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Diverse natural hazards – high human and economic losses

The Obishur watershed in Muminabad district, Tajikistan, experienced severe losses after a flood in spring 2012 (S. Odinashoev)

Mountain systems are very diverse and so is the pattern of natural hazards. Worldwide disaster databases show that associated human and economic losses are significant but vary greatly between and within mountain regions. Continued changes in climate, land use and socio-economic conditions are likely to lead to vastly altered mountain landscapes in the future, with associated implications for hazards and impacts on sustainable mountain development.

Mountains are high-risk environments and they experience multiple hazards, many of which are exclusive to mountain regions (Box 1). Seismic and volcanic activities, geology, topography, climate, vegetation and land use determine the variety, intensity and dimension of hazards. Multiple hazards can occur in one place, and one event can trigger others. The pattern can vary greatly from one mountain region to another, and from one valley to another. This makes it difficult to capture the diversity of hazard environments and to provide an overview of the enormity of hazard events in mountains worldwide. In the following, we draw on two global databases that register geophysical and hydrometeorological hazards with significant social and economic impacts. Nonetheless, the insights present only a part of the whole picture: The databases do not register small-scale but frequent events, nor do they reveal the socio-economic drivers of the disasters.

BOX 1 I Natural hazards in mountains and lowlands

(categories adapted from www.desinventar.net)

Hazard category	Mainly in mountains	In mountains and lowlands	Mainly in lowlands
Geophysical	Rockfalls	Earthquakes, volcanic activities	Tsunami
Hydrological	Landslides (debris / mud flows), avalanches	Floods (riverine and flash)	Coastal floods
Meteorological		Cyclones, storms, hail, extreme temperatures, fog	Wave action
Climatological	Glacial lake outburst floods	Drought, wildfire	

High seismic activity destabilizes mountains

Mountains are often located in zones with elevated seismic activity and a high risk of volcanic eruption. Although mountains cover only about 22 percent of the world's land surface, more than 37 percent of the 4 491 significant earthquakes since the year 1800, and more than 80 percent of the significant volcanic eruptions have occurred in the mountains (Figure 1) [1, 2]. Overall, 55 percent of mountain areas worldwide (compared to 36 percent of non-mountain areas) are susceptible to destructive earthquakes [3]. Through their destabilizing effects, earthquakes often trigger cascading hazards, such as landslides.

Pattern and impacts of hydrometeorological hazards in five regions

Mountain regions are also highly prone to major hydrometeorologically induced disasters caused by mass movements (e.g. avalanches, landslides, debris flows), floods, storms, extreme temperatures and climatologically induced disasters (e.g. due to droughts and wildfires) (Figure 2). However, the following examples from five selected mountain regions (Hindu Kush Himalayas, Eastern African mountains, Andes, Central Asia and the European Alps) point out the heterogeneity of mountain "riskscapes". The data presented are based on the Global Emergency Disaster Database (EM-DAT, see Box 2).

Monsoon-triggered flooding in the Hindu Kush Himalayas

More than half of the major disasters in the Hindu Kush Himalayas are due to floods, followed by mass movements that account for about 30 percent of the registered events causing damage. Floods often occur during the summer months due to the monsoon, and affect mainly the northern parts of Afghanistan and Pakistan, northwestern India and western China. For example, the 2013 Kedarnath disaster in northern India was linked to the early onset of heavy monsoon rainfalls triggering the catastrophic outburst of a small moraine-dammed glacial lake [4]. In Nepal alone, 21 glacial lakes out of the identified 1 466 glacial lakes were assessed as potentially critical [5], with the risk of exposure to such events intensified by increasing infrastructure and habitation in the high mountain regions of the Hindu Kush Himalayas [6].

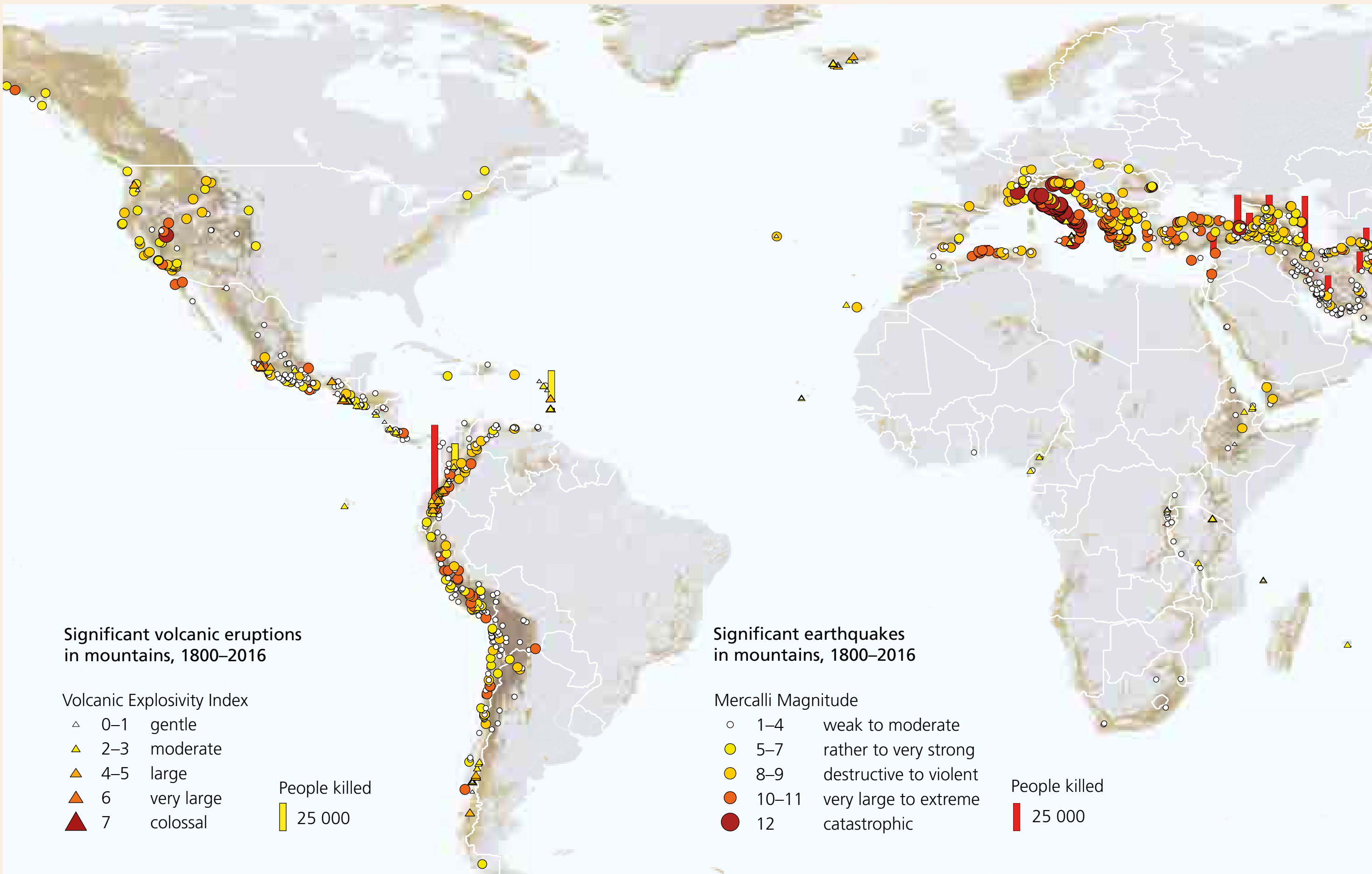
Eastern African mountains hit by droughts and floods

In the Eastern African mountains, disasters are most frequently triggered by floods (65 percent), followed by droughts (18.4 percent) and storms (8.6 percent). However, analysis of the registered disasters showed that drought-induced events affected about ten times more people than floods and storms. The frequency of drought events may be underestimated as they are more difficult to capture and do not destroy infrastructure. Experience from Kenya shows that droughts have a smaller impact in the highlands than in the lowlands because the topography

BOX 2 I Global Emergency Disaster Database (EM-DAT)

The EM-DAT is the most complete public global database on disaster loss for large events at the national scale [7]. It covers natural and technological disasters from 1900 onwards and is based on various reliable sources. EM-DAT includes all disasters conforming to at least one of the following criteria:

- 10 or more people died;
- 100 or more people affected;
- Declaration of a state of emergency or a call for international assistance.



Significant volcanic eruptions
in mountains, 1800–2016
Volcanic Explosivity Index
0–1 gentle
2–3 moderate
4–5 large
6 very large
7 colossal
People killed
25 000
Significant earthquakes
in mountains, 1800–2016
Mercalli Magnitude
1–4 weak to moderate
5–7 rather to very strong
8–9 destructive to violent
10–11 very large to extreme
12 catastrophic
People killed
25 000

Disasters associated with natural
hazards in five mountain regions,
1985–2014
Number of disasters
50
Flood
Drought
Storm
Mass movement
Wild fire
High temperature
Colombia
Venezuela
Ecuador
Peru
Bolivia
Chile
Argentina
France
Switzerland
Austria
Italy
Morocco
Algeria
Afghanistan
Ethiopia
Uganda
Kenya
Rwanda
Burundi
Tanzania
Zambia
Malawi
Madagascar
Lesotho

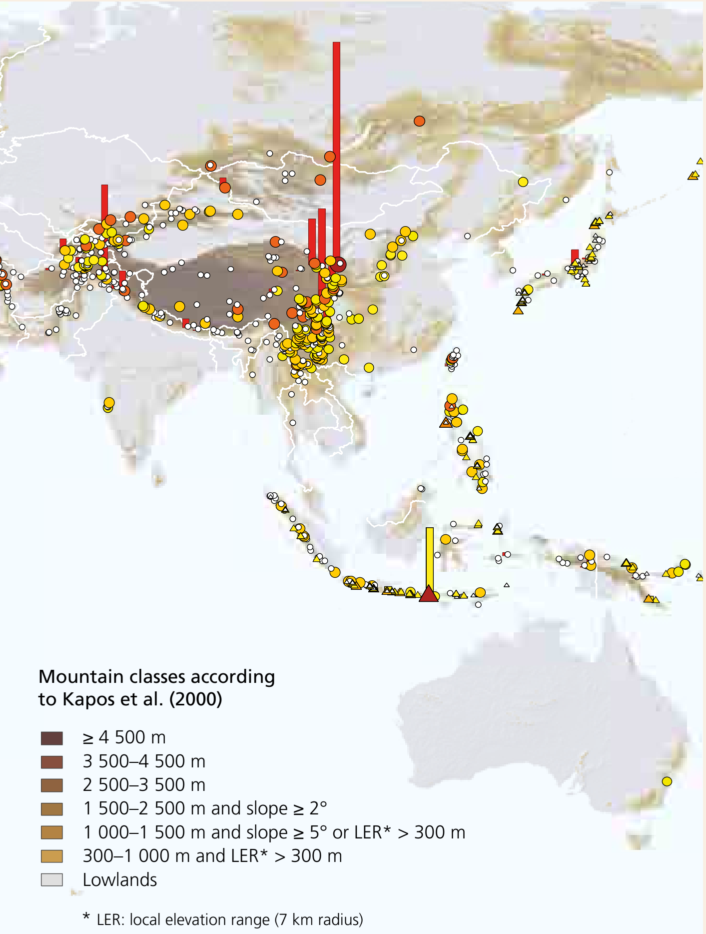


Figure 1. Map of significant earthquakes and volcanic eruptions that occurred between 1800 and the present in mountains. A significant earthquake is classified as one that meets at least one of the following criteria: moderate damage (ca. US$ 1 million or more), ten or more deaths, magnitude 7.5 or greater, modified Mercalli Intensity X or greater, or the earthquake generated a tsunami. A significant eruption is classified as one that meets at least one of the following criteria: fatalities, moderate damage (ca. US$ 1 million or more), Volcanic Explosivity Index (VEI) 6 or larger, the eruption caused a tsunami, or the eruption was associated with a significant earthquake. Definition of mountain areas according to [8].
Map by Juerg Krauer and Ulla Gämperli Krauer, Centre for Development and Environment, University of Bern.
Data source: [1, 2]

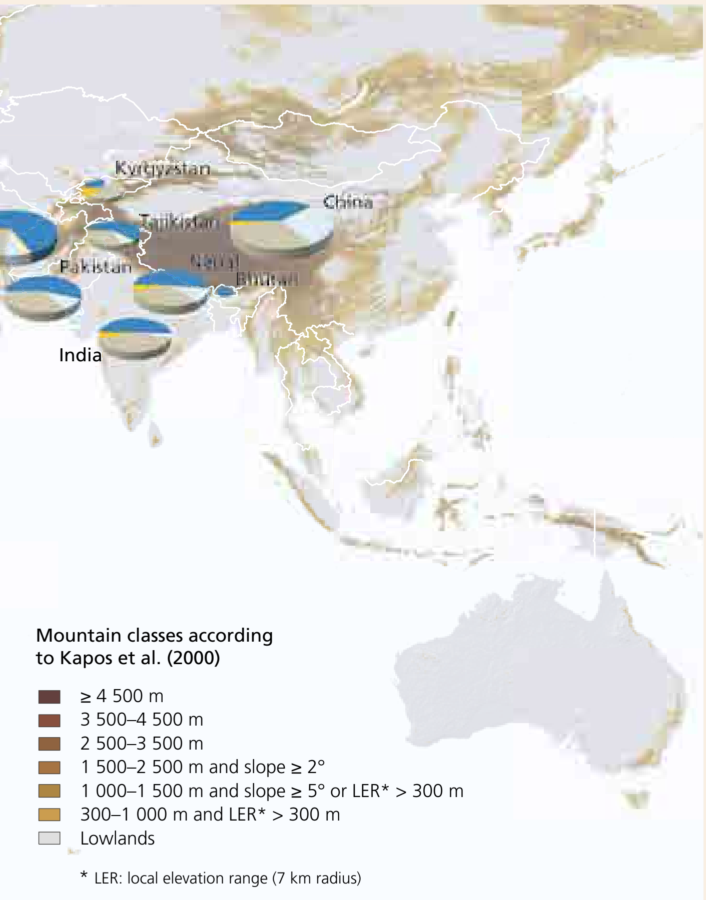


Figure 2. Occurrence of major disasters associated with six types of natural hazards between 1985 and 2014 in five selected mountain regions: the Andes, the European Alps, the Pamir Mountains and the Tien Shan in Central Asia, the North and Eastern African mountains and the Hindu Kush Himalayas. Definition of mountain areas according to [8].
Map by Anina Stäubli, Department of Geography, University of Zurich, Juerg Krauer and Ulla Gämperli Krauer, Centre for Development and Environment, University of Bern.
Data source: [7]

generates some rain even in dry periods. Nonetheless, mountain areas are more vulnerable overall, as their population and its density are much higher than in the lowlands.

Floods and mass movements affect the Andean region

The orographic effects of the Andean Cordillera lead to abundant precipitation that is even more pronounced during El Niño years. This often results in severe floods (50 percent of the registered disaster events), causing damage in the densely populated foothills of the Andes and significant mass movements (28.7 percent). A closer look shows that the Central Andes of Peru and Bolivia are the most disaster-prone areas in the Andes – where natural hazards more often turn into disasters – due to their higher population density and vulnerability. Apart from these hydrometeorologically and climatologically induced disasters, the Andes are among the highest seismic-risk areas globally (cf. Figure 1).

Mass movements and floods affect Kyrgyzstan and Tajikistan

Rainfall is a main trigger of hazards in the mountainous areas of Kyrgyzstan and Tajikistan. More than 5 000 potential landslide sites have been identified in Kyrgyzstan [9], mainly in the south, in the foothills of the Fergana Basin. Tajikistan is most exposed to flood disasters, due to intense rainfalls in the high mountains and outbursts of some of the numerous glacial lakes. In contrast to the Hindu Kush Himalayas where there is a distinct monsoon influence, the climate in Central Asia is continental arid and semi-arid, with maximum precipitation in spring during the northward migration of the Polar front.

Floods and avalanches predominant in the European Alps

The European Alps are heavily affected by floods, while mass movements including avalanches account for a third and storms for a fifth of the major disasters as recorded in EM-DAT. Snowmelt in spring is an important contributing factor for floods and mass movements in the Alps, together with heavy rainfall events which occur also later in the year.

The impacts of these natural hazards on mountain people vary depending on their exposure, resilience and capacity for risk management. In the Hindu Kush Himalayas, significantly more people are affected by an average event than in Central Asia. An average event affects about the same number of mountain people in Eastern Africa as in the Hindu Kush Himalayas, and while livelihoods in both places were highly affected, economic losses in Eastern Africa were considerably lower (Table 1). However, the data reveal only a part of people's reality, as entry criteria for disaster databases are often biased towards economic and monetized loss (and there is less economic value to be lost in poorer countries). Moreover, the data do not capture the frequent small events that also threaten people's livelihoods. In Georgia, for example, more than 380 landslides were recorded per year between 1995 and 2010. Cumulatively, these landslides caused significantly higher economic losses than the fewer but bigger flood events [10, 11].

Mountain region	Number of disasters	Economic losses (in million US$)	Number of people killed	Number of people affected	Mountain population, 2012 [12]
Hindu Kush Himalayas	323	44 690.4	26 991	165 694 879	286 019 683
Eastern & North Africa	163	1 246.8	4 881	76 127 779	146 108 040
Andes	150	3 138.4	6 664	13 006 871	73 090 954
Central Asia	39	257.4	700	3 518 763	4 012 359
European Alps	38	7 245.0	607	33 011	22 814 551

Table 1. Major hydrometeorological hazards (mass movements such as avalanches, landslides and debris flows, as well as floods, storms, extreme temperatures, droughts and wildfires) and their impacts between 1985 and 2014 in five mountain regions based on EM-DAT [7]. Smaller events, even such affecting people and the local economy, are not included (criteria see Box 1).

In 2013, debris flows devastated the village of Kedarnath and downstream settlements in Uttarakhand, India (V. Kaul)

Global change is increasing natural hazard risks

There is a high probability that the disaster risk associated with natural hazards will increase in the future as a consequence of projected climate change and additional stressors. These additional stressors include poor governance and land use practices, land use changes, growth of settlements and infrastructure in hazard-prone areas, tourism expansion and ecosystem degradation. Climate change is altering the magnitude and frequency of hydrometeorological hazards through observed and projected increases in extremes of temperature and precipitation in many mountain regions. While temperature extremes and related melt events (short- or long-term, e.g. snowmelt in spring, or extreme glacier melt during a summer heatwave) are projected to increase globally, there is greater uncertainty and variation in future projections of heavy rainfall events [13]. In general, climate models show a trend of currently wet regions becoming wetter, and dry regions becoming dryer. This means that flooding and landslides can be expected to increase, most significantly across tropical mountain regions. For glaciated catchments, the contribution of glacier melt to overall runoff is generally expected to increase due to greater ice melt in the near future, but to decrease afterwards when there is less ice. Irrespective of extremes, the current retreat of glaciers and degradation of permafrost in response to changes in the mean global temperature will lead to further destabilization of high mountain slopes [14]. As new glacial lakes continue to expand in response to warming, the threat of ice or rock avalanches impacting lakes and triggering catastrophic downstream flooding is thus of paramount concern across populated high mountain regions of Asia, North and South America and Europe [15].

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Cover photo: Goods had to be transported by boat after the Atta Abad landslide flooded 25 km of the Karakoram Highway, Pakistan, in 2010 (D. Butz)