MultiRISK: An innovative Concept to model Natural Risks

T. Glade & K. v. Elverfeldt
Department of Geography, University of Bonn, Germany

ABSTRACT: Analysis of natural risks in arctic and alpine regions includes the study of typical natural processes such as snow avalanches, slush flows, rock falls, shallow landslides, and debris flows. Commonly, the respective processes are modeled individually which might lead to misjudgement of the general natural risks in a specific area. Therefore, fundamental research is needed regarding integrative and multi-processual modeling of natural risks. The aim of this project is to attain a comprehensive, modular risk analysis tool to quantify different natural risks for one area. This software system will be developed in Northwest Iceland and applied to calculate scenarios of global warming and land-use change.

1 INTRODUCTION

In Iceland, natural processes such as snow avalanches, slush flows, rock falls, shallow landslides, and debris flows occur frequently. Although these processes are characterized by varying occurrence in time and space, they result in a constant threat to people and infrastructure. Official statistics denote at least 680 casualties by snow avalanches since 1118, but the real number is estimated to be much higher (Jóhannesson 2001). In 1995, two catastrophic snow avalanches in Súðavik and Flateyri caused 34 casualties. But also slush flows, rock falls, and debris flows are endangering life (Jóhannesson 2001). At the same time, the consequences of global warming and land-use change are completely unknown.

Commonly, the respective processes are modeled individually (Fuchs et al. 2001). Some examples are Aval1-d /2-d and SAMOS for snow avalanches (e.g. Christen et al. 2002, Jóhannesson et al. 2002, Tracy & Jóhanneson 2003), Rocfall, STONE and CRSP for rock falls (e.g. Guzzetti et al. 2002, Jones et al. 2000, respectively), dfwalk and flo-2d for debris flows (e.g. Gamma 2000, O'Brien et al. 1993, respectively), and SINMAP for shallow landslides (e.g. Pack & Tarboton 2004), to name a few models only. In this respect it is of particular importance that the respective processes can not be modeled with the same accuracy regarding their magnitude and frequency as well as location and extent of runout zones.

Hence, fundamental research is needed regarding integrative and multi-processual modeling of natural risks. A comprehensive, modular risk analysis tool with a high temporal and spatial resolution is of great importance to avoid misjudgement of general natural risks in a specific area.

2 STUDY AREA

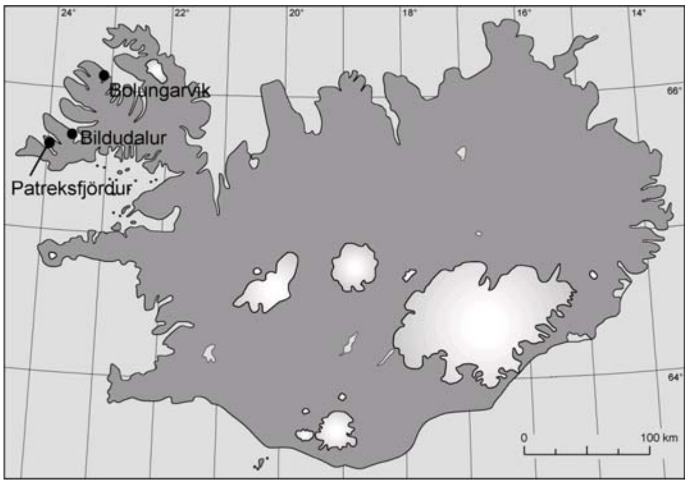

Figure 1. Study area in the Westfjords, Iceland.

The main study area Bildudalur is situated in the Westfjords in Northwest Iceland (Figure 1). Criteria for choosing the study area were (1) the general threat by snow avalanches, slush flows, rock falls, shallow landslides, and debris flows (Figure 2) and (2) data availability for risk calculation. Bildudalur is situated along the northern shoreline of Bildudalsvogur within the Arnarfjördur fjord in the southern part of the Westfjords (lat. 65.4°, long. 23.6°) (Bell & Glade 2004) (Figure 3). Above the village an extensive plateau rises up to 460m a.s.l. The mountainside is dissected into two large and several smaller gullies (Figure 3), comprising the respective debris cones. The lithology consists of various basaltic layers with parallel and nearly horizontal bedding.

Periglacial, gravitational and fluvial processes are dominant (Bell & Glade 2004, Glade & Jensen 2005).

Figure 2. Example for the general threat of rock falls in Bildudalur.

The maritime climate with a mean annual air temperature of 3° C is characterized by cool summers and mild winters. Precipitation amounts to approximately 1250mm (Glade & Jensen 2005).

In the 18^{th} century, settlement has started. Today, almost 300 people are living in Bildudalur. Fishery is the main economic factor.

Two spectacular natural events are exemplifying the general threat within Bildudalur (Bell & Glade 2004, Glade & Jensen 2005). In February 1939, a slush flow passed the schoolhouse, captured the headmaster and brought him to the sea where he was rescued. In December 1971, a boulder bounced towards a house, moving through the door, rebounding on the floor and finally stopped on a bed. Luckily, the owner was staying in the kitchen.

The model development and adjustment is carried out in Bíldudalur. For model validation the two villages of Bolungarvik and Patreksfjördur have been chosen (Figure 1).

Figure 3. Photography of Bildudalur, view towards northwest.

3 MULTIRISK: THE CONCEPT

Within risk analyses, processes are commonly modelled and visualised individually in different software systems (e.g. Stötter 1999). Therefore, the aim of this project is to attain a computer-based, modular natural risk model for different processes. GIS-systems such as ArcGIS are especially suitable due to their open structure.

The respective process models will be integrated as separate modules in an open GIS-platform, hence, interfaces have to be programmed as independent scripts. Calculation of the specific processes will take place in the respective modules. This is the specific importance of the project: Due to the modular structure of the GIS-platform a transfer to other regions (potentially including other processes) is possible. Relevant process parameters have to be defined, e.g. height and density of snow cover, lithology, rock shapes and sizes, precipitation, and surface roughness. All calculations are based on a DEM of at least 10m grid size.

As part of a general natural hazard analysis, the occurrence of single processes in space and time has to be determined for specific magnitudes and intensities. Using DEMs and process parameters, hazard run-outs will be calculated and hazard zones derived. Joining the single hazard maps within the GIS results in multi-hazard maps. Zonation depends on the magnitude and frequency of the respective process, so that different scenarios are possible.

Data on the natural risk due to rock falls, debris flows and snow avalanches is readily available (Bell & Glade 2004). For debris flows and rock falls risk is calculated following a function of the input parameters hazard (H), vulnerability (of people (V_{pe}), property (V_p), and infrastructure (V_{str})), probability of the temporal impact (P_t), probability of the seasonal occurrence (P_{so}), and damage potential (number of people (E_{pe} or E_{ipe}), economic value (E_p)). Snow avalanche risk analysis is based on a preliminary snow avalanche map with two resulting hazard zones (Bell & Glade 2004).

Combining hazard maps with risk elements (e.g. people, houses, roads), their damage potential, and their vulnerabilities to the respective process, risk maps will be achieved. Risk elements have been classified into three groups: (1) population, (2) property, and (3) infrastructure. Data for the damage potential of properties and infrastructure in Bildudalur was obtained from Icelandic statistics (Table 1).

Table 1: Damage potential in Bildudalur.

Risk elements	Damage potential
Roads	396 € / m²
Powerline	36 € / m²
Buildings	240 - 1480949 € / building

Vulnerability assessment is crucial within any risk analysis. Commonly, vulnerability values can only be estimated, which is particularly true for landslide risk analysis (Glade 2003). For Bildudalur, vulnerability values are determined based on the process and its magnitude (debris flow and rock fall) or hazard (snow avalanches). Respective figures are given in Table 2. For detailed discussion of the multi-hazard analysis in Bildudalur refer to Bell & Glade 2004.

The general concept is visualized in Figure 4.

4 MULTIRISK: INNOVATIVE ASPECTS

MultRISK offers several innovations on the conceptual as well as the scientific level. Conceptually, the first innovative aspect is the development of a software system with (1) modular integration of all process models, (2) risk calculation, and (3) utilization of a joint database. Secondly, the open conceptual structure results in different application levels. Calculation can take place on the level of single processes as well as groups of processes, and on the scale of a specific object as well as on a regional scale.

Scientifically, the challenge is (1) to derive an impartial, repeatable, and comprehensible calculation of multiple natural risks. (2) In particular, MultiRISK offers the opportunity to quantify consequences of land-use and climate change.

The MultiRISK project has just started in October 2004. It is aimed to use existing process models for natural hazard analysis. Currently, negotiations are underway with different developers. First results might be expected by end of 2005.

Table 2: Vulnerability values used within this study (Note: Vstr = vulnerability of roads and infrastructure, Vp = vulnerability of properties, Vpe = vulnerability of people, and Vpep = vulnerability of people in buildings; high (1) = 10 year event of the high hazard class, high (2) = 150 year event of the high hazard class) (Bell & Glade 2004).

Hazard	*low*				*medium*				*high*			
Process	V_{str}	V_p	V_{pe}	V_{pep}	V_{str}	V_p	V_{pe}	V_{pep}	V_{str}	V_p	V_{pe}	V_{pep}
Debris flow	0.2	0.1	0.2	0.02	0.4	0.2	0.3	0.06	0.6	0.5	0.5	0.25
Rock fall	0.1	0.1	0.2	0.02	0.2	0.3	0.4	0.12	0.4	0.5	0.5	0.25
Hazard	*low*				*high(1)*				*high(2)*			
Process	V_{str}	V_p	V_{pe}	V_{pep}	V_{str}	V_p	V_{pe}	V_{pep}	V_{str}	V_p	V_{pe}	V_{pep}
Snow avalanche	0.3	0.3	0.5	0.15	0.1	0.3	0.1	0.03	0.8	1.0	1.0	1.0

The resulting risk maps can be displayed either for a single process or a process group or for a single object at risk or a large region (refer to Bell & Glade 2004 for examples).

The model will be calibrated with the results of a mapping and survey campaign in Bildudalur. Validation will take place in Bolungarvik and Patreksfjördur.

Following the development, calibration and validation of the model risk scenarios of land-use or climate change will be calculated. The calculations will be based on data from global climate models and on scenarios of the study areas, respectively. This results in a quantification of possible future risks.

5 CONCLUSIONS

Commonly, the consequences of global warming and land-use change are estimated. MultiRISK offers the opportunity to quantify present and future risks within a given area. Furthermore, the open, modular structure offers the opportunity to include other process models and thus to transfer MultiRISK to other regions than Iceland.

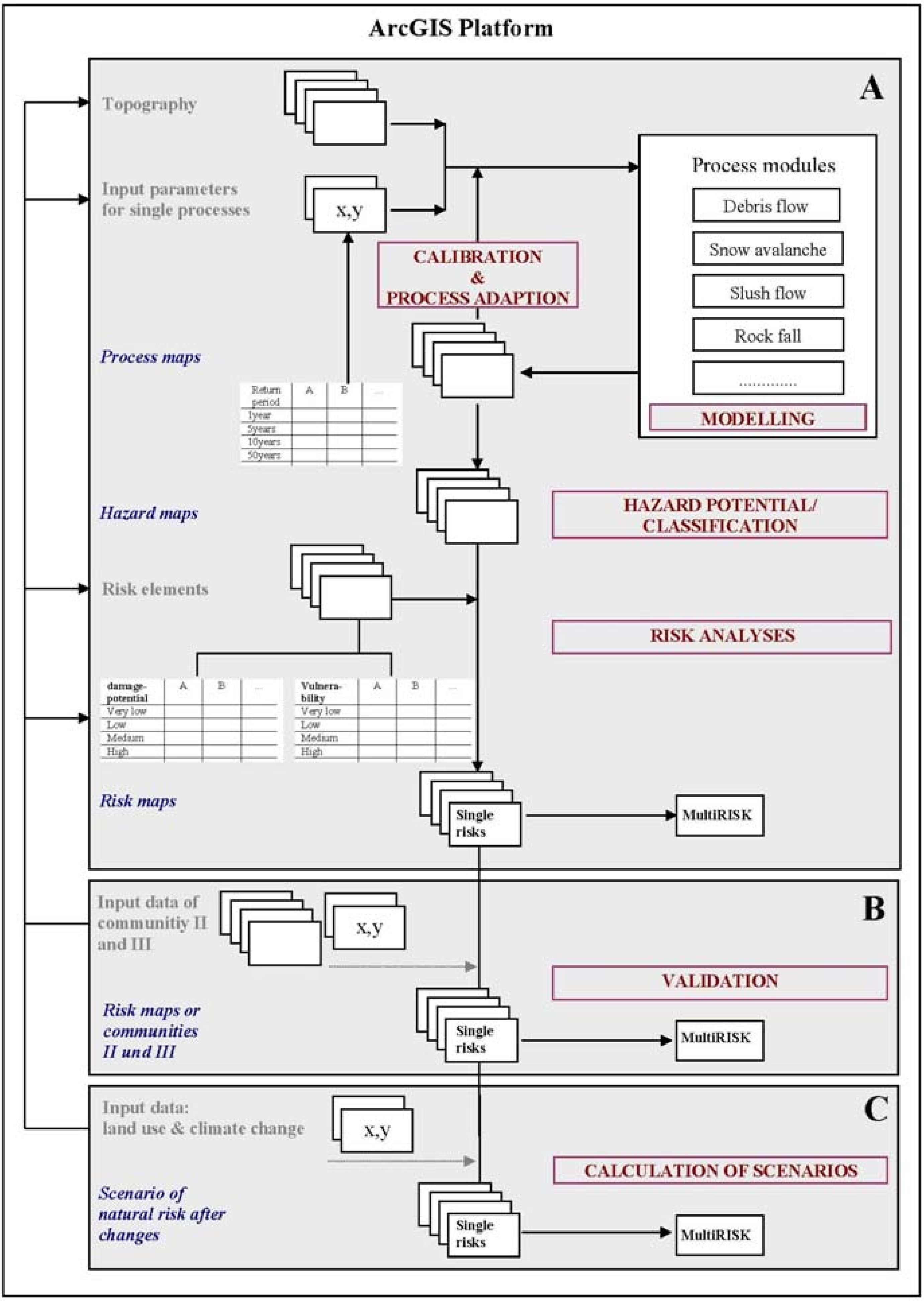

Figure 4. Conceptual flow chart of MultiRISK and procedure.

6 ACKNOWLEDGEMENTS

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