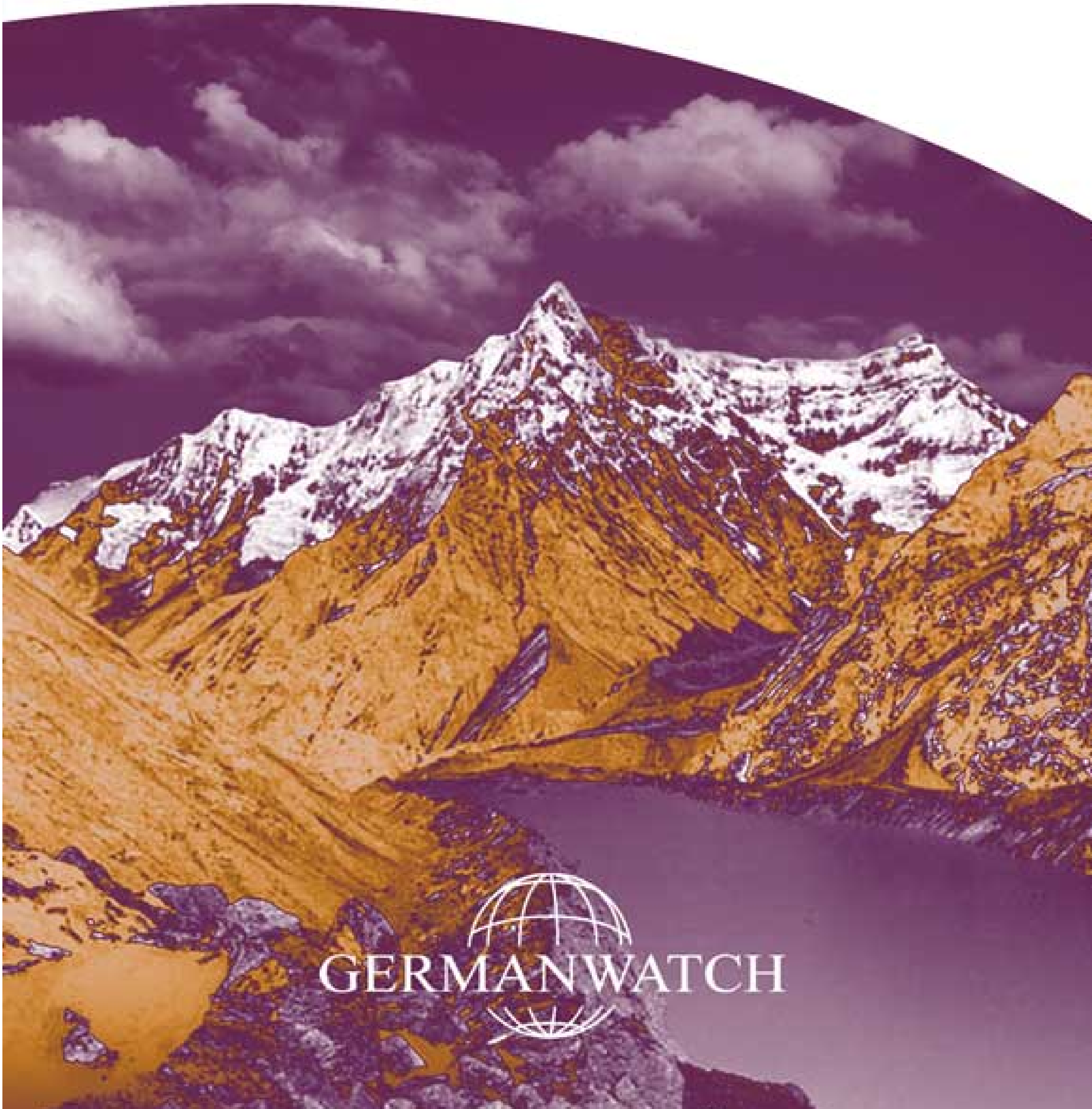
Glacial Lake Outburst Floods in Nepal and Switzerland

New Threats Due to Climate Change



Glacial Lake Outburst Floods in Nepal and Switzerland – New Threats Due to Climate Change

The spectacular worldwide receding of mountain glaciers is one of the most reliable evidences of the changing global climate since mid 19th century. Mountain glaciers therefore, are seen as key indicators for climate changes and act as a sort of "global thermometer" (Haeberli et al. 1998b, IPCC 2001, OcCC 2002). And although the global temperature rise of about 0.6°C in the last hundred years might seem negligible at first sight its impacts are tremendous. Alone the Alp glaciers have lost around one third of their surface area and half of their volume by the 1970s. Likewise, since the 1980s 10 - 20% of the estimated 130 km^2 of ice reserves have been lost (Maisch/ Haeberli 2003).

In countries with high mountainous terrains such a development evokes concerns as with the melting of glaciers the risk of glacial related hazards increases. One of these risks are Glacial Lake Outburst Floods (GLOFs). As glaciers retreat, glacial lakes form behind moraine or ice 'dams'. These 'dams' are comparatively weak and can breach suddenly, leading to a discharge of huge volumes of water and debris. Such outbursts have the potential of releasing millions of cubic meters of water in a few hours causing catastrophic flooding downstream with serious damage to life, property, forest, farms and infrastructure. Such damage can even occur hundreds of kilometres downstream.

In a dramatic way, the phenomenon of GLOFs illustrates the possible impacts of global climate change on the local level. At the same time, this indication of the anthropogenic greenhouse effect also highlights the different possibilities in industrialized and developing countries to react to such impacts, as the example of Switzerland and Nepal illustrates. Both countries alike face a rising threat by glacier related hazards but their capabilities to react differ significantly.

Glacial lake outburst floods can transport enormous masses like this clast in Nepal of about 200 tonnes (photo: Richardson/ Reynolds).

Glacial Lake Outburst Floods (GLOFs)

The acronym GLOF is used for glacier floods caused by the drainage of naturally dammed lakes in the glacier, on or at the margin of glaciers. GLOFs are not a new phenomenon but with the worldwide receding of glaciers and rising temperature the probability of their occurrences has risen in many mountain ranges. "Glacier floods represent in general the highest and most farreaching glacial risk with the highest potential of disaster and damages" (Richard/ Gay 2003).

Glacial lakes are like natural water reservoirs dammed by ice or moraines. A lake outburst can be triggered by several factors: ice or rock avalanches, the collapse of the moraine dam due to the melting of ice buried within, the washing out of fine material by springs flowing through the dam (piping), earthquakes or sudden inputs of water into the lake e.g. through heavy rains or drainage from lakes further up-glacier.

"The greatest concentration of outbursts from moraine-dammed lakes is observed in the middle Himalayas around Mount Everest" (Singh/ Singh 2001).

The Case of Nepal

In its history, Nepal has experienced several Glacial Lake Outburst Floods originating from numerous glacial lakes, some of which are even based outside its territory. Although other natural disasters such as rainfall floods, earthquakes, landslides or wildfires have claimed the lives of thousands of Nepalis in recent decades, glacial lake outbursts are feared for the potential devastation from a single large event (Kattelmann 2003).

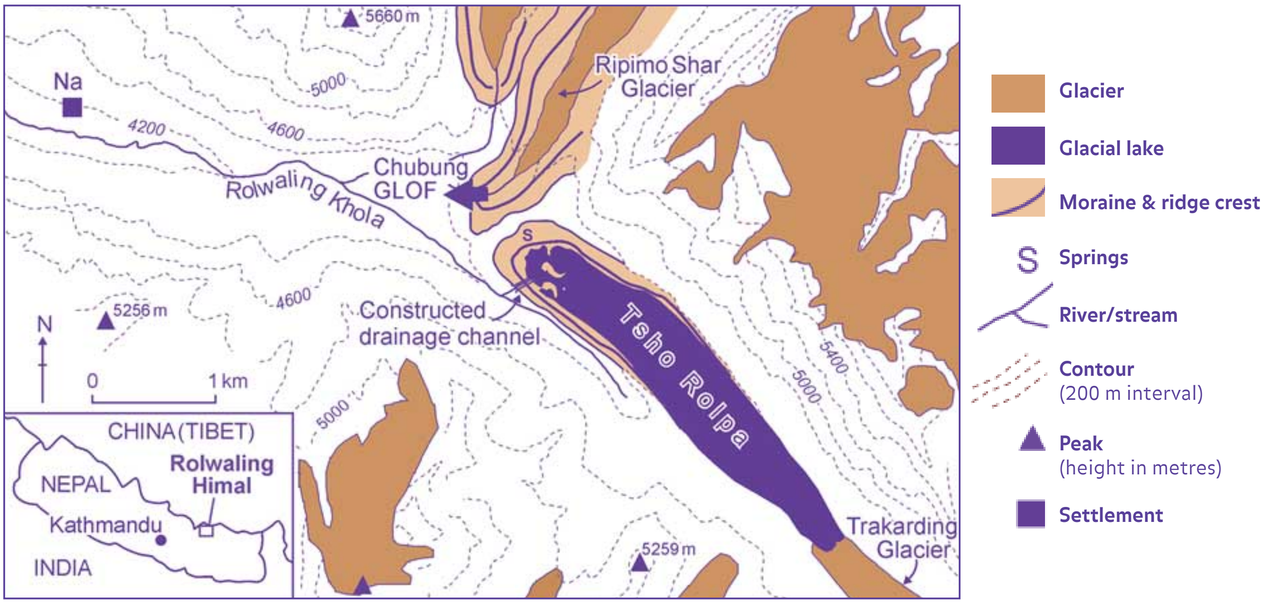
The GLOF event of 4th August 1985 from Dig Tsho glacial lake in Eastern Nepal, in a valley next to Mount Everest, had especially brought about awareness of potentially dangerous glacial lakes in the high Himalayas, nationally and internationally. An ice avalanche impacted the lake and generated a wave about 5 m high which overtopped the moraine dam. The lake, roughly measuring 1500 by 300 m at a depth of 18 m drained almost completely within 4-6 hours. The flood destroyed bridges, homes, agricultural land and the nearly completed Namche Small Hydropower Plant, two weeks before its inauguration, which resulted in an estimated loss of US$ 1.5 million. Remarkably, only 4-5 people lost their lives in the flood itself because a Sherpa festival was in progress and few people were walking the trails at the time (ICIMOD/ UNEP 2002; Kattelmann 2003).

With rising temperatures, many big glaciers have melted rapidly and resulted in a large number of glacial lakes. On average, air temperatures in the Himalayas are 1°C higher now than in the 1970s, rising by 0.06 °C per year (Shrestha et al, 1999). Two years ago, scientists from the United Nations Environment Programme (UNEP) and the International Centre for Integrated Mountain Development (ICIMOD) identified 3,252 glaciers and 2,323 glacial lakes in Nepal out of which they estimate around 20 to be potentially dangerous.

Among the identified critical lakes is the Tsho Rolpa Lake. Tsho Rolpa is the lake of superlatives: in the Nepal Himalayas it is the largest moraine-dammed proglacial lake, the most studied and known as the most dangerous glacial lake. Situated at an elevation of 4,580 metres above sea level, it is fed by the Tradkarding glacier, which is retreating at a rate of over 20 metres, and in some years within the last decade even 100 metres a year (Rana et al. 2000; UNEP 2002).

Investigations have found that as a result of the melting of the glacier, the lake has grown sixfold, from an area of 0.23 square kilometres in the late 1950s to 1.5 square kilometres now. This development poses a high risk to the people downstream as the amount of water released would be around 30 million cubic metres (Rana et al. 2000). "A flood from this lake could cause serious damage down to the village of Tribeni, which is 108 km downstream, threatening about 10,000 lives, thousands of livestock, agricultural land, bridges and other infrastructure," said Pradeep Mool, remote sensing expert with the International Centre for Integrated Mountain Development (ICIMOD). Similar to the Dig Tsho outbreak in 1985 it also threatens a big hydroelectric project, the Khimti Hydropower – a 60 MW complex located about 80km below the Tsho Rolpa Lake. Its destruction could result in rebuilding costs of about US$ 22 million, plus the losses in electricity production (Richardson 2004).

Tsho Rolpa is known as the most dangerous glacial lake in Nepal. Situated at an elevation of 4,580 metres above sea level at the source of the Rolwaling Khola river in the Tama Koshi basin. At present it is 3.3 km long and 0.5 km wide, spans over 1.5 sq. km of surface area and contains nearly 100 million cubic metres of water. Its average depth is 55 m and maximum depth is around 132 m (source: Rana et al. 2000; photo: RGSL).



Summary map of the Tsho Rolpa area with a location map of the Rolwaling Himal (picture: Richardson, 2004).

As a result of the melting glacier nearby, the lake has grown six-fold, from an area of 0.23 square kilometres in the late 1950s to 1.5 square kilometres in 2000 (source: RGSL)

Costly Adaptation Measures at Tsho Rolpa Lake

In order to mitigate the risk, the first flood warning system in the country was installed in May 1998 to warn the people living downstream of Tsho Rolpa. Additionally, since 2000 an open canal constructed to lower the lake level has been operating. The open channel lowered the lake level by 3 m and is expected to reduce the risk of GLOF by about 20 % (Rana et al. 2000). But it is not a permanent solution. "There are fears that the lake could still burst through the moraine dam which continues to degrade as the ice within it melts", explains Dr. Shaun Richardson, Principal Glacial Geologist with Reynolds Geo-Sciences Ltd. (RGSL). The company was involved in the assessment and remediation of Tsho Rolpa for the Nepalese Government since 1994. Preliminary assessments suggest that a further lowering of 17m of the lake is necessary for the permanent prevention of a GLOF event (see also Rana et al. 2000).

The government agency responsible for the site, the Department for Hydrology and Meteorology (DHM), is currently preparing such plans for a next phase. For its implementation, however, Nepal relies on funding from the international donor community, as it was the case in the previous phases. The flood warning system at Tsho Rolpa, which cost roughly US$ 1 million, was financed by the World Bank. For the reduction of the lake level, the Dutch government provided a grant of nearly US$ 3 million. Nepal provided a small share of US$ 231,000 to the project.

Tsho Rolpa is but one example of a growing risk and of why money is needed urgently for the development of monitoring and early warning systems for the other glacial lakes if catastrophes are to be averted. "As far as Nepal is concerned, the hazard potential is likely to increase," warns Shaun Richardson. "The long flat glaciers that extend to the valley bottoms are generally debris-covered. This debris acts as a buffer between the glacier and the effects of changing climate on the glacier snouts. As a consequence it is thought that the glaciers are out of phase with, or lagging behind, climatic changes. This means that when the glaciers do become exposed to warmer conditions and ponds develop the rate of melt and pond growth can be very rapid and irreversible. Many glaciers are in this condition."

For a poor country like Nepal, which is not even able to cover the prevention costs, these are bad prospects let alone the potential losses associated with another outburst occurring. In-depth analysis of water resources in Nepal have identified GLOFs and the variability of river runoff as the two critical impacts of climate change, both of which pose significant impacts on hydropower, rural livelihoods and agriculture (Agrawala et al. 2003). Regarding Nepal's electricity sector e.g., 91% of the nation's power comes from hydropower. "A reduced hydropower potential might imply that Nepal will have to seek for alternative sources of power generation, including from fossil fuel sources," states Agrawala, main author of a 2004 OECD report.

The survey on GLOFs in Nepal only covers a very small part of a common problem in the Hindu-Kush-Himalaya region. Many floods in Nepal have originated in Tibet and similarly, floods from Nepal do not respect national boundaries and have the potential to run into India and even Bangladesh. Despite the growing threat, there is still no detailed inventory of glaciers and glacial lakes in the region, let alone of their impact on downstream populations and investments.

But apart from reducing risks on the local level, only the reduction of greenhouse gases can curb global warming and thus the retreat of glaciers in the long run. This is important, since there is more involved than the direct risks through GLOFs for the people in Nepal. The water reserves for nearly 500 million people downstream are at stake due to glacier melting. The glaciers of the Hindu Kush-Himalayas are the renewable storehouse of fresh water and serve as the perennial source of the rivers Indus, Brahmaputra, Mekong and the Ganges just when it is most needed – in the dry hot season before the monsoon (Gustard/ Cole, 2002).

Construction of the canal at Tsho Rolpa, 2000 (photo: RGSL).

The Case of Switzerland

The modest expansion of one of the most beautiful marginal glacial lakes of the Swiss Alps, the Märjelensee, hardly reminds one, who stands on the shore today, of its former dangerousness and its numerous outbreaks. Still in 1878, containing a volume of approximately 11 million m^3, comparable in size to Lake Dig Tsho in Nepal before its outbreak, the lake frightened the population in nearby Fieschertal and Fiesch. At this menacing high water mark all that was needed was a strong tempest to make the lake burst into the valley Fieschertal.

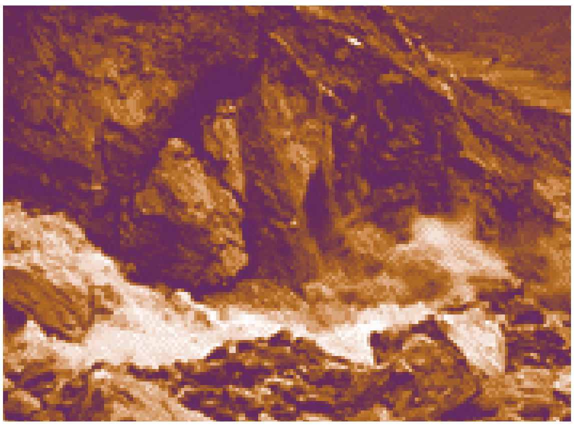
The heavily hit population of the valley was driven to hardly accomplishable vows at that time which they hoped would avoid disastrous outbreaks of the lake. One of these for example, called for the abandonment of the fields´ irrigation from Saturday to Sunday evening. Since the vows harmed the peasants in the long run, the pope altered them afterwards on their request. One of the most peculiar promises, by which the population of Fiesch tried to ward off the Märjelensee´s water, consisted of a pilgrimage into the forest Ernerwald on the north-eastern slope of the Rhone valley, at which women were not allowed to wear coloured underwear (Bachmann 1978).

Nowadays, the Märjelensee has nearly disappeared because of the retreat of its associated glacier, the Aletschgletscher. With it, the old 'techniques' used when dealing with such glacial risks vanished - fortunately, since the threat of glacial lake outburst floods is still prevalent in Switzerland. "Glacier shrinkage induced by athmospheric warming may eliminate problems relating to ice-dammed lakes in some places but create new ones in others," warns Prof. Wilfrid Haeberli, internationally proven expert in glaciology and head of the Physical Geography Division at the University of Zürich. "In many cases the situation has become less dangerous due to the pronounced retreat of the glaciers during the twentieth century, but on the other hand new lakes have emerged at places where there had never been lakes before."

One of those relatively new problems developed at the glacier Grubengletscher which flows from the summit of the Fletschhorn at

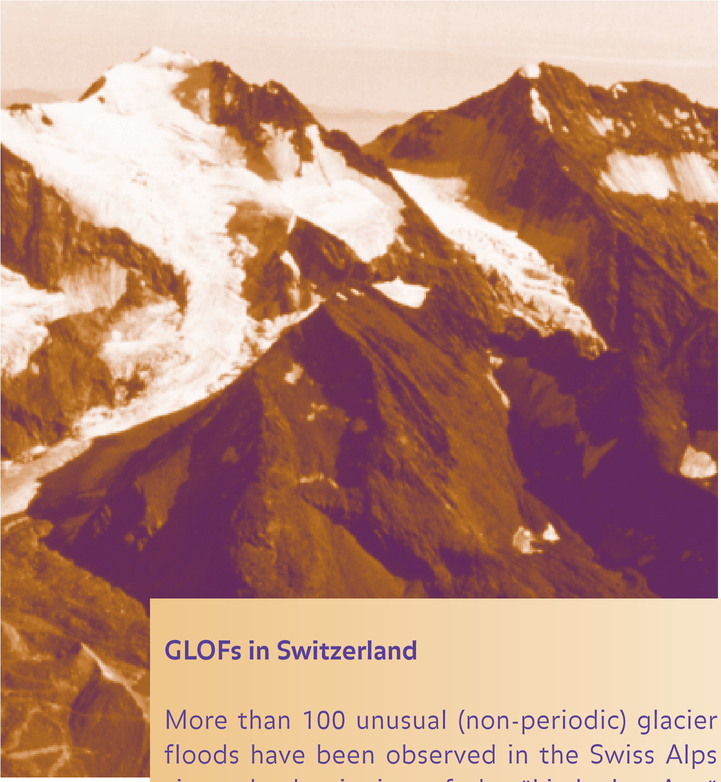
3993 metres above sea level in the southern valleys of Canton Wallis. During the 20th century the minimum temperatures in Switzerland have increased by 2° C (Haeberli/ Beniston 1998) with a temperature increase of 0.4 - 0.6° C in the last three decades being higher than in the global mean (0.1 - 0.2° C; OcCC, 2002). Six new lakes had formed as a consequence of glacier recession and permafrost degradation.

In the summer of 1968, one of those lakes drained catastrophically, causing heavy damage in the village of Saas Balen. The outburst eroded about 400,000 m^3 of debris (Haeberli et al. 2001) which is equivalent to about 1,000 de-



The outbursts of the glacier-dammed lake 3 in 1968 and 1970 triggered debris flows and caused heavy damage in the village of Saas Balen (photo: Kääb).

The Gruben Glacier at its highest point, the Fletschhorn (photo: Kääb)



GLOFs in Switzerland

More than 100 unusual (non-periodic) glacier floods have been observed in the Swiss Alps since the beginning of the "Little Ice Age" whereby less than 40 glaciers, or about 2 - 3 per cent of all Swiss glaciers are involved. GLOF events concentrate in the southern valleys of Canton Wallis and occur most frequently in the months of June, July and August, after the onset of snow-melt (Haeberli 1983; www.glacier-hazards.ch).

The lakes in Switzerland are generally smaller than in Nepal and the infrastructure and settlements are situated much closer to the hazard zone. As a result, even small glacial lakes can cause considerable damage (Huggel et al. 2000). In one of the world's most densely populated mountain ranges, this also relates to the constant advancement of infrastructure and settlements into high Alpine areas.

tached family houses. Another similar event took place only two years later in summer 1970 when the same lake bursted a second time.

Dangerous beauty

In reaction to these catastrophic events, flood prevention was introduced. The measures proved to be successful during a period of glacier growth in the 1970s and early 1980s. New problems, however, developed when glacier thinning started to accelerate again. Preventive measures had to be applied anew to avoid the development of dangerous situations. A hazard mitigation scheme was developed with the responsible authorities, the Community of Saas Balen, the Canton of Valais and the Swiss Confederation. "Finally, in 1997 we had to drain one of the lakes completely as it became inceasingly dangerous", remembers Andreas Kääb, specialist in the observation of glacial hazards and chair of the International Working Group on Glacier and Permafrost Hazards in Mountains. "The lake was a real beauty. Its disappearance left our research team with mixed feelings of relief and regret".

At the moment, there is no immediate risk from the remaining lakes for the communities situated downstream. The levels of the lakes were lowered by channels, ditches and even gates that can be regulated. A continued or even accelerated warming, however, could thin the tongue of the Grubengletscher beyond available experience or could even cause its complete disappearance. As a consequence, large volumes of water could collect again. "Such a potentially hazardous development would be without historical precedent but could be identified at an early stage with the help of an adequate observation system," says Haeberli. "All in all, the damage events at the Grubengletscher caused costs of around 20 Million Swiss franc. The costs for monitoring, field investigations etc., however, would be less than 10% of the damage sum."

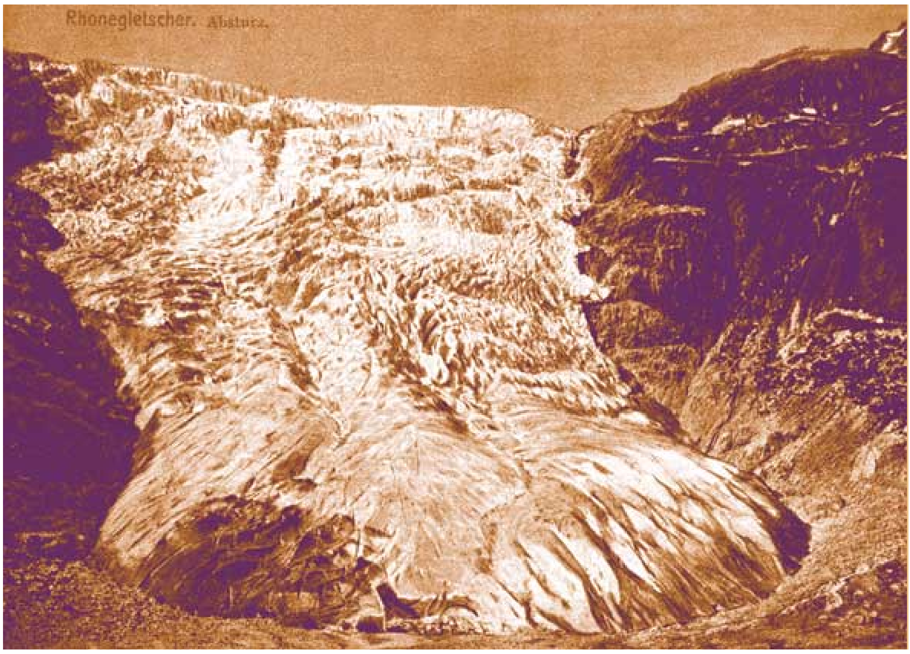
Human induced climate change is going to continue for several centuries. In order to mitigate climate change it is necessary to drastically reduce the worldwide emissions of greenhouse gases. A stabilization of the CO_2 concentration in the atmosphere can only be achieved by reducing today's global emissions by more than half.

In need of new local hazard maps

The outburst floods at Grubengletscher pinpoint to one of the main problems Switzerland faces regarding the ongoing thawing of glaciers and permafrost. The hazard potential of existing and newly formed lakes and glacial risks in general can change rapidly, especially as in some areas of the Alps infrastructures and settlements were developed only recently (Richard/ Gay 2003). "The threats change beyond experience. Old chronicles and records suddenly turn out to be invalid and new threats can suddenly emerge at places which used to be safe in former times. As a consequence, new local hazard maps have to be drawn, coupled with a constant monitoring as the changes are so fast" Haeberli says.

To forecast when and how a GLOF event will take place is difficult and needs detailed and multi-disciplinary investigations of the total environment of the lakes and associated factors in the surroundings as a whole. Different than in Nepal, Switzerland has one of the most intensively studied mountain ranges of the world and does not rely on foreign aid to take up measures. But similar to Nepal, the risks through global warming will not disappear with the glaciers.

With the retreat of the glaciers, one important source of the irrigation cultures at, e.g., the rivers Rhine, Rhone or Po is lost. "Already in the very dry year of 2003, streams and rivers which were not fed by glaciers could in parts be crossed with dry feet and the river Rhine almost



Rhone glacier, postcard taken from around the year 1910
Source: Sammlung Gesellschaft für ökologische Forschung

Thawing of Glaciers - mirror of human influence on climate change

Since the end of World War II, annual mass balances for more than 50 glaciers are being determined. "When you average the annual mass balance of the directly measured glaciers [...], you observe an average loss of mass of about 30 cm for the years since 1980. The annual melting of such a layer of ice is equivalent to a power of 3 Watts/m^2. The melting of glaciers, therefore, is a quantitative measure for the pace of climate change.

The value determined through the glacier mass balance of about 3 Watts/m^2 can be compared to the current human influence on the global greenhouse effect of 1 to 2 Watts/m^2, as estimated by climatologists" (Maisch/ Haeberli 2003).

exclusively contained glacier water." says Haeberli. Furthermore, revegetation of terrain following deglaciation is slow under high-mountain climatic conditions and leaves deglaciated morainic deposits unprotected against erosion for decades or centuries (Haeberli/Beniston 1998).

" Part of our homeland is going to be lost"

"The Swiss are very concerned about the continuing retreat of the glaciers. Finally, also part of our homeland is going to be lost," Haeberli sums up. The timeframe for this is already outlined: Foremost small glaciers and thinnly iced glacier regions are the first to be affected by the tendency of melting ice (Maisch et al. 2000). The larger and longer glaciers, due to their delayed reaction time and adaptation period, most likely are lagging behind the recent development of the climate for several years time or even decades (Maisch/ Haeberli, 2003).

All in all, until 2035 about half, and after the middle of the 21st century already three quarters, of the current Swiss glaciers will be vanished. "A considerable part of this pessimistic, but not extreme, scenario has already come true as a result of the extraordinarily warm 1980s and 1990s" (Maisch/ Haeberli 2003). "The extent of Alpine ice is probably more reduced today than ever before during the past ca. 5000 years" (Haeberli/ Beniston 1998).

The Rhone glacier in the year 2003.
Source: Gesellschaft für ökologische Forschung, Sylvia Hamberger

Nepal and Switzerland in comparison	Nepal	Switzerland
CO_2 Emissions Per Capita (2000)	0.13 t	5.8 t
GDP (US$)	5.5 billion	267.4 billion
Official Development Aid (ODA, US$, 2002)	received 365 million	disbursed 933 million
Population (2002)	24.1 million	7.3 million
Surface area	147,200 km^2	41,290 km^2

Source: World Bank, 2004; Deutsche Welthungerhilfe/ terre des hommes Germany 2003

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What Germanwatch does

The non-profit organization Germanwatch has been working for a social and ecological shaping of globalization since 1991. Some of our main aims are:

- implementing climate protection with efficient and fair instruments and economic incentives
- fair opportunities for developing countries by reducing dumping and subsidies in agricultural trade; a fair world trade system
- ecological and social investment
- compliance with social and ecological standards by multinational corporations

By means of a dialogue with politics and business as well as by public relations work, Germanwatch promotes necessary changes in structures and strategies. The economical and ecological reorientation in the North is a precondition for people in the South being able to lead a humane life and for all regions being able to develop sustainably.

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