Overview of Climate Change Impacts in the Alps
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The industrial development provoked huge greenhouse gazes release into the atmosphere. This greenhouse effect enhancing, combined with natural climatic variability, led to the so-called "Global Warming". Even if the Intergovernmental Panel on Climate Change (IPCC) reports giving more and more details about the possible impacts and the observed climatic variations, many uncertainties remain, especially at the regional scale. Only few Regional Climatic Model (RCM) have been developed at this stage and the downscaling methods are not unequivocal. Furthermore, the climatic models, both global and regional, do not represent all of the existing interactions. For example, vegetation cover, cloud cover or orographic features are poorly integrated in the calculations.

The further you go into impact assessment, the greater are the uncertainties as presented in the following scheme. This overview is not exhaustive, but proposes some observed and possible impacts of climate change in the Alps.

Atmospheric parameters

Alpine temperatures

The reconstructions of the past climate show that the second half of the 20th century was the warmest 50 year period of the last 1300 years on the global scale. The last 15 years rank among the warmest for the last 500 years in the Alps. The four warmest years have all been observed after 1990 and the 2003 summer was the warmest summer of the last 500 years. During the 20th century, the Alps experienced a warming of temperatures comprised between 1° and 2°C. This warming trend seems to have accelerated in the last decades.

The mean winter temperature increased more than the mean temperature for the other seasons; this is even more marked for the minimum temperature increase. However, some contrasts appear, depending on the location and elevation of the observation sites. According to the results proposed by the regional and global climatic models, temperatures will certainly continue to rise. This evolution should be more significant in the Alpine arc than in the rest of Europe. This warming should also be much important for minimum temperatures.

Alpine precipitations

The precipitation variability is very important in the alpine range. Thus, no general trend can be found concerning precipitation trends. However, in some specific massifs, a winter precipitation increase and a summer precipitation decrease have been found. Climatic models predict an increase of winter, autumn and spring precipitations, whereas the summer precipitations should decrease. In winter, precipitations should increasingly fall as liquid precipitations (and so less as solid precipitations). This is especially true for medium altitude areas. However, it is still difficult to include the specific orographic parameters in the climatic models. Indeed, simulation results show great variability depending on the site observed, the scenarios chosen and the model used.

Alpine natural systems

Snow cover, glaciers and permafrosts

A decrease of the snow cover duration and snow volume in the Alps has been observed since the 1960s. Nevertheless, strong differences appear, depending on the site elevation. It seems

that this decrease is especially marked for low and medium elevation sites, but is still unequivocal for high elevation sites where the results are in contradiction. For each degree of warming, the snow line should rise by 150 m in altitude and the snow cover duration should decrease by 15 to 20 days, especially towards the end of the snow cover season.

The alpine permafrost has experienced important changes in the last 100 years, because of rising temperatures. Despite the fact that the evolution of permafrost is complex and less documented than that of glaciers, it may follow similar degradation.

The lower limit of permafrost potentially rose from 200 m during the twentieth century and the temperature in frozen ground increased significantly since 1980. The inertia of permafrost to changing climatic conditions is quite strong and the reaction of this ground takes place over long time. Studies and observations of this frozen ground are recent and all the patterns are not well understood. It is also important to differentiate between cliff permafrost and medium slope permafrost (>30°).

Since 1850, the European alpine glaciers have lost about 30 to 40 percent in icy surface area and around 50 percent in ice volume. During the decade 1980 - 1990, glacier mass losses further increased by more than 50 percent with respect to the secular average for the 20th century. The extent of Alpine ice is probably more reduced today than ever before during the past 5000 years. The Alpine glaciers mass balances show an ablation increase while the accumulation during winter can not compensate these losses. The glaciers mass losses tend to increase since the 1980s. The smaller is the glacier and the stronger is its reaction to climate change. The glacier's mass and volume losses should continue and even accelerate as global warming straighten. Some glaciers may even disappear toward the end of the 21st century.

Vegetation, forest and fauna

Climate change leads to a longer vegetative period (with an earlier bud blooming and later leaf falling in the season) and an increase of the vegetation indication. In a general manner, there is a delay in the physiological need period to climatic factors for the species (for example: need for heat or cold).

The most vulnerable species to climate change are ones with the least dissemination possibilities, especially the old forests (linked to long-term forest conditions, independent of the age of the population), with migration speeds not above a dozen meters per century. Climate change may have impacts on tree diseases and on parasitic insects by affecting their biology and their repartition or indirectly by affecting the biology of their host or their enemies and competitors.

Alpine ecosystems constitute important biodiversity stocks showing a wide range of species on small area. The altitude ecosystems are already under constant stress because of pollution, agriculture, alien species, etc. Climate change would come on the top of these existing problems and induce further loss of biodiversity in the Alps. The most spreading and adapting species may "steal" the weaker species ecological niche.

Erosion, river hydrological pattern

The flow of rivers seems to be evolving in a heterogeneous manner. However, nival rivers and those fed by glacier have encountered a modification in the intensity and temporality of their flow. Therefore, it is mainly the melting of glaciers and rainfall rather than snow fall which affects river's regimes within the context of global warming.

The rivers of nival regimes will be the most affected, the peak water level rise will take place approximately one month earlier than at present and the average annual flow should decrease with strong seasonal contrasts. Summer and spring flow would decrease whereas winter flow would increase.

Regarding many factors, erosion should increase in mountainous area. Freezing and defreezing cycles, running water, decrease in snow cover and vegetation cover may enhance erosion in the Alpine slopes, which already showing important erosion rate.

Alpine natural events

The consequences of climate change on natural events and, thus, the evolution of the natural hazards and natural catastrophes are really hard to assess. The crises situations usually correspond to extreme characteristic of the events (considering the intensity, frequency or localisation of the events), while the climate studying concerns especially the mean values. Thus, the link between a global and mean phenomenon with local and extreme events is quite hard to provide.

The floods in the Alps do not show significant trends in the past. An increase in flood damage is mainly the consequence of human development rather than from any changes in precipitation and river patterns. For the future, rivers should have reduced nival and glacial pattern in the Alps, leading to earlier flood peaks in spring and stronger drought during summer.

Debris flow in the Alps may be strongly influenced by glacier retreat and permafrost degradation. It is mainly sediment and detritus materials availability that may change with climate change.

Avalanches show no trends at all in the Alps. Considering the importance of human development and the increase in extreme sports, avalanche damage still remains low. Perhaps, this could mainly be explained through protection measures and emergency services efficiency. Avalanche evolution is really hard to appreciate, but in the future hazards should be the same or even reduced.

The mass movements (landslides, rock falls and mud flows) should experience changes due to fluctuation in extreme and mean precipitations, shortening of the cold season (during which most water falls as snow or freezes), melting of permafrost on rock faces, etc. Once again, climate change mainly enhances dangerous situations that already exist (due to land use, lost in protection forest and vegetation cover) and sometimes create new hazardous situations, potentially within the vicinity of glaciers.

Glacial hazards are very complicated phenomena and, presently, some triggering factors are still unknown (such as glacial water pocket burst). However, it seems possible that a stronger glacier retreat may lead to more glacial lakes and a limited stability for the hanging glaciers.

Forest fires will be influenced by climate change, because there will be more frequent drought situations during the summer, and new vegetation cover will lead to greater fire hazards. Yet, forest fire hazards are mainly traced back to humans. Forestry workers, farmers, tourists and inhabitants need to provide efforts to reduce fire triggering events.

Climate change may have many consequences on natural events, but it is rather human development which already threatens mountainous areas. The human factor will be a crucial issue for future management of natural hazards.

Climate change will induce climatic vulnerabilities and climatic opportunities. Unfortunately, it seems that climatic vulnerability will be greater than climatic opportunities. Climate change impacts on human activities are numerous. We still underestimate all of the possible impacts society will face. However, this does not mean that we must view climate change as being the "evil" behind each extreme catastrophic event or winters without snow.

Nonetheless, today we need to assess impacts and propose adaptation measures. Currently, hydro-power production, winter tourism, agriculture and natural hazards managements already face difficulties in the Alps. If we do not prepare for climate change and its impacts, these sectors may face even stronger difficulties. Reactions must be both private and public, both local and national, both individual and collective, everyone as a rule to play.
Get a grip on climate change!!!

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