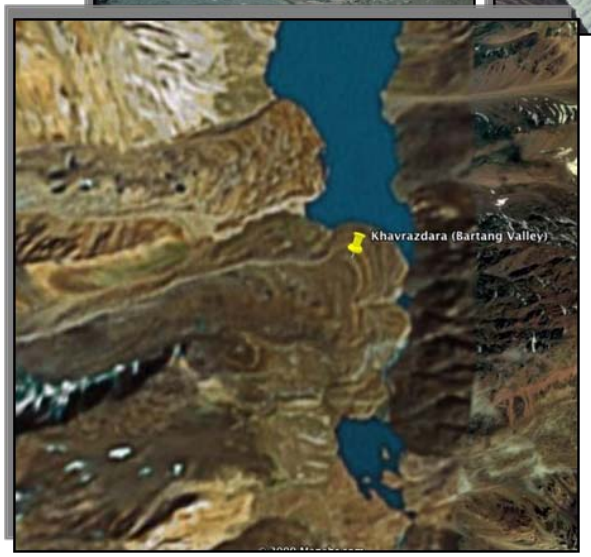
bedrock

solid ice

broken ice

moraine: frozen
unfrozen
consolidated
loose





rock glacier

landslide

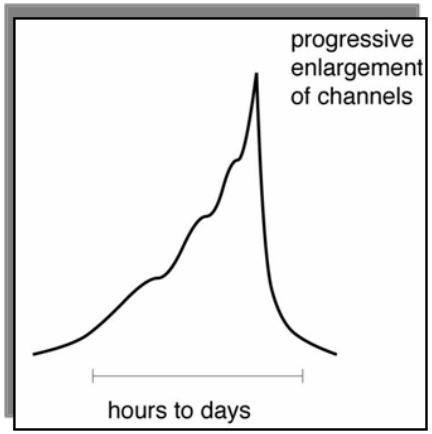
dead ice

slow mass movement

3. Outburst mechanisms

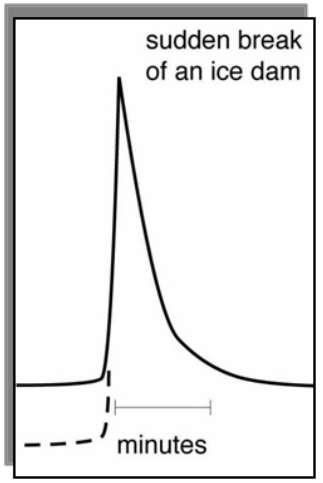
overtopping

impuls wave from
ice/rock avalanches*
or moraine slides



progressive
enlargement
of basal ice
channels

$Q_{max} < 46\ (V/10^6)^{0.66}$



sudden rupture

$Q_{max} < V/1000$ sec

moraine breaching

$Q_{max} < 2V/1000$ sec

slope failure

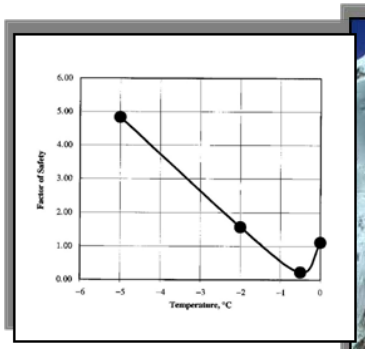
retrogressive erosion

piping

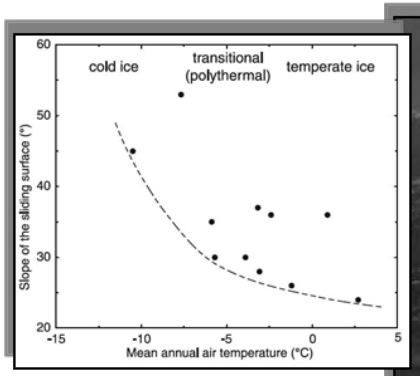
$F\ (m/h, \tan \phi, \tan \beta^{-1})$

$I_c = (\gamma\text{-}1)/(1+n)$

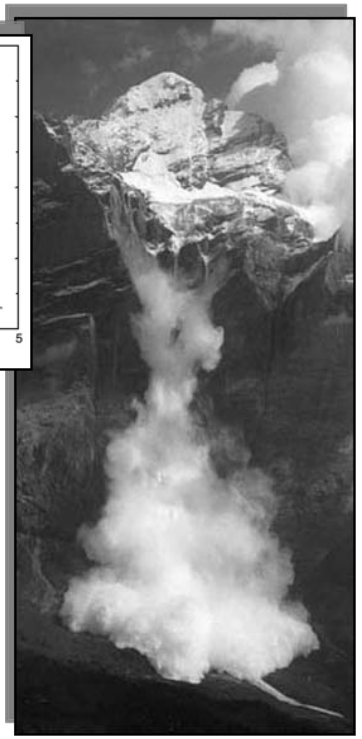
* Special on ice/rock avalanches

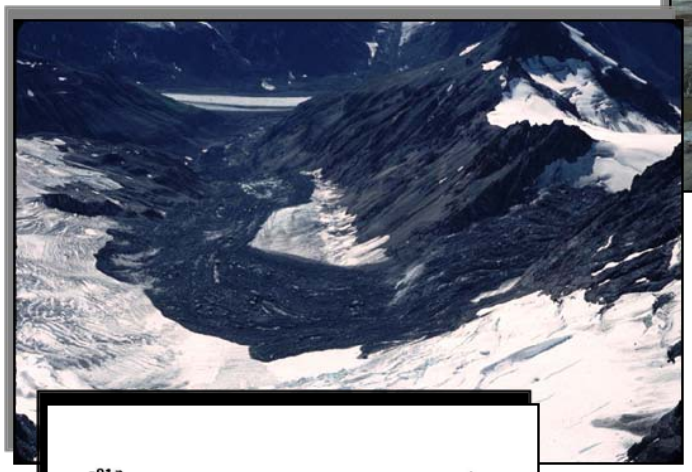


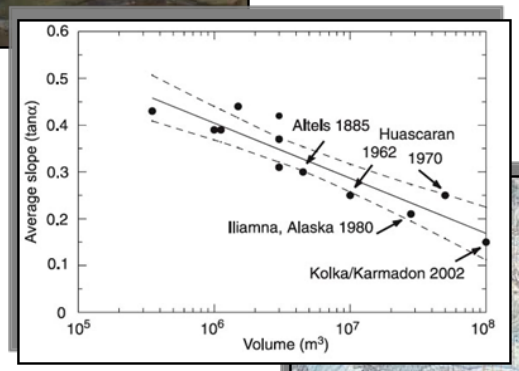
ice/
rock

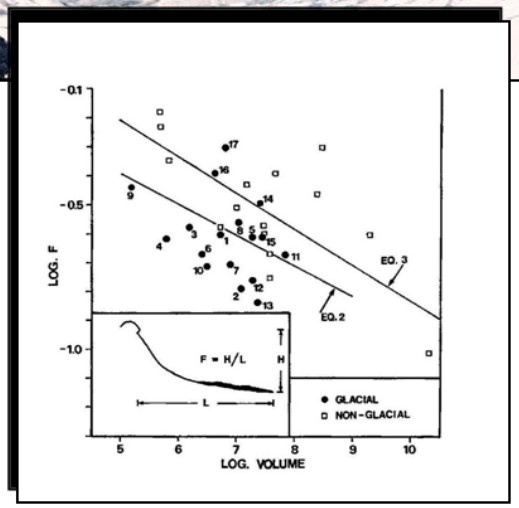


ice

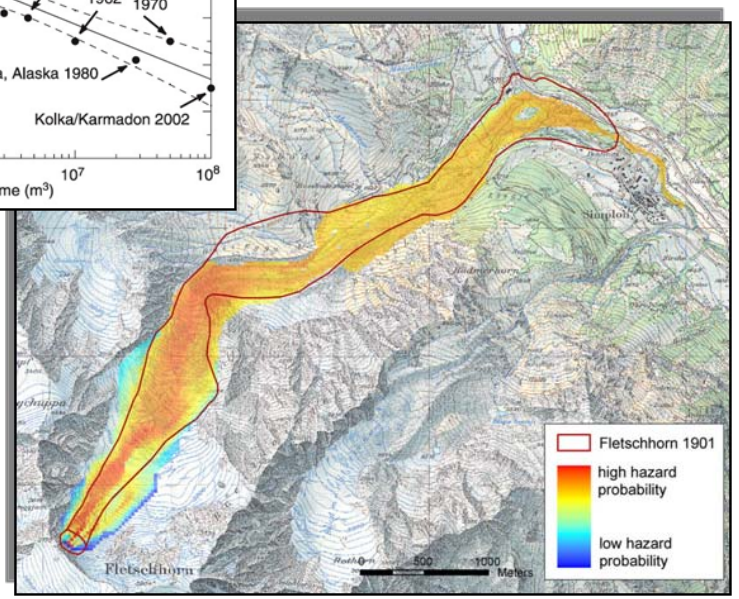




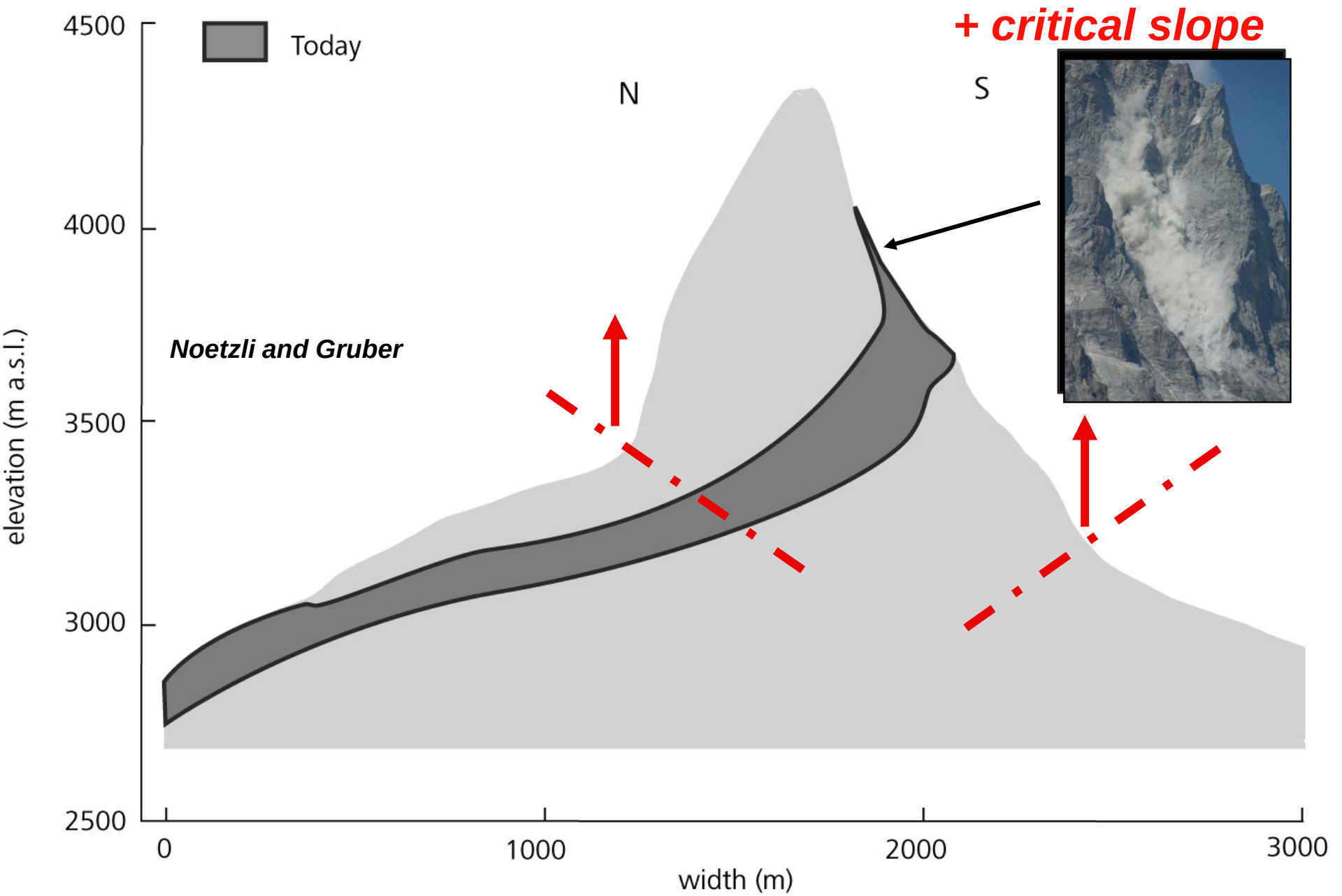




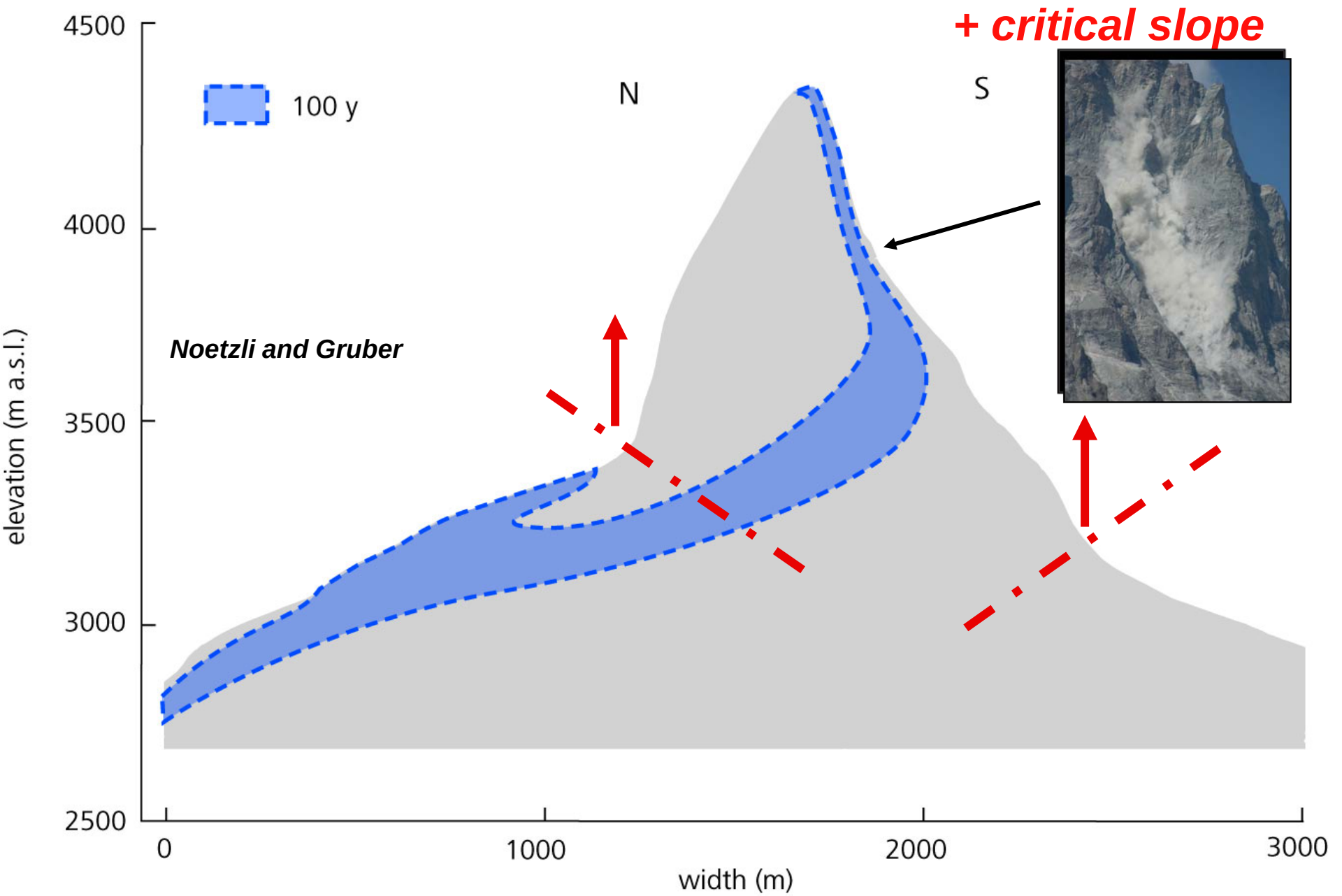
rock
on
ice



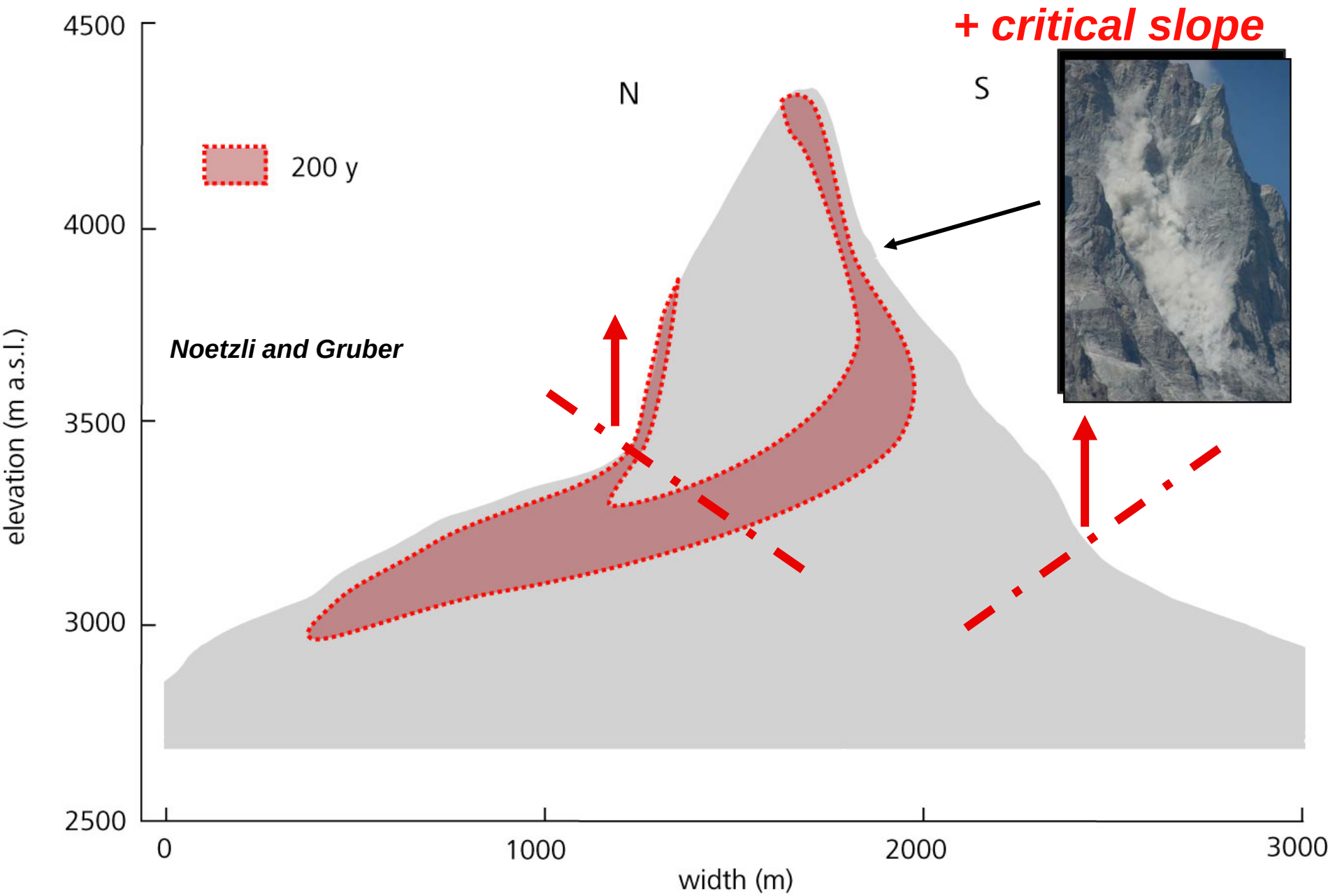
Matterhorn: critical temperature



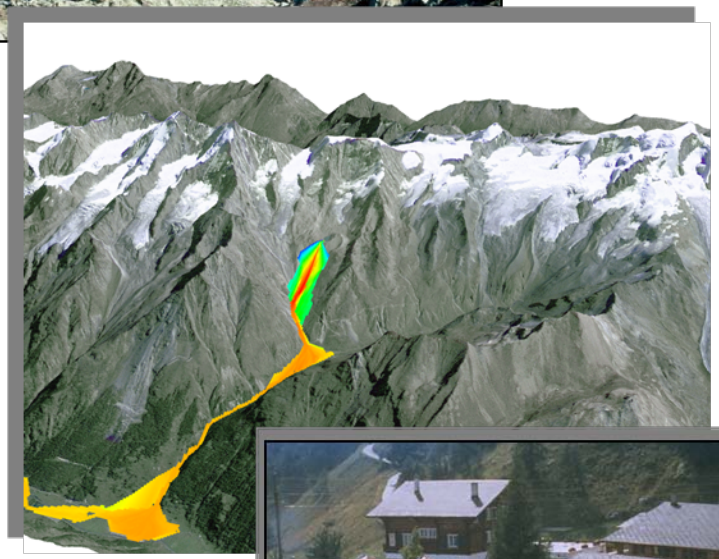
Matterhorn: critical temperature



Matterhorn: critical temperature



4. Downvalley processes



debris flow

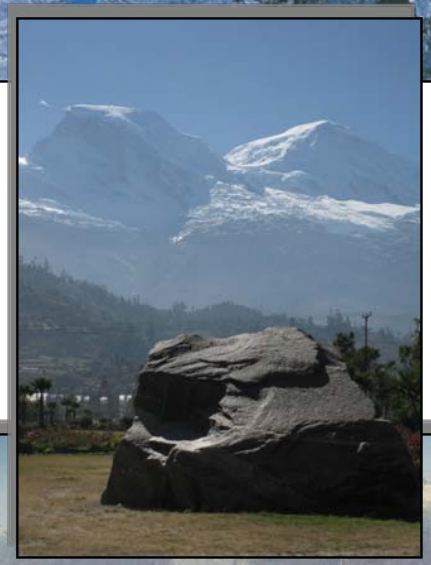
flood wave

lahar

5. Process chains

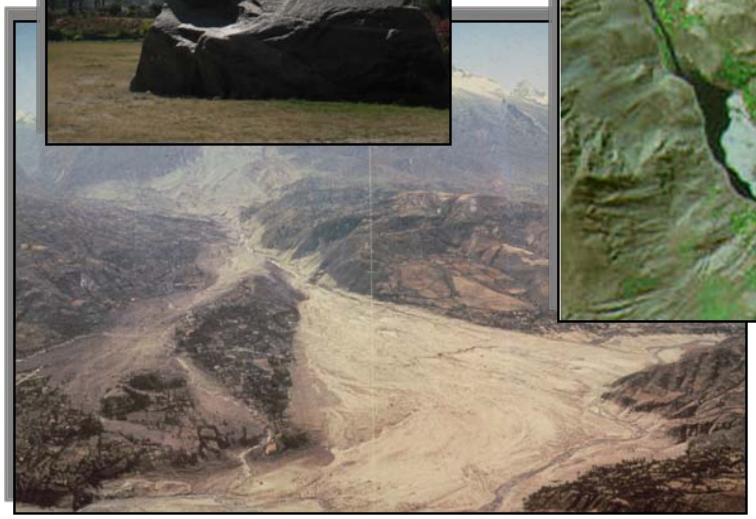
snow avalanche trigger

series of lakes

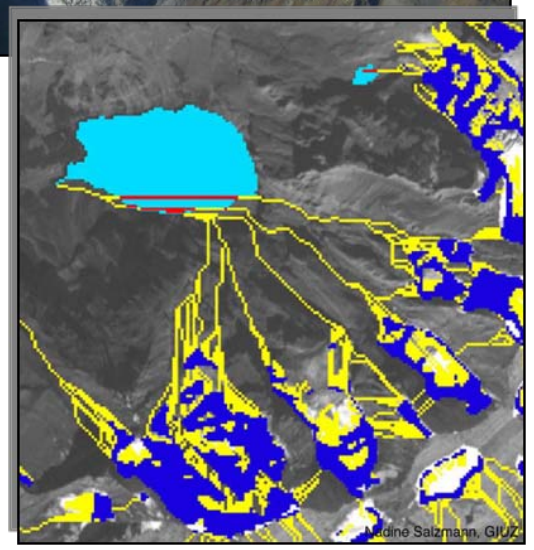


flow transformation

glacier erosion



river damming



impact wave

Illustrative cases

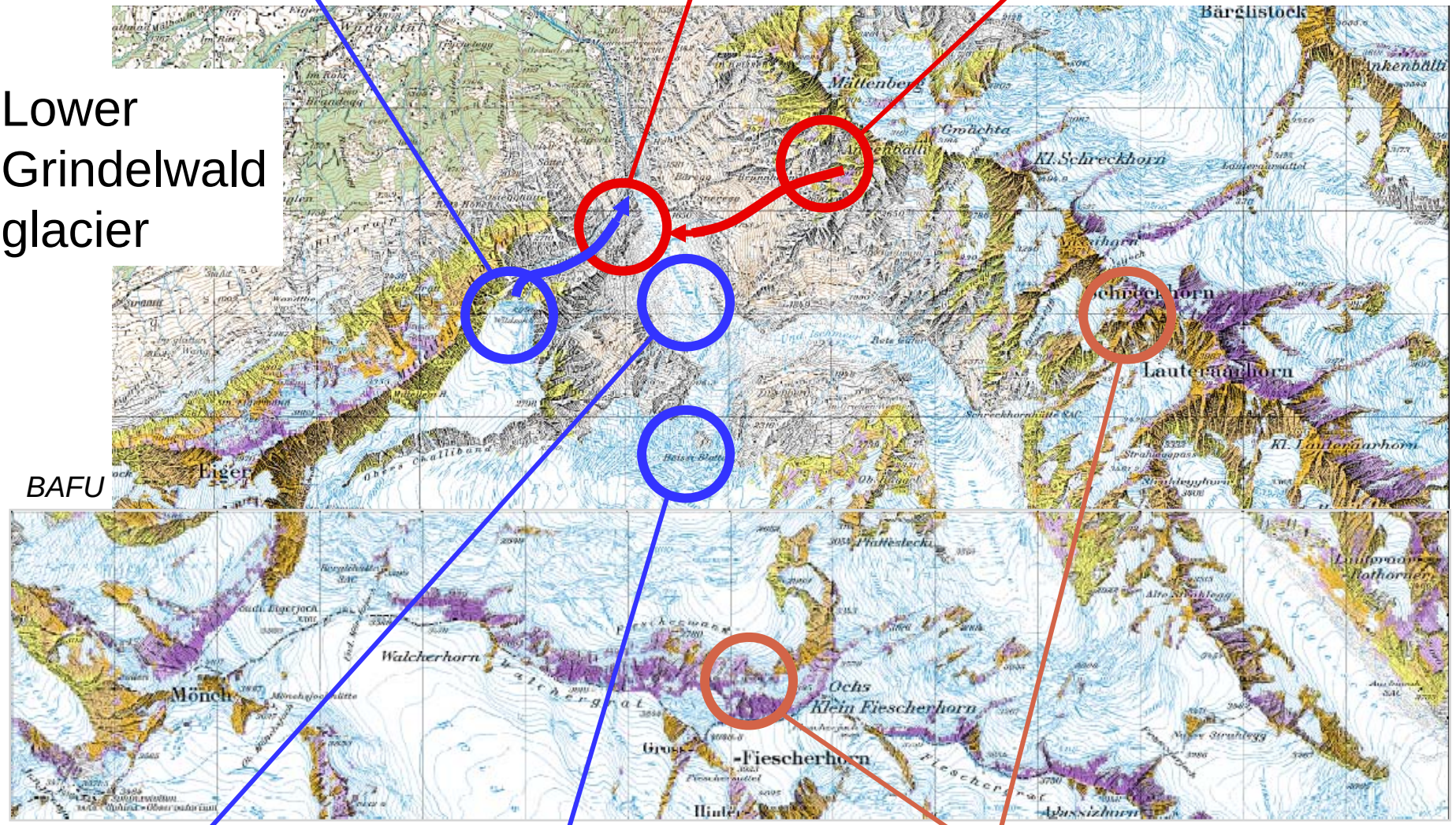
Lower Grindelwald glacier

Ice avalanches from hanging glacier

Rock instability following glacier shrinkage

Debris flows from degrading permafrost

Lower Grindelwald glacier



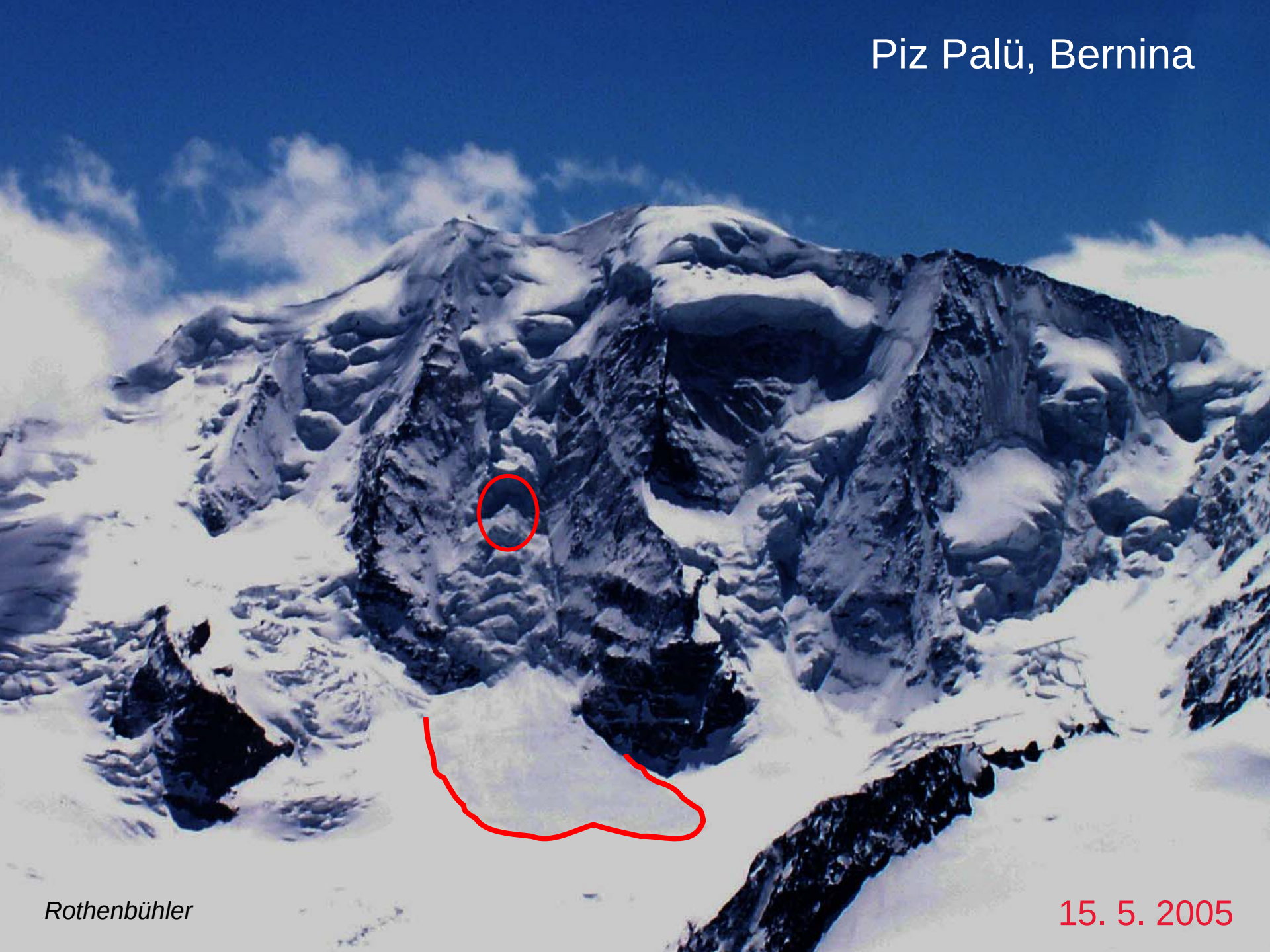
BAFU

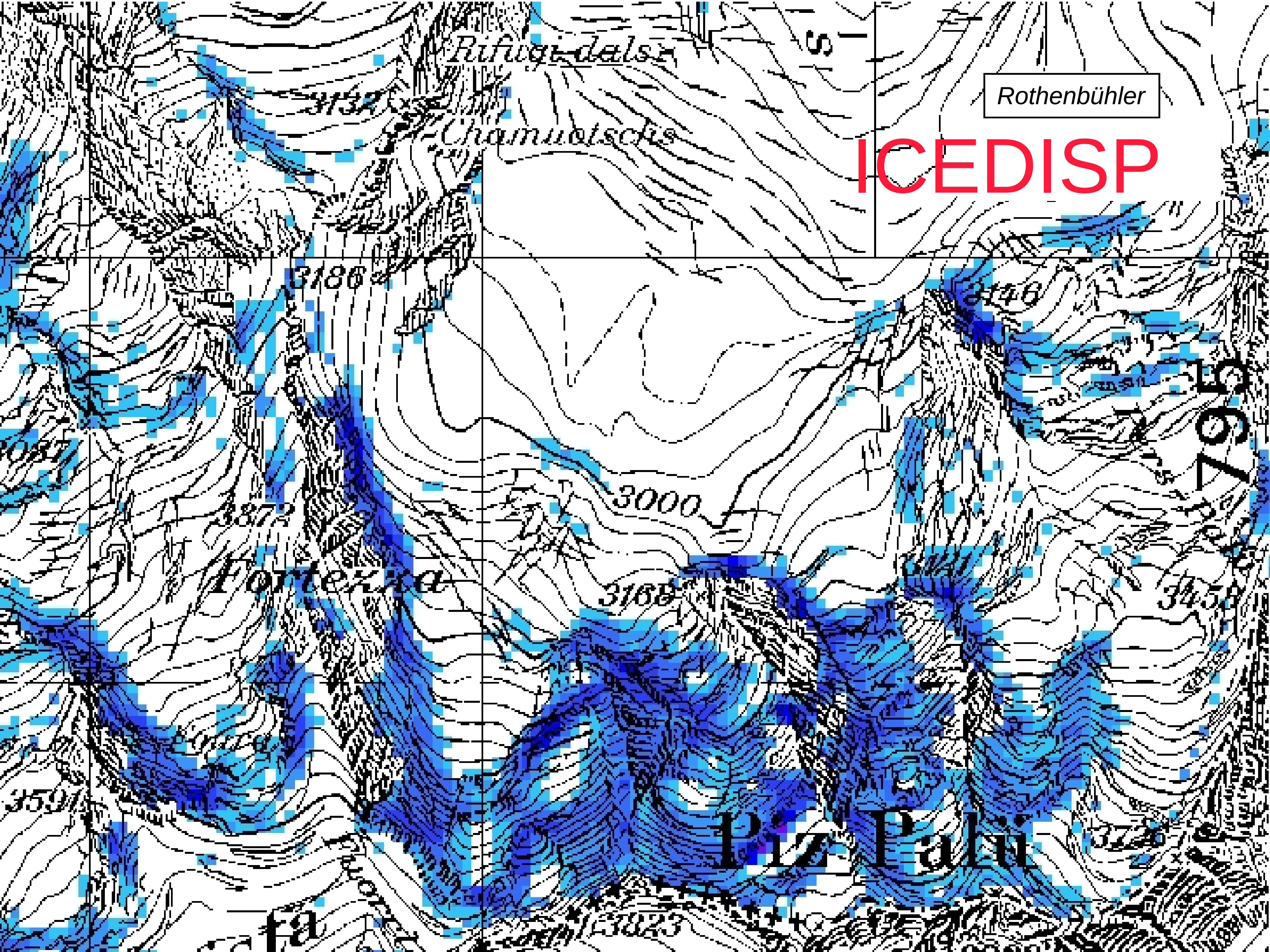
Lake formation on debris-covered glacier

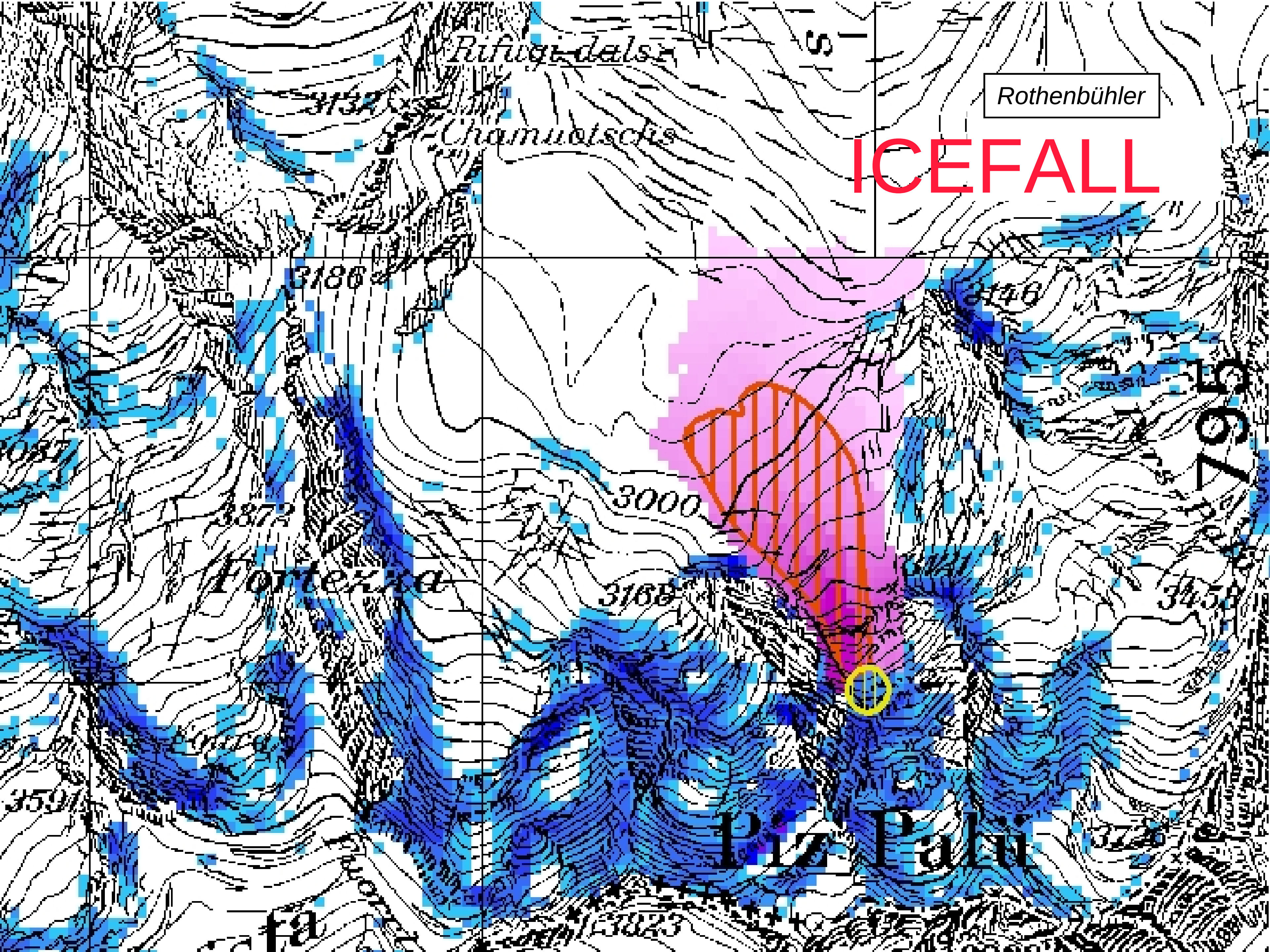
Rock falls from permafrrost onto glaciers

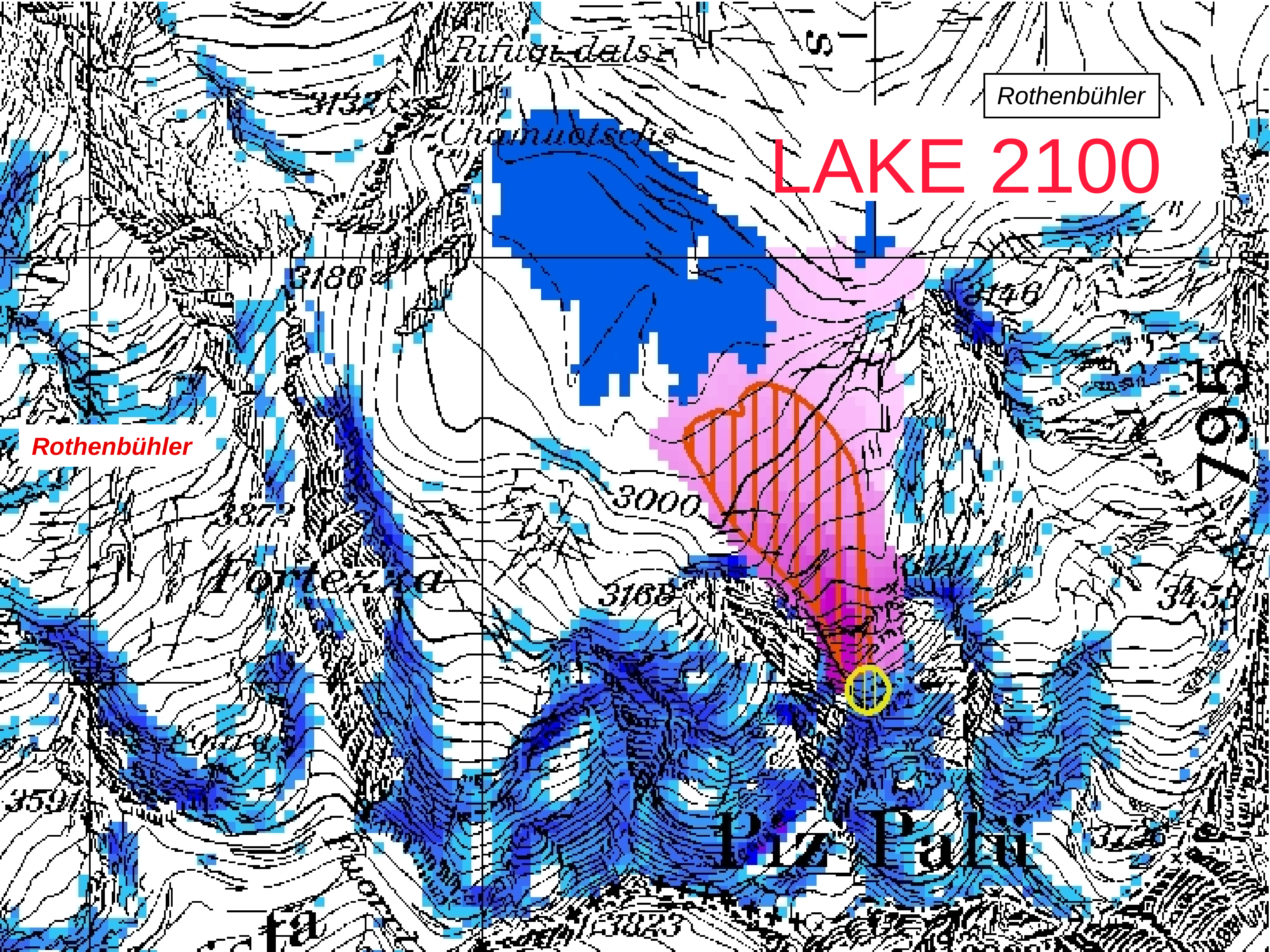
Process chains?

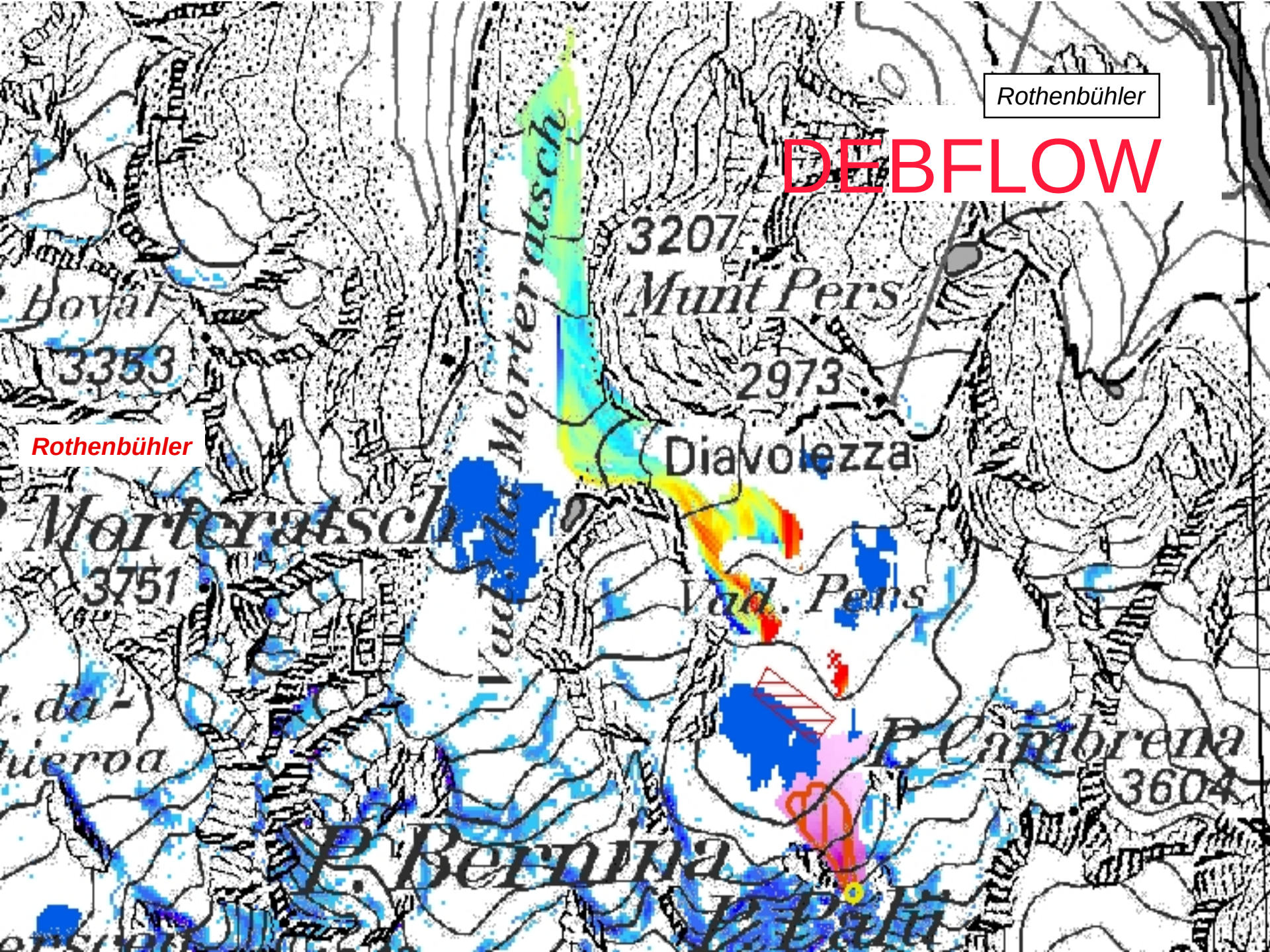
Ice avalanches from steep hanging glaciers


Piz Palü, Bernina
Rothenbühler
15. 5. 2005


Rothenbühler
ICEDISP
Chamuotschs
3186
3000
Fortezza
Piz Palü
795
3823


Rothenbühler
ICEFALL
3186
3000
3169
Piz Palü
3823


Rothenbühler
LAKE 2100
Rothenbühler
3186
3000
Fortezza
Piz Palü


Rothenbühler
DEBFLOW
Rothenbühler
3207
Munt Pers
2973
Diavolezza
Vad. Pers
3353
3751
3604

Primary challenges

- Complex situations to be assessed -
  check list of processes and phenomena
- Interactions and process chains to be considered -
  integrated and comprehensive approach
- Evolution beyond empirical historical/Holocene knowledge basis -
  future-oriented scenario calculation
- Policy-oriented work
  understandable language



Overviews:

Clague, J.J., and Evans, S.G. (2000): A review of catastrophic drainage of moraine-dammed lakes in British Columbia. QuarternaryScience Reviews 19: 1763-1783.

Evans, S.G., Clague, J.J. (1994): Recent climatic change and catastrophic geomorphic processes in mountain environments. Geomorphology 10: 107-128.

Gruber, S., and Haeberli, W. (2007): Permafrost in steep bedrock slopes and its temperature-related destabilization following climate change. Journal of Geophysical Research 112: F02S18 (doi:10.1029/2006JF000547).

Haeberli, W. (2005): Investigating glacier-permafrost relationships in high-mountain areas: historical background, selected examples and research needs. In: Harris, C. & Murton, J. B. (eds): Cryospheric Systems: Glaciers and Permafrost, The Geological Society of London, Special Publication. 242, 29-37

Huggel, C., Haeberli, W., Kääb, A., Bieri, D. and Richardson, S. (2004): An assessment procedure for glacial hazards in the Swiss Alps. *Canadian Geotechnical Journal*, 41, 1068-1083.

Kääb, A. , Huggel, C., Fischer, L., Guex, S., Paul, F., Roer, I., Salzmann, N., Schlaefli, S., Schmutz, K., Schneider, D., Strozzi, T., and Weidmann, Y. (2005): Remote sensing of glacier- and permafrost-related hazards in high mountains: an overview. Natural Hazards and Earth System Science 5; 527-554.

Kääb A., Reynolds, J. M. and Haeberli, W. (2005): Glacier and permafrost hazards in high mountains. In: Huber, U. M., Burgmann, H. K. H. and Reasoner, M. A. (eds): Global Change and Mountain Regions (A State of Knowledge Overview). Springer, Dordrecht: 225-234.

McKillop, R.J. and Clague, J.J. (2006): A procedure for making objective preliminary assessments of outburst flood hazard from moraine-dammed lakes in southwestern British Columbia. Natural Hazards 41: 131-157

McKillop, R.J. and Clague, J.J. (2007): Statistical, remote sensing-based approach for estimating the probability of catastrophic drainage from moraine-dammed lakes in southwestern British Columbia. Global and Planetary Change 56.

Zemp, M., Roer, I., Kääb, A., Hoelzle, M. Paul, F. and W. Haeberli (2008): Global glacier changes: facts and figures. UNEP and WGMS, Nairobi and Zurich.

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