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Climate change and the development of mountain areas: what do we need to know and for what types of action?

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EDITOR'S NOTE

Translation: Brian Keogh

- 1 Climate change is today a reality at the international level (IPCC, GIEC, 2007) as well as more local levels. Because of their characteristics, and especially their fragility, mountain areas are particularly relevant laboratories for studying climate change and its consequences. Our knowledge about climate change is continually being refined as its reality becomes increasingly apparent. This is particularly the case for the accelerating increase in average temperatures over the last twenty years. Changes in other climatic variables, however, have not been so clearly discernable. This is the case for precipitation figures, for which it has been difficult to identify a clear trend, such has been their variability. Considerable care must therefore be exercised in their interpretation. Current knowledge on future climate changes also suffers from another shortcoming. Models of future climate change, set up in the GIEC¹, are based on regional scales in the planetary sense of the term, that is, on a resolution of about a few hundred square kilometres. These models are therefore incapable at the moment of taking into account the variability observed at the scale of mountain massifs such as the Alps, resulting from local phenomena related to topography, valley effects, contrasting exposures, and different altitudes.
- 2 There is therefore considerable uncertainty, firstly about climate change itself, and then about the consequences in terms of natural hazards and the frequency and intensity of such events. Indeed, the extreme manifestations of such phenomena must be taken into

account far more than the averages, which currently are quite logically the focus of climate change analyses. In addition, the first part of our study will explore the changing nature of the different risks in response to climate change. This analysis in turn brings us to examine the way in which both economic and political actors perceive and react to climate change. The second part of our study therefore brings us back to adaptation strategies. However, it would seem important to extend this observation by analysing mountain areas in terms of their vulnerability, given that their socioeconomic development is closely linked with the dynamics of natural risks. We will explore this perspective in the final part of the study.

- 3 From a methodological point of view, the analyses put forward in this article are based on the participation of the authors in different studies relating to climate change: an Interreg ClimChalp² programme, participation in an exploratory study on climate change in the Alps at the request of the mountain area's regional authority (DATAR, 2008), and monitoring of local initiatives and strategies conducted in the French Alps or in other mountain areas.

Are mountain areas becoming more dangerous?

- 4 This is an interesting question that needs to be addressed if we are to plan for the future, but one that is not easy to answer in that the impacts of climate change on those phenomena that generate natural risks in mountain areas are at least as uncertain as elsewhere, if not more so. Furthermore, it is important to understand how climate change will affect land use in mountain areas and the associated activities, as well as the consequences of such developments on risk management.
- 5 With respect to the changes affecting different phenomena, the only clear trend observed today is the rise in average temperatures. However, there are few phenomena that generate natural risks in mountain areas that are determined solely by temperature. Precipitation, for example, is often a predominant factor in the generation of extreme phenomena. But the scenarios for changing precipitation patterns are still very uncertain. The knowledge base of "Alpes-Climat-Risques", prepared by the Pôle Alpin des Risques Naturels (Alpine natural risk centre) as part of the Interreg IIIB Espace Alpin ClimChAlp (2006-2008) project in partnership with the ONERC and the Rhône-Alpes Region, provides a review of available literature both on changes in the natural phenomena that generate risks in the Alpine Arc under the influence of climate change and on the impact for natural risk management (Loglisci et al., 2008; Prudent et al., 2008). Based on the summaries provided by this base, the types of natural phenomena that generate natural risks are examined, beginning with those that appear to be more directly influenced by temperature.

Phenomena of glacial origin

- 6 Even for phenomena of glacial origin, which a priori are amongst those most related to temperature, are not solely determined by temperature. Thus winter accumulations of snow and radiation, for example, influence both the mass and dynamics of glaciers. However, many glaciers will continue to retreat considerably, and in some cases will disappear (North *et al.*, 2007). The glacier systems whose accumulation zones are situated at altitude will be less affected, particularly if the hypothesis of an increase in winter

precipitation is confirmed, since above about 2 500 m winter precipitation will continue to fall in the form of snow (Durand *et al.*, 2009).

- 7 The risks to be feared as a consequence of the accelerated melting of glaciers are of several types. A European database for events of glacial origin has been set up as part of the Glaciorisk³ project (Richard, Gay, 2004). Some of these phenomena result from the flow of water, often brutal, in its liquid form after having been momentarily stored in a glacial landform: sudden rupture or emptying of glacial lakes, emptying of intraglacial pockets of water. Other phenomena result from the gravity movement of water masses in solid form (ice) which become detached from the glacier: falling seracs or breaks in the glacier due to rapid changes in glacier length or to “cold” glaciers (where the ice adheres to the bedrock) that evolve to “temperate” glaciers, where adherence is no longer assured and the temperature at the base of the glacier allows water to flow beneath it (Vincent *et al.*, 2007).
- 8 The consequences of these two types of phenomena are markedly different. The emptying of glacial lakes or water pockets may produce floods downstream of the glacier, depending on the volumes of water involved and the suddenness of the outflow. These floods may act like a mountain torrent, carrying heavy loads of sediment, or even like lava flows if the amount of sediment transported is particularly concentrated. In the case of glacial lakes, such drainage may be due to a break in the natural dam that created the lake or to a break in the dam made of ice and/or moraine materials. They may also result from the sudden drop into the water of a large volume of ice (calving), rocks (rockfall), earth (landslide) or snow (avalanche), generating a spillover on the natural dam if the “run-up” is sufficient.
- 9 Falls of ice may also generate direct damage in downstream zones: destruction of chalets, infrastructures, forest stands, hikers... They may also have indirect consequences, such as triggering avalanches or the formation of torrential flows if the mass of ice temporarily blocks a flow.
- 10 Added to this are phenomena that can follow the melt of the permafrost, soils which contain ice that may return to a liquid state under the influence of a warmer climate. This can result in rock subsidence or movements of the slopes where water in its liquid form no longer “cements” the terrain as it did in the form of ice (ProClim, 2005). Fresh sediments would thus become mobile under the effect of torrential flows or other erosive processes in the catchment basins concerned.
- 11 The rarity of these events obviously precludes any generalisation, but a certain multiplication of these manifestations of glacial origin is nevertheless to be feared under the influence of increasing average temperatures.

Avalanches

- 12 After glacial phenomena, it is undoubtedly those relating to snow that should be most directly influenced by a increase in temperatures and the reduction in the number of days when freezing occurs. A gradual reduction in snowfall at medium altitudes (number of days with snow covering the ground and accumulations of snow) has been observed (Durand *et al.*, 2009). Measurements made by MétéoFrance at the Col de Porte above Grenoble provide a precise picture, but unfortunately they only concern this particularly well-instrumented and well-monitored site (Etchevers and Martin, 2002). However, the

measurements indicate that overall precipitation, in the form of snow or rain, has not decreased, which seems coherent with the hypothesis of a probable increase in winter precipitation. Numerous avalanche corridors have their departure or source zones at altitudes where winter precipitation will continue in the form of snow. We may also experience more frequent and more marked mild spells in winter than at present. The average increase in temperatures may also be reflected in different types of snow (cold, dry, wet, heavy) and perhaps more spatial and temporal variations than today (Baggi *et al.*, 2009). What effect will the different possible combinations of these potential modifications have on the type of avalanches affecting threatened areas? Are we to expect increases in frequency, stopping distances, the volumes of snow in movement, and the pressures developed? Recent studies, which are still only provisional, do not seem to reveal any detectable trends in the number of avalanches, though there has been a slight tendency towards shorter stopping distances since the 1980s (Eckert *et al.*, 2010). But again, it only concerns average trends, which cannot preclude the possibility of events occurring that are even more extreme than we have known to date. The abnormal number of avalanches during the winter of 2008-2009 is a perfect illustration of this risk.

River and mountain torrent floods

- 13 It is important to distinguish between the essentially liquid floods of alpine rivers flowing along valley bottoms with a moderate slope from the floods of mountain torrents where the slope enables the mobilisation of large quantities of sediment, which may become preponderant in the overall composition of the flow. Both components, liquid and sedimentary, of the floods on these mountain rivers are examined here.
- 14 The formation of runoff and liquid discharges involves numerous interactions and successions of multiple processes. The response of a river to two rainy episodes that are exactly the same may thus be totally different if the initial conditions are not the same: snow cover, initial soil saturation state, state of plant cover, slope surface conditions, etc. Anthropogenic factors, and in particular land use, are not the least of the factors that influence the response of a river to climatological “forcing”. Thus the absence of significant changes in flood volumes on French rivers (and even less that which can be clearly attributed to climate change) is not surprising. Rivers with snow and ice regimes seem to exhibit more marked changes in their seasonal regimes (Lang and Renard, 2007).
- 15 With regard to solid discharges in rivers with steep gradients, a distinction is generally made between two main types of transport. Solid transport in the form of bedload is determined by the amount of sediment that can be mobilised in the catchment basins, but also by the liquid discharges of floods corresponding to “maximum transport capacity”. This deterministic relationship does not exist for torrential lava flows, which have a much higher concentration of sediments, sometimes representing more than three quarters of flow volume. The volume of lava torrents is much more influenced by the volume of sediments mobilised in the catchment basins when there is abundant and intense precipitation. Even if it is not possible today to detect any trend or changes, it is not unreasonable to suppose that the volumes that can be transported by lava torrents, and in a secondary manner by river floods in the form of bedload, will increase because of melting permafrost, when present, or the retreat of glaciers, which in certain cases could make moraine materials available for mountain torrents (Béniston and Stephenson, 2004).

Slope movements

- 16 A wide variety of slope movements exists, including different forms of landslides, creep, rockfalls, and falling blocks. This characteristic significantly limits the constitution of exploitable databases to detect changes in these very diverse phenomena. Such phenomena are also governed by different weathering and degradation processes that are likely to be directly influenced to a lesser or greater extent by climate change. An increase in precipitation, for example, associated with earlier snowmelt would no doubt favour landslides. Furthermore, a change in the vegetation on slopes that are vulnerable to landslides could have a stabilising effect (Meusburger and Alewell, 2008). But if the change in precipitation patterns is accompanied by an increase in fire risks (Zumbrunnen *et al.*, 2009), the consequences could be entirely different.
- 17 On the other hand, in the concerned areas, an increase can be expected in the number of slope movements under the influence of the probable increased melting of permafrost, alternating freeze-thaw periods, and periods of drought and summer heat-waves.

What response?

- 18 This context of climate change unquestionably places the actors involved in the prevention of natural risks in mountain areas in a position where they are obliged to take a decision and to act in a situation of uncertainty. Different scenarios may be prepared in function of the level of knowledge available. Contradictions between scenarios may also emerge on account of the uncertainties inherent in their preparation.
- 19 Obviously further research will progressively reduce these uncertainties, without them entirely disappearing. Thus, one of the first impacts of climate change in most fields, including the management of natural risks, is to impose decision-making in a context of uncertainty. These decisions concern adaptation as much as attenuation. But the hoped-for beneficial effects are certainly more general for the attenuation measures, and more local or regional for the adaptation measures, and thus more relevant with regard to the preoccupations for developing mountain areas, namely from an economic and tourism point of view.

Adapting the prevention of natural risks

- 20 With regard to the prevention of natural risks, a suitably adapted prevention policy cannot be developed, at least in the short or even medium term, on the basis of solid hypotheses of the effects of climate change on the phenomena involved. It is more important to examine the methods of prevention themselves, the effectiveness of public policies and the instruments of public action for preventing risks. The measures currently used in France are mainly aimed at three complementary registers, information on prevention, land-use regulations (with the Prevention Plan for predictable Natural Risks) and the organisation of protective measures in the event of a harmful natural phenomenon occurring (with the Communal Protection Plan). Adaptation to climate change in this field suggests the need to examine the robustness of these measures in relation to the different and poorly defined changes of potentially dangerous phenomena. Adaptations and improvements to the tools themselves, their implementation, and the

way they are used in relation to one another should emerge from this examination. The question of changes in the hypotheses defining the event selected as a reference for zoning or development choices will also inevitably be asked.

- 21 Adaptation, however, assumes that it is known to what situation the adaptation is being made. If future forecasts are impossible, it is important to at least know what changes have already been observed. There is therefore a real need to build up a database and to implement observation procedures so that future changes can be monitored over the long term. This will improve our knowledge of the different manifestations of climate change and will enable decisions to be based on information that is as sound and objective as possible. These databases and observation procedures must be organised and networked, and must take on a European dimension. Regional particularities will probably appear in certain manifestations of climate change (this is already the case for certain parameters). For these differences to be validated, it will be important to establish coherent, if not identical, observational and data processing protocols. Similarly, the models used to analyse the data with a view to detecting possible trends resulting from climate change must also be comparable.

Towards an adaptation of mountain area economies

- 22 An adaptation policy at the scale of a particular territory should not be limited simply to addressing the issue of natural risk prevention. By their very nature, adaptation strategies will have to be “multisectoral” and the prevention of natural risks is but one component. Climate change is a global phenomenon and involves numerous components of the mountain environment: understanding natural risks, and their prevention, calls for a more global approach, integrating different development methods for mountain areas. In this regard, the mountain areas of France, and especially the Alps, have been largely developed thanks to tourism, and particularly winter sports.
- 23 At the end of the Second World War, mountain resorts were seen as a real planning and development tool, capable of counteracting rural decline from both an economic and demographic point of view. Today, winter resorts are considered as a lever for development, synonymous with jobs, and increasing population. Maintaining winter tourism, if not further developing it, also undoubtedly constitutes a central objective for all actors in the tourism industry. The recent slogan of the Syndicat National des Téléphériques de France⁴ (2008), the French national union of ski lift operators, is a good example: “The time when skiing alone was sufficient is over, but without skiing, everything is over (translation!)” and bears witness to the preponderant role of skiing in the operation and structure of resorts and, more generally, of entire areas.
- 24 It is therefore easy to understand why the principal measures relating to winter tourism have essentially focused on securing the position of skiing. The development of artificial snow machines is a reflection of this concern. According to ODIT data (2009), the number of resorts equipped with such installations has increased from 10 to 204 over the period 1980-2009, while the total ski area covered by this equipment has gone from about 100 hectares in 1994/95 to 5 333 hectares for the 2008/09 season. Despite this rapid progression in the field of artificial snow making, the French resorts have still not reached the hoped-for levels of our Austrian and Italian competitors.
- 25 The role of artificially produced snow in the operation of winter resorts is a significant reflection of the increasing influence of climate change. However, artificial snow began to

be used in resorts even before climate change was recognised and accepted as a reality in mountain areas. Thus, following the first winters without snow in the 1990s, and realising the dependence of resort activities on natural elements, the resorts embarked on their first programmes to produce artificial snow, or “cultivated” snow as it later became known in France. These installations met several objectives, making it possible to fix dates for the opening of the ski season, guaranteeing the possibility of returning to the heart of the resort on skis, and ensuring a minimum area for skiing in the event of unfavourable weather conditions, reasons that were as much motivated by the need to improve the quality of the tourism product as by the feared climate changes. In this context, the most concerned resorts were those situated at higher altitudes, given their strong dependence on snow-based activities and their need to be able to guarantee the resort being open for a minimum number of skiing days.

- 26 Gradually, as climate change and its impact on snow cover were taken more seriously, installation programmes for snowmaking equipment became more widespread. Recently, it has been mainly the mid-altitude resorts, which *a priori* are more sensitive to a decrease in the snow cover, which have invested most heavily in such facilities. This development has given rise in recent years to strong controversy both over the conditions required for the production of snow and over the pressure exerted on the natural environment. By means of a media campaign, the SNTF has reaffirmed that artificial snow is exclusively composed of water and air, without any additives. The liveliest debates have concerned the question of water resources, indispensable for producing artificial snow. They underline the issue of conciliation among competing uses, namely between drinking water and water destined for producing snow in low water periods; they also raise concerns about pressure on water resources (Paccard, 2010) for certain sites that are already affected by shortages. Finally, little by little, the controversy has shifted towards energy needs, particularly electricity, to produce the artificial snow.
- 27 Climate change has also been instrumental in bringing about new services and products offered by the tourism industry. Thus some sites have developed offers integrating bad snow conditions by offering to reimburse customers for ski passes in the event of such conditions. In the same manner, it seems likely that climate change may well encourage a return to the Nivalliance system set up by ski lift operators at the beginning of the 2000s. The keyword in this system is solidarity, based on the following simple principle, as outlined by the SNTF:
- “every year, at the beginning of the season, all the operators pay an insurance premium based on their average turnover. At the end of the season, if turnover is well below the average of the turnover for the last three years, the operators are compensated for a fraction of their losses (translation)”⁵.
- 28 These measures, whether they be localised or based more on an activity sector, call into question more generally the viability of all resorts in the context of climate change, in terms of economic profitability, changing clientele, the need to renew tourist infrastructures, etc. Can all the sites provide artificial snow without running into economic difficulties? What services need to be provided to maintain a certain level of visitors, or even to further develop it? Such questions underline the need to plan for the future of winter tourism and the appropriate public policies.
- 29 Indeed, it is public policy that has in recent years imposed new criteria in planning procedures. Thus snow conditions and changes affecting them have to be taken into account in applications submitted under the Unités Touristiques Nouvelles (New Tourism

Units) programme since the decree of 2006. More generally, public action, implemented by the French administrative departments and regions, has had to integrate factors of the more global context (particularly climate change) in which resorts operate. Here again, the mid-altitude resorts are directly concerned by these public policies, designed and implemented at the different departmental, regional and national levels. By way of example, for a number of years now, the Rhône-Alpes region has been developing measures to help mid-altitude resorts. Within this framework, different measures have gradually integrated climate risks (agreements for mid-altitude resorts for the period 2000-2006), while today the agreements for sustainable resorts are aimed at encouraging a diversification of resort activities.

- 30 Here again, diversification practices often appear contingent upon climate change in rhetoric and discussions (Marcelpoil-François, 2010). However, diversification existed even before the observations on climate change and the search for causes. The diversification of tourist activities affects every resort and calls into question the economic model adopted by resorts as well as the economic options taken by the supporting regions, and particularly the orientation with respect to tourism.

Understanding mountain areas in terms of vulnerability

- 31 As we have seen, mountain areas are considerably affected by climate change, and in numerous ways. With regard to natural risks, the occurrence of catastrophes related to events that are more extreme than today (Décamps and Mathieu, 2005) is an important issue and, for the winter tourism economy, the effect of climate change on snow cover is of the utmost concern (Etchevers and Martin, 2002; OCDE, 2007). These considerations are taken into account at the different territorial levels and the various actors concerned will necessarily integrate, and even “weigh up”, the different objectives and issues regarding the protection against natural risks with the other issues and objectives that they consider strategic in their area. The hierarchy of issues will undoubtedly vary from area to another. An illustration of this integration of the various concerns can be seen in the mountain reservoirs. A lot of these were primarily built for producing artificial snow and clearly serve the purpose of making a winter tourist activity more secure economically. But these structures are also exposed to the natural hazards of mountain areas (avalanches, rockfalls, landslides, torrential flows), which are potentially generators of dangerous phenomena in the event of the hydraulic structure closing these reservoirs becoming submerged or damaged. New regulations on the safety of hydraulic structures (decree of 11/12/07 laws of 20/02/08 and 12/06/08) have also reinforced requirements regarding the consideration of such specific risks in the design and administrative authorisation of these reservoir projects, and have thus helped further the links between the development of tourist activities and risk prevention.
- 32 Starting from the effects of climate change on mountain areas, we propose to examine these areas in terms of their vulnerability. The aim is to arrive at a more balanced analysis of the situation as opposed to a vision that is exclusively focused on the threat, characterised by strong uncertainty, and a vulnerability that is only seen in terms of the passive exposure of the area to the threat from natural causes. Vulnerability must be understood both as the result of the impact and, above all, as an element that was pre-

existing in the area. This approach makes it possible to focus on the margins for manoeuvre for mountain areas in response to climate change.

- 33 In geography, the term “natural” as used in the expressions *natural* catastrophes or *natural* risks is being called into question. Thus, in a given territory, it is suggested that catastrophes are not so much due to the existence of natural phenomena as to the conditions of exposure and the development of human activities in the area. The level of risk and the extent of a catastrophe may also be determined by the capacity of a territory to respond before, during, and after the catastrophe. In the current classic scenarios, an extreme event, of climatic or other origin, is an event that is rare in its intensity, frequency and/or duration. This event that may be qualified as an external disturbance may influence and lead to an extreme response in the attributes of the system or impacted territory. This interpretation distinguishes the disturbance from the reaction. Nevertheless, it only expresses the threat in terms of what is imposed by an external natural phenomenon, characteristic of the risk paradigm focusing on the natural hazard or the “physical”. The response to the disturbance is certainly identified but it is confined and very much a function of the characteristics of the disturbance. In short, it is the nature of the disturbance that counts above all, understood as the aggression of a more or less passive system or territory. This system is itself resilient to a certain extent, capable of adapting to change and absorbing the disturbances, but also of reorganising itself after the crises (Walker *et al.*, 2002).
- 34 In the context of climate change, a complementary vision to that described by a line of reasoning that goes from an exogenous source to a target, from the natural milieu to man, from Nature to culture, is possible. Thus the mutuality paradigm (Oliver Smith, 1999), considering the more complex links maintained between vulnerability, disturbance and capacity to respond, appears more balanced. From this perspective, the capacity of a territory to respond could be weakened if the potential disturbances of climate change are not taken into account in a satisfactory manner by those responsible, such as those in charge of tourism planning or the management of natural risks. The capacity to respond could also be affected by incorporating procedures or measures that are too rigid into an illusory mechanism to control disturbing phenomena or their effects.
- 35 The hazard/vulnerability relationship, which is no doubt still mainly understood as the deterministic effect of hazard on vulnerability, can provide a simplistic vision and separate the different approaches. Understanding vulnerability in an active, interactional and dynamic context means recognising that all the constituent dynamic elements of mountain areas do not respond in the same way to a particular disturbance.
- 36 The degree of vulnerability is above all influenced by factors endogenous to the area, whether these be anthropogenic (lack of forecasting, rigidity of measures, limited diversification, lack of consultation and participation, dilution of decision-making processes, responsibility issues, lack of concerted action, etc.) or environmental (sensitive milieus and/or milieus made fragile by anthropogenic degradation). As A. Magnan (2009) suggested, it is a question of considering two types of vulnerability, one “intrinsic” to the start of the disturbance, and the other “resulting” from this disturbance.
- 37 Vulnerability must be interpreted in an open-ended manner, where change is possible and where it is recognised that exposure of an area to risk is not a constant over time. This dynamic perspective on vulnerability constitutes an important link between the classic approach to vulnerability and an approach that takes into account the gradual risks inherent in climate change. It calls for monitoring the level of vulnerability rather

than occasional assessments. Reducing the vulnerability of mountain areas with respect to the impact of global changes (possible aggravation of extreme phenomena or rarity of snow resources, for example) involves careful assessment of the way areas actually function in their relationship not only with the milieu but also with the activities that develop there. It is not so much a question of introducing measures here and there (development of artificial snow facilities, recommendations on the safety margin on protective dykes) as to deciding on a more global plan covering changes in tourist activities, land-use and development practices, decision-making tools and the democratic processes that must accompany social as well as climate change. Although understanding the past should facilitate projections for the future, innovation and the integration of issues in the areas concerned would appear more than necessary to reduce intrinsic as well as resulting vulnerabilities. One of the challenges of research is to try to improve the links between the organisation of scientific knowledge and decision-making processes (Sarewitz and Pielke, 2001), and to do so in a manner that better balances the respective contributions to risk studies of the different scientific disciplines.

Conclusion

- 38 Mountain areas unquestionably constitute useful laboratories for observing climate change and its effects. They also provide examples for the monitoring and assessment of strategies and practices of both private and public actors on a daily basis. The challenge for these mountain areas in the future can perhaps be best understood in terms of several conclusions in the form of recommendations.
- 39 The first concerns the necessity of continuing to build up a solid base of knowledge on climate change and its extent. This requires not only introducing operational measures, such as the deployment of networks to observe hydro-meteorological variables in mountain areas, but also pooling technical and scientific expertise, along with financial cooperation to set up and manage these shared observation systems over the long term.
- 40 The second conclusion concerns the monitoring of climate change within a given territory at scales that are relevant to planning. Focussing on a defined territory would make it possible to identify and qualify the effects of climate change, by examining, on the one hand, the interrelations between the sectors of economic activity present within the territory and, on the other, the interactions between the economy and natural phenomena. Such an approach, which is certainly heavy from a methodological point of view, would provide input for adaptation strategies on the basis of an appreciation of spatial impacts rather than simply examining impacts in terms of type, or sector by sector, and ignoring the integration of planning measures to develop the said territory and, ultimately, ignoring its particular vulnerabilities.
- 41 Finally, in terms of public action, these experiments would help close the gap between engineering sciences and the social and human sciences, and help involve the different systems of actors in decisions and adaptation procedures. More generally, climate change calls into question decision-making, the actors involved, the indicators, social as well as physical, and the tools and devices mobilised. By way of example, although today climate change does not, a priori, have any effects on the methods of implementing PIDAs (Intervention Plans for the Triggering of Avalanches) in ski areas, it is possible to imagine defining indicators to reflect changes in public action in this field in response to climate change. It would be interesting to see how the different actors modify or adapt this

mechanism according to their perception of climate change. In the same vein, adaptation also implies that the preferred decisions would themselves be adaptable, and possibly “reversible”, sometimes qualified as “no regrets” decisions. For this reason, efforts should be made to improve their traceability.

Invert: Case study

Within the framework of the operation “Pilot site for the integrated management of natural risks in the Alps” (managed and financed by the Rhone-Alpes and PACA regions, the French State (DATAR), as well as European organisations (FEDER), and coordinated by the Pôle Alpin des Risques Naturels (Alpine natural risks centre), different areas of the Alps are encouraged to experiment with new approaches and management practices. The objective is to take into account the entire management cycle from prevention to crisis management by using new methods of governance that bring together the area’s major players (elected representatives, decentralised technical services, the economic community and civil society) with a view to encouraging closer links or even integration between the technical side and organisational side of risk management.

Two examples from Savoie may be mentioned here: the pilot sites of the Haute-Maurienne region (Project developer: Nondicat du Pays de Maurienne) and Bourg-Saint-Maurice - Les Arves (Project developer: Communauté).

With regard to phenomena, these two areas of Savoie are subject to the same types of risks: mountain torrents, avalanches, and seismic movements. For the Haute-Maurienne region there are also risks of glacial origin. In terms of risks, the two areas are confronted, in a recurrent manner, by blocked winter roads and torrential flows potentially capable of affecting urbanised zones (floods on the River Arv in 2008, the Arbonne in 1999, the Rivoire in 1981, threat of glacial lake of Rochemelon bursting in 2004, etc.)

Concerning intrinsic vulnerability, the development of these two areas for tourism has been accompanied by a marked expansion of urbanisation and infrastructures. This has gone hand in hand with increasing visitor numbers particularly in the holiday periods. The increase in the vulnerability of these areas has thus been concomitant with the possible increase in the level of risk.

Towards a reduction in “resulting” vulnerability:

In Bourg-Saint-Maurice, the actors of the pilot site chose to reduce “resulting” vulnerability by developing a culture of risk among the resident population and tourists, backed by awareness campaigns and actions (exhibitions, debates), but also through participation (three-dimensional model on risks).

In Haute-Maurienne, the actors of the pilot site (locally elected representatives, government technical services, highways department, local farmers, tourism public-private partnerships, etc.) targeted their action on their capacity to act rapidly, and in a coordinated manner, before, during and after the crisis. Thus they are currently preparing and experimenting with an inter-commune and inter-services monitoring and early warning system. The aim of this system is to pool information on potential risks and threats to the region and to provide input to assist elected representatives in decision-making in times of crisis management (launching and coordinating the PCS (Commoned protection plan) at the scale of the entire Haute-Maurienne region or part of it) with a view to minimising the time taken to react to potentially dangerous and destructive events.

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NOTES

1. GIEC, Groupe Intergouvernemental des Experts du Climat (Intergovernmental group of climate experts).
2. ClimChAlp, Programme Interreg,3B Espace alpin, Climate Change, Impacts and adaptation strategies in the Alpine Space 2006-2008.
3. <http://www.nimbus.it/glaciorisk/gridabasemainmenu.asp>
4. This became “Domaines skiabiles de France” in 2010.
5. May be consulted on the SNTF site: <http://www/sntf.org>

ABSTRACTS

Climate change is today a reality at both the international and more local levels. Recent studies have focussed mainly on analysing the consequences of climate change. The present article seeks to examine and qualify the impact of climate change in the mountain areas of the Alps. A first line of enquiry concerns the changing level of danger in the mountain environment. Are mountain areas becoming more dangerous and, if so, in terms of what types of risks and to what degree? However, adopting an approach based on an analysis of natural hazards and their dynamics in response to climate change cannot ignore the economic activities and types of development that already exist in these areas. In this respect, the tourism economy is predominant in mountain regions. Its durability and vitality undoubtedly constitute a priority for local actors. It is not surprising therefore that the latter have set up strategies for adapting to climate change. For planners and decision-makers to ensure integrated approaches in dealing with climate change, it is important that the complex links between natural risks and the types of development in mountain areas are better understood, which calls for a more detailed analysis of the environment in terms of territorial vulnerability.

Le changement climatique est aujourd'hui une réalité au niveau international comme à celui des territoires locaux. Les travaux récents mettent préférentiellement l'accent sur l'analyse des conséquences du changement climatique. Cet article se propose de questionner et de qualifier l'impact du changement climatique dans les territoires montagnards des Alpes. Un premier axe de réflexion concerne l'évolution de la dangerosité de la montagne. Une montagne plus dangereuse se profile-t-elle ? Selon quels types de risques et avec quelles intensités ? Cependant, l'approche des risques naturels et de leur dynamique face au changement climatique ne saurait occulter le type d'activités économiques et les modes d'aménagements déjà existants de ces territoires. En ce domaine, l'économie touristique est prédominante en montagne. Sa pérennité comme sa vitalité constituent à l'évidence une priorité pour les acteurs territoriaux. Ces derniers ont mis en place des stratégies d'adaptation face au changement climatique. Pour mettre en place des approches intégrées face au changement climatique, les relations croisées entre risques naturels et modes d'aménagement des territoires montagnards appellent à encourager des lectures en termes de vulnérabilité territoriale.

INDEX

Mots-clés: Alpes, Changement climatique, risques naturels, tourisme hivernal, vulnérabilité territoriale

Keywords: Alps, Climate change, natural hazards, territorial vulnerability, winter tourism

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