Dealing with climate-change impacts on glacier and permafrost hazards: adaptation strategies in mountain regions

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For anticipation, and essentially the management, of natural hazards in the future, we need to know:

- location of events
- magnitude of events
- frequency of events

=> Important basis for future adaptation and mitigation actions
Content

• Effects of climate change, and related understanding and hazards:
  • glaciers
  • permafrost
  • interactions between surface and subsurface ice

• Adaptation strategies

• Mitigation options
Effects on glaciers

Retreating and decaying glaciers and lake formation and growth
=> Glacial lake outburst and floods
Effects on glaciers

Debuttressing/unloading effect due to glacier retreat
=> rock-/landslides

Findelen Glacier, Valais
Effects on glaciers

Retreating glaciers and uncovering of unconsolidated sediment => Debris flows

Kaltwasserpass, Valais

Guttannen, Bernese Alps, 2005
Effects on permafrost

Permafrost degradation and hydro-geologic implications in debris accumulations
=> Changes in debris flow activity
Effects on permafrost

Large rock avalanches from permafrost-affected rock walls: e.g. north-south exposed ridges

Brenva/Mt. Blanc 1997, Italy

Thurwieser 2004, Italy

Regione Lombardia
Effects on permafrost – glacier interactions

Permafrost and steep glacier interactions: glacierized high-mountain walls => large slope instabilities

Kolka-Karmadon Rock-ice avalanche, Caucasus 2002

I. Galushkin
Adaptation strategies

Comparatively well understood processes and developed tools

Glacial lakes

Monitoring

Understanding

Anticipation

active/passive adaptation and mitigation measures

Important gaps and uncertainties

Permafrost-affected rock walls
Adaptation strategies: glacial lakes - science

Monitoring
Understanding
Anticipation

1999

2000

2001

2003

Glacier lake detection, Cordillera Blanca, Peru

Trift glacier Lake: Satellite remote sensing: Landsat-TM, IKONOS, ASTER
Adaptation strategies: glacial lakes - science

Glacier retreat and glacial lake evolution

Monitoring
Understanding
Anticipation
Adaptation strategies: glacial lakes - science

Glacier retreat and lake outburst flood modeling and assessment

Monitoring
Understanding
Anticipation

Image processing & glacier outlines: F. Paul
Permafrost distribution: S. Gruber
Lake outburst modelling: C. Huggel
Rockfall avalanche: J. Noetzli
Adaptation strategies: permafrost-affected rock walls - science

Rock wall temperature measurements

Monitoring

Understanding

Anticipation
Adaptation strategies: permafrost-affected rock walls - science

Findings from centrifuge modeling on rock failure in permafrost conditions

Factor of safety
< 1 with T < 1.5°C
But:
FoS > 1 without ice

M. Davies, University of Dundee
Adaptation strategies: permafrost-affected rock walls - science

3D temperature distribution modeling for conditions in depth

Thurwieser, Italy

[Graph showing temperature distribution in permafrost-affected rock walls with North (N) and South (S) orientations and elevation in meters above sea level (m a.s.l.)]
Adaptation strategies: permafrost-affected rock walls - science

Projected temperature change in depth of a North-South ridge situation (i.e. similar to Thurwieser, Brenva)
Adaptation and mitigation strategies: decision-makers

- Land-use planning
- Structural protection measures
- Warning systems
- Vulnerability and risk assessments
- Preparedness (emergency plans etc.)
- Relocation

Saas Almagell, Valais, 1953
Saas Almagell, Valais, 1980
Täsch, Valais, protection dam
Adaptation strategies: decision-makers

Land-use planning

Structural protection measures

Warning systems

Vulnerability and risk assessments

Preparedness (emergency plans etc.)

Relocation

Cordillera Blanca, Peru
Adaptation strategies: decision-makers

Cordillera Blanca, Peru

Huascarán, 1970

Relocation
Adaptation strategies: decision-makers

Colombia: Relocation? – Alternatives?

Nevado del Ruíz/Armero, 1985

Ibagué/Combeima, June/July 2006

Relocation

Janda, USGS

Cruz Roja Colombiana
Conclusions

• Climate change strongly affects cryospheric systems on the surface and thus directly observable in the sub-surface and often only indirectly observable in coupled systems (glacier-permafrost) all having potentially severe impacts in terms of hazards.

• Methods and tools for hazard monitoring and assessment have been developed for much longer time in relation with glaciers than with (mountain) permafrost.

• Monitoring, understanding, modeling and anticipation/prediction can be viewed as an integrative part of adaptation efforts, and has to be considered for taking further measures.

• The choice of adaptation and mitigation measures is often limited by economic, social or cultural conditions of a region/country. In general, a shift from high-cost to low-cost measures may be necessary.
Thanks for your attention!

Studies presented here were partly funded by the Swiss National Science Foundation and the Swiss Agency for Development and Cooperation.