RESEARCH VIRUS

ENVIRONMENTAL TRANSITION

SAMUEL MORIN

CLIMATE-CHANGE CHALLENGES IN MOUNTAIN AREAS

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ENVIRONMENTAL TRANSITION
A SERIES IN THE **RESEARCH VIRUS** COLLECTION

With growing awareness of the climate emergency and its environmental challenges, scientists are speaking out!

Under the aegis of the scientific council on the Green Capital and Transition, this new series of e-books offers previously unpublished articles by researchers from many backgrounds: hard science, Earth science, engineering, and human and social sciences.

In relation to the agenda of the scientific council – made up of almost 40 scientists representing a full range of disciplines – these short texts aim to disseminate knowledge on issues raised by environmental transition and its impacts.

All the way through 2022 publications in this series have reflected ongoing debate as part of European Green Capital status awarded to the city of Grenoble by the European Commission. Every month has seen a new topic addressed, including climate, atmosphere, energy, mobility, food and urban life.

Scientists are passionate people too. Their papers reveal their learning, but also cast light on the controversies affecting their subject and the sensitive nature of their work in research, with its tentative progress, doubts, puzzles but also its hopes.

Have a stimulating read!

CLIMATE-CHANGE CHALLENGES IN MOUNTAIN AREAS

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The effects of climate change are particularly apparent in the mountains. Indeed such places are ideal outposts for observing the changes underway. They have natural and socio-economic assets in terms of water resources, biodiversity, farming and cultural heritage. Moreover their particular environment supports emblematic leisure and tourist activities. But they are also the site of many random natural phenomena which add to the complexity and cost of their development. Climate change impacts almost all of these interconnected stakes. It modifies their characteristics and upsets traditional ways of managing these assets and coping with their intrinsic difficulties. Meanwhile scientists are busily developing inter-disciplinary knowledge and tools to make more allowance for such challenges in territorial development strategies.

The climate is changing in the mountains, as elsewhere

Human activity and the mountain environment are particularly sensitive to weather conditions. Changes in these conditions in recent decades correspond to local instances of global climate change. In the mountains, as elsewhere, this trend has impacted both average weather conditions spread over several years (temperature, precipitation, snow cover, etc.) and the distribution of rare, intense or even extreme phenomena. In the French Alps and the Pyrenees the average annual temperature has risen by almost 2°C since the beginning of the 20th century. Altitudinal zonation of mountain habitats and the prevailing weather conditions explain to a large extent why the signs of climate change depend a great deal on elevation.

Contrasting outlook for snow and glaciers

Warming generally leads to less snowfall, replaced increasingly by rain, particularly at low and medium elevations. Moreover snowmelt in the spring is more intense. The reduction in snow cover is noticeable throughout the winter and in spring at low and medium elevations (snow cover has been shortened by almost a month since the 1970s), but only noticeable in the spring at high elevations[1]. Glacier retreat is probably the most dramatic sign of climate change in the temperate latitudes. It is caused by a growing imbalance between the accumulation of snow during the winter and greater snowmelt driven by higher temperatures in summer and particularly by heat waves.

It is inevitable that the climate crisis, and its effects, will become increasingly acute in the coming decades, because greenhouse gas emissions (due to burning fossil fuels and changes in land use) will initially stay close to their current level, despite progress towards reducing them. The speed and scale of cuts to global emissions, here and now, will determine how the climate changes in the second half of the 21st century. The characteristics of seasonal snow cover are directly linked to the degree of heating. Were the climate to stabilize, thanks to humans achieving carbon neutrality, the characteristics of snow cover would stabilize too. But the outlook for glaciers is very different, because the climate would stabilize at temperatures – and corresponding snowmelt intensities – unfavourable to glaciers. Indeed this is already the case. So glaciers will go on retreating. All the present (climate change) scenarios predict that the vast majority of mountain glaciers in Europe will disappear in the course of this century, leaving only those at very high elevations.

Chain reaction

The consequences of such retreat for water resources depend on the season and the distance from existing glaciers. As their surface area is relatively small, they primarily impact water resources in summer and in their immediate proximity. Reduced snow cover and changes in seasonal patterns of precipitation

1. R. Hock, G. Rasul, C. Adler, B. Cáceres, S. Gruber, Y. Hirabayashi, M. Jackson, A. Kääb, S. Kang, S. Kutuzov, Al. Milner, U. Molau, S. Morin, B. Orlove and H. Steltzer, High Mountain Areas, in IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)], 2019, Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 131-202. https://doi.org/10.1017/9781009157964.004

(higher in winter, lower in summer) change the seasonal flow rate of rivers: increasing in winter, with a peak in spring earlier than previously, and dropping in summer – except in the immediate proximity of glaciers, as long as they have not been substantially reduced[2].

Increasingly intense precipitations may lead to flooding, landslides and other events caused by heavy rainfall. Glacier retreat increases the likelihood of random gravity-driven events related directly or indirectly to glaciers: landslides in areas of unstable moraine, collapse of seracs, or even the combination of several interrelated events producing a chain reaction.

The risk of avalanches is changing too. They are becoming less frequent at low and medium elevations but are nevertheless still a hazard. There will also be more wet-snow avalanches, even in mid-winter. Climate change is thawing and destabilizing permafrost too, which in turn increases the risk of rock falls at very high elevations.

Climate change is increasing the likelihood and gravity of almost all random gravity-driven events, extending their seasonal variation and range of elevations at which they occur. This trend throws doubt on current strategies to prevent and mitigate risks. It also affects mountain ecosystems, arable and livestock farming. More broadly these trends concern the relation of human communities to the mountains, including the major change in the landscape brought about by retreating glaciers, changing the face of the natural and cultural heritage of European societies. It goes without saying that the conditions for all forms of mountaineering are changing radically.

Winter sports and artificial snow, an emblematic case

The winter-sports industry is particularly dependent on weather conditions, in particular the dependability of natural snow cover and the ability to produce [artificial] snow. The latter requires sufficiently low temperatures and little wind. Snow production and grooming techniques, initially developed to cope with occasional poor snow cover, are now widely used to manage snow resources.

Interdisciplinary research carried out in recent years by the National Centre for Meteorological Research (CNRM, Météo-France and CNRS) and the Mountain Ecosystems and Societies Laboratory (Lessem, INRAE), in France, has quantified the variation in the dependability of snow cover on ski areas. All the existing climate projections indicate that the conditions for operating ski areas will deteriorate over coming decades, to varying degrees according

2. Ibid.

to the elevation and position of resorts, and with diverse consequences depending on their business and territorial development model.

Artificial snow is a key issue in much debate and controversy among mountain communities, relating to their attitude to developing tourism, how they stand on climate change, and its present and future consequences, and the relationship between the various players involved[3]. In particular – at a local level and avoiding misleading generalizations – providing such communities with the wherewithal to analyse their situation may pave the way for more constructive debate than the antagonism and mud-slinging that often mar political or media discourse on this subject.

A fresh start for the governance of mountain territories

Adaptation to climate change aims to reduce the risks entailed by inevitable alterations in climate factors, by reducing the exposure and vulnerability of relevant human systems. In the mountains adaptation is already underway, either as a deliberate policy or by force of circumstance.

Our work on the pathways for winter sports resorts endorses the conclusions of the IPCC Special Report on the Ocean and Cryosphere[4]. The success of adaptation processes is above all a matter of governance, facilitated by the production and dissemination, in an inter-disciplinary framework, of knowledge and information on the local climate and its effects. The same is true of natural hazards and the management of water resources.

The challenges for adaptation in the mountains are largely horizontal[5]. They provide an opportunity to renew dialogue between different sectors in the face of a threat affecting all fields of activity. So adaptation to climate change is an opportunity to call into question and to reinvigorate decision-making bodies and processes in mountain areas in order to cope with the coming emergency.

Discover more contributions in the RESEARCH VIRUS collection.

3. L. Berard-Chenu, H. François, S. Morin and E. George, The deployment of snow-making in the French ski tourism industry: a path development approach, *Current Issues in Tourism*, https://dx.doi.org/10.1080/13683500.2022.2151876, 2022.

4. Op. cit.

5. M.-P. Arlot, Le projet AdaMont, enjeux, valeurs et fondements méthodologiques, Revue *Science Eaux & Territoires*, Changement climatique: quelle stratégie d'adaptation pour les territoires de montagne?, 28, 8-11, https://dx.doi.org/10.14758/SET-REVUE.2019.2.03, 2019.