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Climate Change in Mountains

S. Kummer

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The global context

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.

Urs Neu
ProClim
Forum for Climate and Global Change
Swiss Academy of Sciences, Bern, Switzerland

Pamir from the air (D. Maselli)

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.

Figures 1.2 and 1.3 show the regional distribution of temperature and precipitation changes and the position of principal mountain regions. While most mountain areas are in regions of medium to high temperature change, changes in precipitation vary considerably for different mountain areas.

Climate change: Mountain specificities

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.

Mountains exist in many regions of the world. They occupy very different positions on the globe and they differ in shape, extension, altitude, vegetation cover, and climate regime. They will therefore be affected differently by climate change. However, they share some common features relating to climate change:

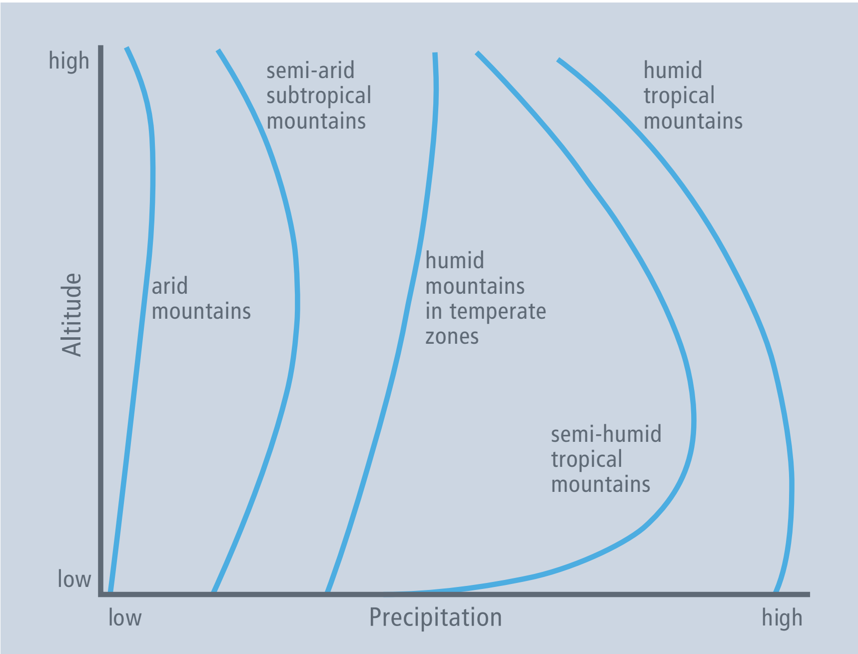
Firstly, mountain areas have a marked and complex topography and so their climates vary considerably over short distances (Figure 1.1). Climate change projections are therefore difficult to make. Unfortunately, reliable long-term and high-altitude records of mountain climate which allow verification of regional climate models exist for only a very few areas such as the European Alps.

Secondly, temperature changes with altitude. The impacts of a warmer climate are different for different elevations. Areas at the snow line or freezing line will be affected particularly heavily, as they might undergo a shift from mainly snow-covered to mainly snow-free. For example, every degree Celsius increase in temperature will cause the snow line to rise on average by about 150 m, and even more at lower elevations. In such regions precipitation will change from snow to rain. The decrease in snow cover will lead to an above-average warming of mountains, because snow-free surfaces absorb much more radiation than snow-covered surfaces.

Thirdly, melting of glaciers and permafrost will trigger the release of loose rock and soil and exacerbate the danger of rockfall, debris flows, and mud flows. A specific risk is the build-up of glacial lakes and the threat of lake outbursts, which could result in destruction of property and death.

Fourthly, mountains themselves play a major role in influencing regional and global climates. They act as barriers for wind flow, which induces enhanced precipitation on the windward side, and reduced precipitation and warmer temperatures on the leeward side. Changes in atmospheric wind flow patterns may induce large and locally varying precipitation responses in mountain areas, which could be much stronger than average regional climate change (IPCC 2007a). For example, model simulations show that in Scandinavian mountains, enhanced westerly wind flow might induce up to a 70% increase in precipitation, while average warming without changes in wind flows would lead to an increase in precipitation of up to only 20%.

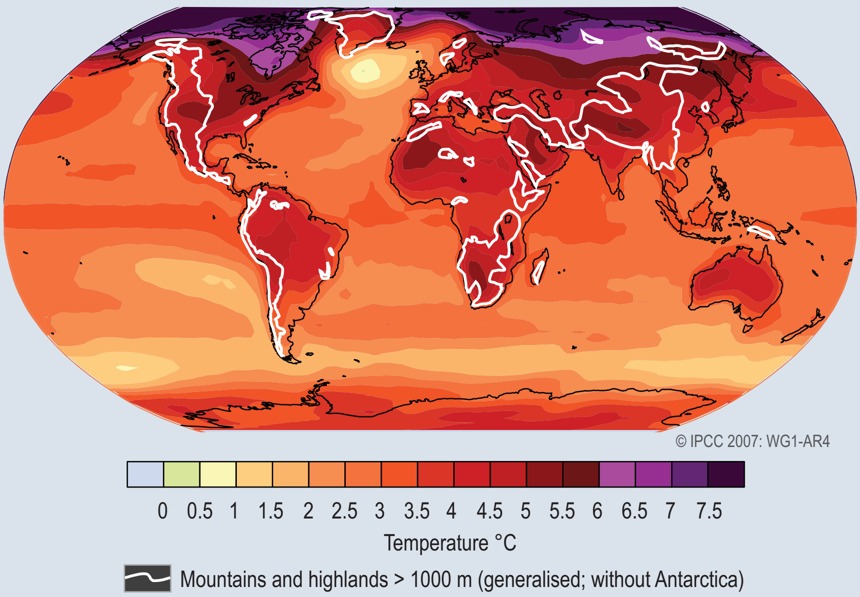
Overall, model simulations of climate change in mountain areas are very difficult because existing climate models do not yet adequately represent complex topography and its effects on climate. This lack of more precise, regional models concerns the largest mountain massifs in the world including the Andes, the Hindu Kush-Himalaya, and Central Asia. As a result, the magnitude of projected changes in temperature and precipitation still differs greatly between models, for extremes as well as for mean values.



Precipitation increases with altitude due to uplift of air masses and condensation - the main reason for the role of mountains as water towers of the world (see Chapter 2). Precipitation maxima vary and occur at different altitudes in different mountain regions of the world (Richter 1996).

Figure 1.1: Altitudinal gradients of precipitation in different mountain regions of the world.

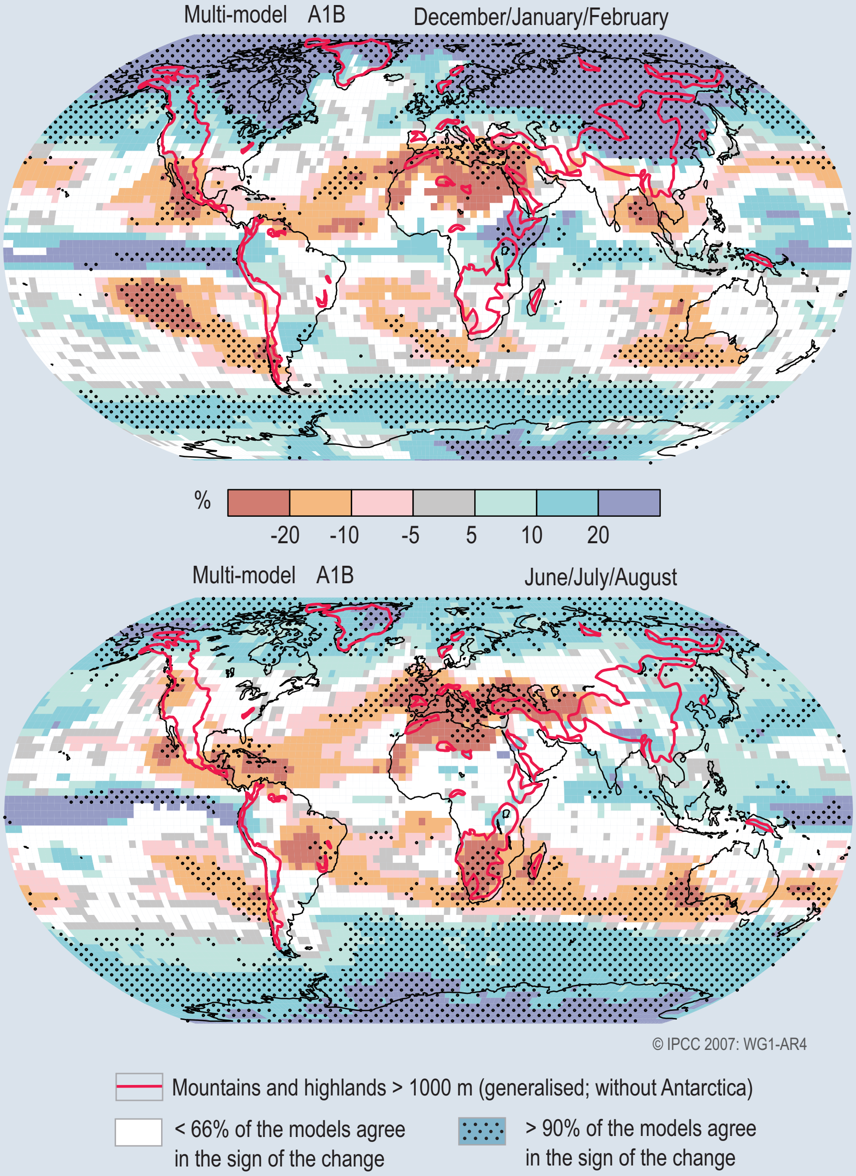
Projected patterns of temperature changes



Cartography, mountains: Ulla Gaemperli Krauer, CDE University of Bern 2009

Figure 1.2: Changes in temperature at the end of the 21[st] century compared to 1990 for a high greenhouse gas emission scenario. White contours depict important mountain regions. (adapted from IPCC 2007, Fig. WGI-SPM-6)

Projected patterns of precipitation changes



Cartography, mountains: Ulla Gaemperli Krauer, CDE University of Bern 2009

Figure 1.3: Relative changes in precipitation (in %) at the end of the 21st century relative to 1990 for a medium greenhouse gas emission scenario in the Northern Hemisphere in winter (left) and summer (bottom). Purple contours depict important mountain regions. (adapted from IPCC 2007, Fig. WGI-SPM-7) 1

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 (Urrutia and Vuille 2009). 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 threefold 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 uncertain. 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 (Westerling et al 2006).

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 (see Fig. 1.2). 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 known 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 (Oerlemans 2003), 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.