Science



158. John Innerdale, *Horns of Paine*, Chile, chromacolour, 64 x 48cm, 2002.

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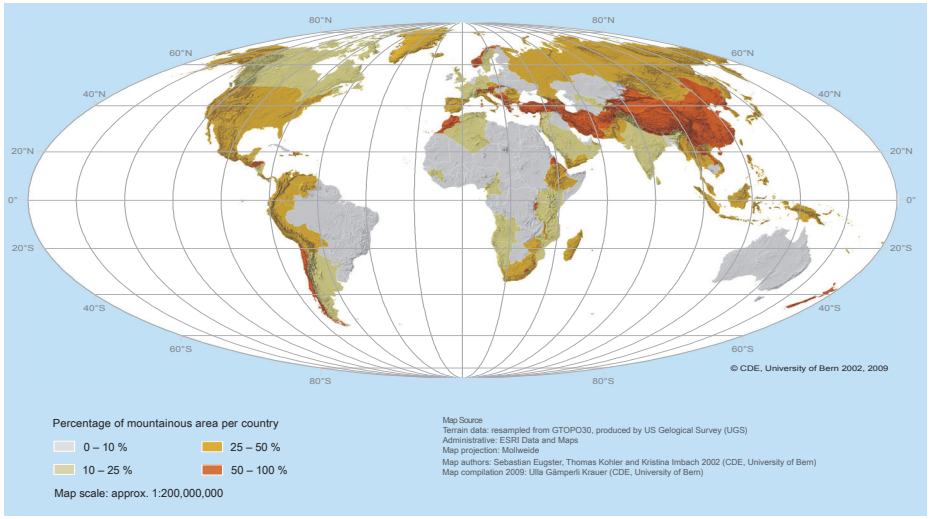
Mountains and Climate Change: A Global Concern

Mountains are among the regions most affected by climate change. Alpinists are front line witnesses to some of the most obvious signs of a warmer world: glacier retreat, increased rockfall and the formation of glacial lakes. But the implications of climate change will reach far beyond mountain areas, with profound consequences. The article that follows is based on the first and final chapters of an 80-page brochure entitled 'Mountains and Climate Change: From Understanding to Action', prepared at the Centre for Development and Environment, University of Bern, Switzerland, for the Swiss Agency for Development and Cooperation and presented at a side event at the United Nations Climate Change Conference in Copenhagen on 12 December 2009. The Alpine Journal is grateful to the editors, Thomas Kohler and Daniel Maselli, for permission to publish this summary on an issue that should concern us all.



159. The map shows the countries of the world classified according to the percentage of their mountain area. Countries with a high percentage of mountains are found on all continents, and range from large countries such as China and Iran to small ones such as Lesotho, New Zealand, Switzerland, Norway and Slovenia. Other countries such as the United States or Russia, or India, Canada and Algeria with important mountain areas have a lower percentage due to their large plains and lowlands. The underlying hill shading shows that even countries with low percentages of mountains – Australia, Brazil, or Thailand – do have mountains, which play a much more important role than their land percentage would indicate, for example for the provision of fresh water. The map therefore indicates that mountains play a key role in global development, feature prominently in the leading economies, and that climate change in mountains is a key concern for humankind that needs to be addressed in all regions of the world.

Man-made greenhouse gas emissions are expected to lead to average global warming in the period 1990-2100 of between 1.1 and 6.4°C, depending on the global release of greenhouse gas emissions. This warming will not be uniform but will vary considerably between different regions. In general, it will be greater over land and in high northern latitudes. The most robust precipitation projections are for increases in the monsoon regions and in middle and high latitudes, and a decrease in the subtropics. The area of snow cover will decrease in general, while snowfall may increase in regions with very cold temperatures such as high mountains. Most glaciers and ice caps will lose mass or disappear in the long term.

Climate change is a reality today, and some of the best evidence such as melting glaciers comes from mountain areas. Many scientists believe that the changes occurring in mountain ecosystems may provide an early glimpse of what could come to pass in lowland environments, and that mountains thus act as early warning systems.

Regional Climate Projections For Mountain Regions

ANDES

Annual precipitation is likely to decrease in the southern Andes, with relative changes being the greatest from June to August. For the rest of the Andes, future precipitation changes will depend heavily on changes in El Niño patterns, which are poorly understood at present.

A recent regional climate model study for the tropical Andes shows more warming at higher elevations and an increase in inter-annual temperature variability for scenarios with greater global warming. Glaciers in many parts of the tropical Andes may disappear over the next few decades, which could entail severe problems in water supply – in Peru, for example, 10 million residents of Lima depend on freshwater from the Andes.

ROCKY MOUNTAINS

Higher elevation sites in the Rocky Mountains have experienced a three-fold increase in warming compared to the global average during the last few decades.

Climate models show above-average warming with the greatest warming at high latitudes from December to February, and from June to August in the mid-latitudes. Annual mean precipitation will increase, except in the South, but precipitation is influenced by El Niño and the North Atlantic Oscillation, for which predictions are unreliable. There will be earlier snowmelt in spring and a shift from snowfall to rainfall, particularly at middle and lower altitudes. Moreover, the incidence of forest wildfires has increased significantly in recent decades; this is closely associated with increased spring and summer temperatures and with earlier spring snowmelt.

HINDU KUSH HIMALAYA

As the largest high-elevation land mass in the world, the Himalaya-Tibet massif plays an important role in global climate and climate change. Warming is predicted to be well above the global average, which can be seen even in global climate projections. Many climate models project that monsoonal flows will weaken, which would lead to a precipitation decrease. However, it seems probable that this effect is more than offset by enhanced water transport due to greater moisture in warmer air. Model projections show an increase of precipitation in December, January and February. These projections are uncertain, as they depend on poorly understood changes in the monsoon regime and El Niño patterns.

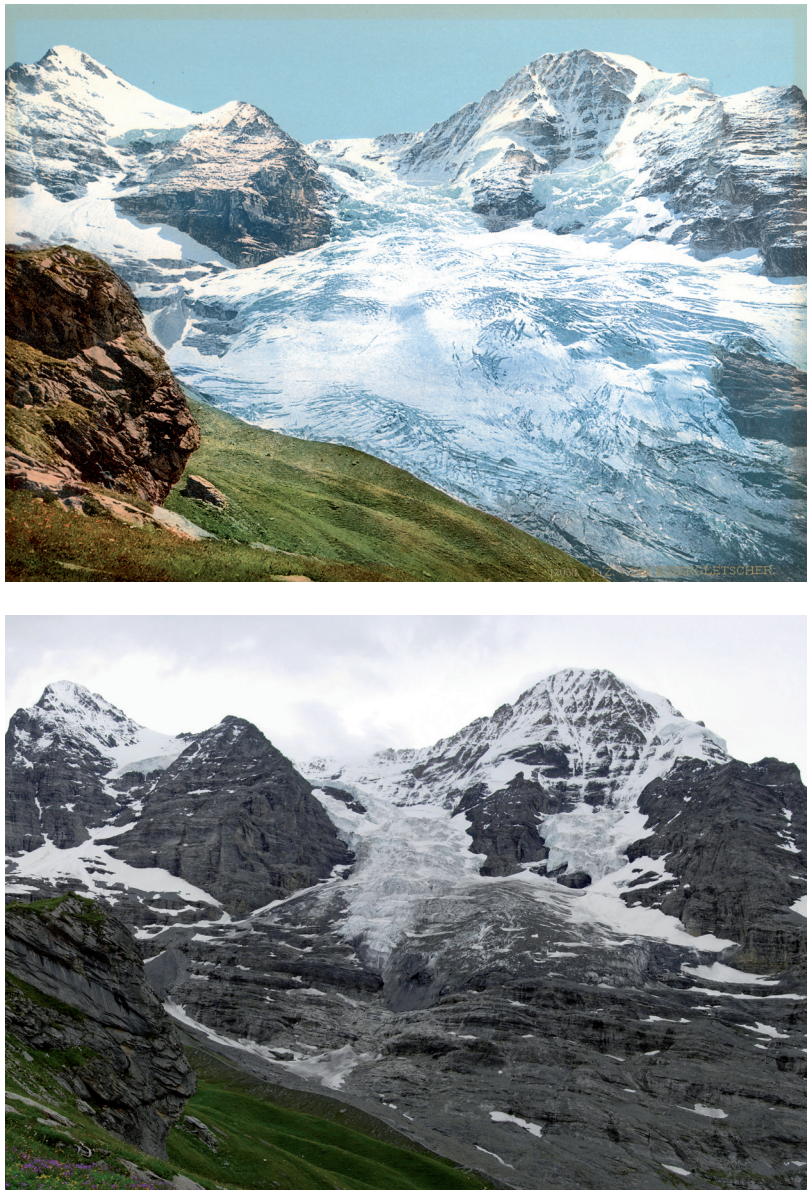
EUROPEAN ALPS

In general, Europe has shown a greater warming trend since 1979 compared to the global mean, and the trends in mountainous regions are still higher (Böhm et al. 2001). Regional climate projections indicate warming of about 1.5 times the global average, with greater warming in summer. Precipitation is projected to decrease in summer and on an annual average, and to increase in winter. General warming is expected to lead to an upward shift of the glacier equilibrium line by between 60 to 140 m per °C temperature increase, along with a substantial glacier retreat during the 21st century. The duration of snow cover is expected to decrease by several weeks for each degree C of warming at middle elevations in the Alps region.

Mountains: a Key Concern on The Global Climate Change Agenda

Mountains provide freshwater to half of the world's population. Climate change will affect the availability of water. In many cases, this will mean less water when it is most needed. Regions with the most mountain land are also the regions where mountain water for surrounding lowlands is most important – including the countries across the Eurasian continent from the Middle East to China, the Andean countries, the Nile Basin, and western North America. Also, many countries with less mountain land critically depend on mountain waters for specific regions or uses. Climate change in mountains will thus have important implications for irrigation, urbanisation and industrialisation, and hydropower generation. This will mean using water more efficiently, increasing storage capacities, and establishing, or re-visiting, institutional arrangements for sharing water equitably within and between nations.

Mountain areas are typically exposed to multiple hazards. Climate change is likely to increase this exposure, as extreme events such as storms, landslides, avalanches, and rockfalls are likely to become more common and more intense in mountain areas, threatening both livelihoods and infrastructure. Hazards cannot be prevented, but mountain regions can be supported



160. The climate of the European Alps is warming at 1.5 times the global average. Glaciers here, as in many other mountain areas, have been reduced close to their minimum extent during the climate optimums of the past 10,000 years. This pair of photographs of the Eiger glacier, Switzerland, with the Eiger and Mönch in the background, illustrate the marked retreat of the ice over one century. Top photograph taken around 1900. *(Photochrom picture from private collection of Samuel U Nussbaumer)* Lower photo taken 12 July 2009. (*Samuel U Nussbaumer*)

in managing the risks emanating from these hazards. This support begins with preparedness and ends with recovery; key ideas include effective early warning systems, land use zoning, and strategies for intervention.

Half of the global biodiversity hotspots are in mountain regions. They are an important global heritage that is being threatened by climate change and human action. Impressive achievements have been made in safeguarding this heritage; protected areas have been the fastest growing land use category in recent decades, especially in mountains. While mountain biodiversity is thus increasingly seen as a global common good by many, local communities who directly depend on its services must be included in stewardship of this valuable resource. Mountain communities should see more tangible benefits from conservation efforts than has been the case in the past. Payment for Environmental Services is a way to achieve this aim.

Mountains are home to about 10% of the global population. The large majority of mountain people live in developing countries. One third of them are food-insecure, a high proportion in global comparison. Mountains are often limited-choice environments due to harsh living conditions and a marginal position in terms of economic integration and political decision-making. External support is needed in order to reduce poverty levels. As temperatures rise, however, climate change might hold prospects for mountain agriculture – for crops previously not grown or limited to lower altitudes – provided that water, land, labour and capital through credit schemes or remittances from migrants are available to exploit such opportunities, and that access to markets is assured.

The Importance of Moving Beyond Climate Change

Much recent and current debate on adaptive capacity and vulnerability has been driven by the climate change agenda, but understanding the multidimensional nature of drivers of change, responses and feedback mechanisms is essential. This also applies to mountain regions, which are exposed to a wide range of mainly external drivers of change, including political, economic, and socio-cultural forces. Climate change action must therefore be embedded into a more general framework as provided, for example, by the concept of sustainable development. Any such framework will have to take note of the great diversity of mountain development contexts relating to environment, people, economies and cultures. Specific and tailored strategies will therefore be needed when it comes to climate change action. Human factors such as governance need to be considered in order to avoid simplistic projections about the impacts of climate change.

Many mountain countries, especially those with a high percentage of mountain territory, are developing countries with lower levels of industrialisation, and many are smaller nations. For these countries, adaptation is the main answer; they are far less the cause of the problem than they are the victims when it comes to climate change. For them, this change

is a huge externality that will mean substantial additional costs in future. As adaptive measures are designed and implemented, the involvement of mountain populations is a must, as they have important knowledge and will be among those most directly affected by climate change and remedial action. As case studies show, the involvement of local people is increasingly becoming a reality.

Adaptation will have to be supported by mitigating measures that address the root causes of climate change: the emission of greenhouse gases and other substances that cause global warming. The involvement of economic and population centres outside mountain regions in industrialised, emerging and developing economies will be critical for achieving a tangible reduction of these emissions, as a major share of the greenhouse gases are released in these areas. Some of the largest emissions of greenhouse gases come from countries with a significant proportion of mountain areas, such as China, the US, and Russia (*see map*).

The Way Forward

At the global level

Chapter 13 of Agenda 21, with its focus on mountain areas, as well as the UN Framework Convention on Climate Change and its Clean Development Mechanism (CDM), provide frameworks for concrete action to tackle the drivers of climate change and to mitigate its impact. As many mountain countries are smaller developing nations, they have not benefited much from the CDM programme and the carbon market, due to institutional constraints and the complexity of accessing funds. This requires urgent re-examination. Mountains and money do not easily come together. Technological, financial, and institutional support for development in mountain countries thus need be strengthened. Mechanisms for coordinating and extending such support include the *Global Environment Facility* (GEF), the *National Adaptation Programmes for Action* (NAPA), and the *Global Climate Change Alliance* of the EU, to mention but a few mechanisms already in place.

At national and regional levels

Many countries have established national focal points and regional bodies for managing climate change and have carried out impact assessments to determine how climate change is likely to affect them. However, progress on mainstreaming climate change adaptation has been limited, especially in relation to key development concepts such as poverty reduction policies, land use planning and zoning, and national development strategies. There is a growing number of Payment for Environmental Services (PES) programmes with proven track records in industrialised and developing countries. PES relating to watershed management, water regulation for hydropower and irrigation, biodiversity conservation, and hazard prevention are a means for ensuring that mountain communities can benefit from the implementation of measures to maintain environmental services that are important for lowland areas and their large population centres. Many of the efforts made to date in climate change adaptation are generic. Proven practices that could be upscaled are as yet lacking. Documentation and lessons learnt will thus be crucial for establishing a body of sound experience tailored to the specific needs of mountain regions.

The importance of research

The research community has a responsibility to sensitize policy-makers and the public about climate change in mountains and its implications in wider highland-lowland interactive development contexts. Research should also focus on designing integrated mitigation and adaptation measures. Given the paucity of reliable and long-term data on mountain climates and resources, especially in countries of the South and East, there is a need to establish long-term observatories and monitoring mechanisms that will allow more accurate projections of climate change, more precise assessment of impacts, and documentation of existing adaptation strategies in and beyond mountain regions. For the research and education communities, capacity development and trans-disciplinary approaches will be important components of all these activities.

Now is the time for action in addressing climate change issues in mountains. This could help transform currently perceived problems into opportunities for a better future in mountain regions and in the many lowland areas that depend on their services.

The editors of 'Mountains and Climate Change: From Understanding to Action' were Daniel Maselli (Swiss Agency for Development and Cooperation) and Thomas Kohler (Centre for Development and Environment [CDE], University of Bern). The first chapter, 'Climate Change in the Mountains', which forms the first part of this article, was written by Urs Neu of the Forum for Climate and Global Change, Swiss Academy of Science, Bern. The second part was written by Thomas Kohler with members of the Mountain Focus Group of CDE, Bern. The full brochure can be downloaded at www.cde.unibe.ch/Research/MA_Re.asp