THE LOCALIZATION MAP OF AVALANCHE PHENOMENA (CLPA): STAKES AND PROSPECTS

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ABSTRACT

The Localization Map of Avalanche Phenomena (CLPA in French) was created in 1971 as a response to the deadly avalanche that occurred in Val d'Isère (February 1970, 39 persons killed). The aim is to inventory and record the areas where avalanches have occurred in the past and their widest limits. The CLPA has rapidly become an essential part of mountainous area development planning.
After another catastrophic avalanche, which occurred in the village of Montroc (Chamonix) in February 1999, the Ministry for the Environment decided to continue and to modernize the CLPA, a mission that was assigned to the Cemagref with the collaboration of the ONF. This modernization included digitizing maps and eye witness account records, compiling summary notes on the main avalanche information for each mountain massif, updating avalanche maps, and making all this information available online (www.avalanches.fr). The information recorded in the database is also very important for research.

Keywords: snow avalanches, risk management, mapping, information systems

INTRODUCTION

Since the creation of the Division Nivologie (the Division of Snow Sciences) in 1971, the entity that later became the Cemagref has completed and managed two databases:
- Begun in the 19th century, the Avalanche Permanent Survey (EPA) records the date of events occurring in more than 4500 sites selected throughout the French Alps and Pyrenees, as well as other information;
- The Localization Map of Avalanche Phenomena (CLPA) records, on a 1:25,000 scale map, the widest limits of all the known avalanches having occurred in the French Alpine and Pyrenean massifs (the CLPA today covers more than half of the corresponding surface).
Scientific developments using those data are complementary to their practical purpose.
On 9 February 1999, an exceptional avalanche killed 12 persons in the hamlet of Montroc (Chamonix, Haute Savoie, France). The Ministry for the Environment decided to renew and to pursue the observation of avalanches, in particular the CLPA, and entrusted the mission to Cemagref, with the cooperation of the National Forest Office (ONF). The principles and the approach were formalized through an agreement for the 2002–2006 period.
The agreement recognized the public utility of avalanche observation. It is the first agreement of this type to systematize the knowledge on a natural hazard.
The renovation mainly concerned the normalization of the processes of data collection and management, the completion and digitization of the maps and identification sheets based on eye witness accounts, the compilation of massif notes synthesized for the main information on avalanches,

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the updating of the maps, and the creation of a website (www.avalanches.fr) where all this information is collected (fig. 1).

Fig. 1 Home page of the website www.avalanches.fr

Since 2007, the methods have been stabilized and more appropriate tools chosen. The system is continuing to evolve to ensure long-lasting function beginning in 2011. This renovation of French avalanche observation and records opens numerous perspectives on how the data can be used in all projects of mountain area development and management as well as for public information. In addition, new scientific needs are addressed: data for numerical models of avalanche flow and stoppage, the study of regional avalanche models, spatial analysis of avalanche-prone zones (start zones in particular), and application of the research results using information systems. The applications and the perspectives made possible by the CLPA are detailed below.

WHY SHOULD AVALANCHES BE OBSERVED?

The collection, processing, and dissemination of the known historic events are the first source of knowledge of the avalanche phenomena in their spatial and temporal dimension. This is indispensable for public information and is the basis of avalanche risk management in development planning.
Avalanche release and dynamic phenomena are physically very complex. It is generally impossible to determine the precise sites where and when an avalanche will start, which is why the knowledge of these phenomena on a local scale is particularly difficult to refine. Consequently, all risk prevention and management decisions concerning human life and property damage result from expert-based knowledge of the historic events, but more reliable, objective and systematic information is needed.
The traces left by avalanches in the environment, however, are often not easily seen and eye witness accounts are rare and tend to be centered on the resulting damage more than on the precise and

complete description of the phenomenon. As a result, observation of avalanches is the foremost means of acquiring knowledge of these phenomena.

THE CLPA, AN INVENTORY MAP OF AVALANCHES

Origin

Further to the deadly avalanche of 10 February 1970 in Val d'Isère (39 persons killed), the report of the Interdepartmental Mission of Study on Mountain Resort Safety, recommended "the establishment (…) of an inventory map of avalanches". This mission was entrusted to the Division Nivologie (Division of Snow Science) of the CERAFER (which became CTGREF and then CEMAGREF) in association with the IGN (French National Geographic Institute). At that time called the Map of Probable Localization of Avalanches, the objective of this map was to assess known historic phenomena or traces visible in the field. The purpose was to provide a precise reminder of the places where avalanches had actually occurred in the past.

The CLPA was an A0 (841 per 1189 cm) size paper map, first on a 1:20,000 scale and then on a 1:25,000 scale, recording the broadest limits of avalanches recognized by photo-interpretation (in orange) as well as by investigations in the field (in magenta). Afterward, the main protection structures were added in black. Identification sheets had already been drawn up to describe avalanches based on field investigations that were numbered on the map. The first maps were established in the 1970s and 1980s. Beginning in the 1990s, these maps were updated for the first time and new zones were studied. At the same time, the appearance of Geographical Information Systems (GIS) allowed the digitization of the entire CLPA.

Description

The CLPA is a descriptive map of the observed or historic phenomena, designed to inform the population on the existence of zones where avalanches had actually occurred in the past. The avalanche limits are represented on these maps (fig. 2).

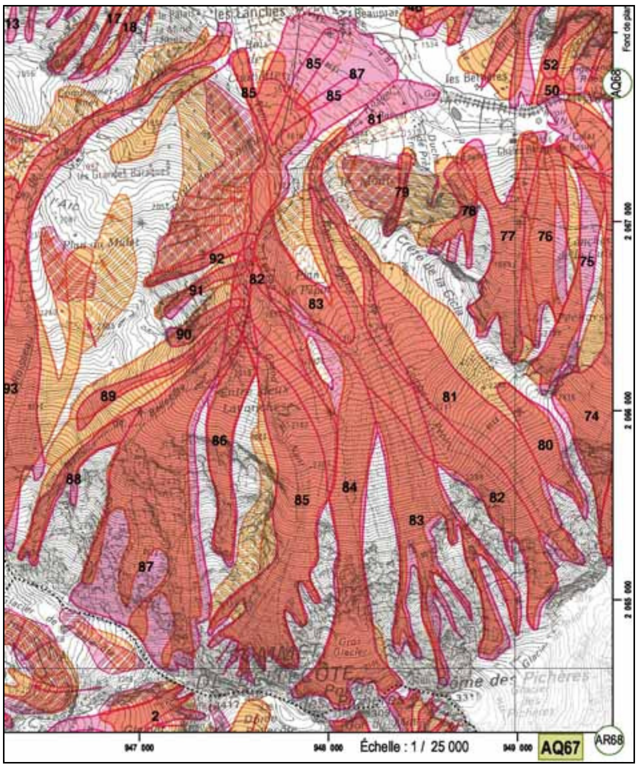

Fig. 2 CLPA extract (CLPA AQ67 sheet, 2006 edition)

The CLPA is not a prospective analysis. It does not take into account the potential risk considering return periods and the power of the avalanches in the studied zone.

Principles of CLPA mapping

Interpreting past events

Photo-interpretation consists of a stereoscopic study with pairs of black and white and 1:30,000 scale summer aerial photos (fig. 3). The objective is to determine the physical traces left by past avalanches (fig. 4). The main elements are deposits (rock debris, snowy moraines), marks in the vegetation such as broken trees along a slope line, more scattered zones, a line of trees that are younger than the surrounding plants or partially torn away, the presence of shrubs (alders, more or less bushy birches, sorbs), and traces of destruction (broken trees, sometimes ruins of houses). This information can be used to characterize the path and sometimes the runout zone of avalanches but cannot closely define their limits on the map, particularly the start zones.

Fig. 3 Photo-interpretation with a stereoscope

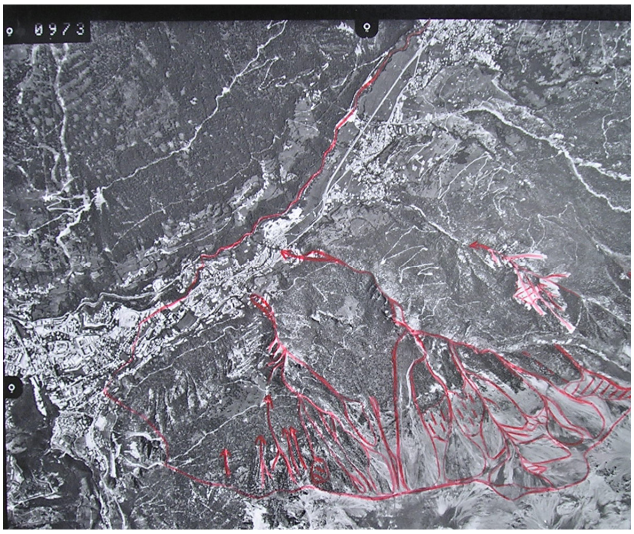

Fig. 4 Traces left by past avalanches and determined by photo-interpretation

Consequently, interpretation requires complementary analysis of the photos. The stereoscopic study also allows a meticulous examination of the topography and the search for diverse geomorphologic indications favorable to the release of avalanches: steep slopes (30–50°), with a sufficient vertical fall distance, especially those with a convex longitudinal profile, smooth ground (fine mass of debris rocks, paving stones, glacier, bent grass), and the presence of streams or shrubby vegetation. This makes it possible to specify the start zones situated over the treeline.

As for the runout zone, the photo-interpreter often can only use personal experience to identify where the avalanche stopped, because of the frequent absence of clear traces. Photo-interpretation either provides a clear demonstration of the phenomenon studied or allows for simple assumptions. It can

substantiate eye witness accounts and is particularly important in poorly known or unknown areas. One of its greatest advantages independencies that it is independent of human, economic, or political influences despite the subjectivity of the interpretation of the aerial images, most particularly in the runout zones.
This work is therefore completed by a careful field investigation by the author of the photo-interpretation in order to search for details that may have gone unnoticed when examining the air photos. In addition to validating the photo-interpretation, the field observation aims to search for additional indications that were missed in the photographic survey such as branches broken on the sides of a path, tree trunks locally broken, damages to the forest undergrowth, the existence of microreliefs or very localized changes in the plants or ground cover, for example.
This complementary data is particularly important when the studied area is poorly known or where eye witness accounts are insufficient or unreliable. These interpreted data appear on the map in the layer of the interpretation of the past events.

Collecting eye witness accounts

The photo-interpretation study remains, however, incomplete because all the necessary information is not detectable on photos or in a complementary field investigation. Therefore, eye witness accounts of inhabitants (fig. 5), elderly residents and mountain professionals such as forest rangers, ski patrollers, rescue services, transportation network managers, shepherds, and mountain guides can help specify the events of the last century.

Fig. 5 Eye witness account of an inhabitant

All the information obtained with these persons during a field study of the entire zone is analyzed. The eye witness accounts considered the most reliable collected from knowledgeable individuals are faithfully reported. Only the information provided by eye witnesses is precisely noted, including information from archive documents (fig. 6) if they can be used. All the protection structures built in the working zone are added (gas exploders, snow shed and others active protection systems).

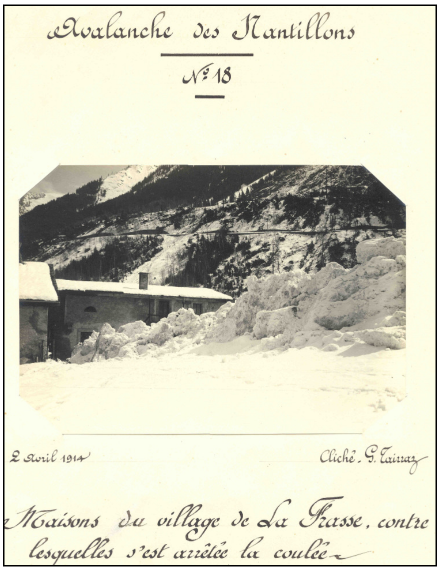

Fig. 6 Avalanche snow deposit picture considered as an archive document

Regrettably, all these studies cannot provide the necessary data for avalanche maps in low avalanche frequency zones. Near inhabited zones, avalanche paths are more clearly defined by eye witnesses, because their activity has had effects that are particularly easy to specify on a given area where there are many traces and the impacts have been noted by a large number of observers. On the other hand, it can be harder to obtain information from those who have economic interests and land use pressures are sometimes too great for the investigation to be bias-free and honest.

However, the CLPA is now considered an indispensable tool for land management, rather than a restraining measure, evidence of changing attitudes.

Presentation of the CLPA project before official distribution

When the investigative and mapping work has been completed, and before official distribution of the CLPA, the project is presented to mayors and concerned municipalities, technical services, and all other invited persons.

The CLPA is introduced and its objectives and principles explained. Then a cartographic presentation of avalanches based on eye witness accounts is provided as well and the corresponding identification sheets are presented.

The audience is then invited to express its observations, in particular on the eye witness accounts, which Cemagref will take into consideration. Cemagref remains the only entity responsible for the final editing of the CLPA.

Associated uses

The CLPA is an informative document designed to inform all persons interested in the area's avalanches. It has no statutory value itself.

The CLPA contains essential information that can be used to help protect against avalanches in equipment projects in mountain areas (communication routes, ski lifts, etc.). It is intended to prevent errors in development projects in their beginning stages. Indeed, the least expensive solution in the fight against avalanche risks is preventing a project from taking root in an avalanche path. The CLPA is particularly important in drawing up an Intervention Plan of Releasing Avalanches with explosives (PIDA in French) as a reference document in which all the known sites are inventoried. The PIDA often details the limits of avalanches zones with a larger scale, because the essential purpose is to specify the location of the explosion points.

The CLPA is a technical informative document of particular concern to mayors and administrative and technical departments involved in natural hazard management in mountain areas, specialists who need to be informed on how it was made and to understand the nature of the information it contains to use it to its fullest potential. It has an important role to play in the establishment of evacuation and

crisis management plans, risk mapping (risk prevention plan) and urbanism and preventive information documents, as it defines the zones where avalanches have already occurred.
However, the map cannot be directly used as a hazard map given the fundamental difference between the collection of historic events and the prediction of danger zones. A hazard map includes return periods and the power of the known or possible phenomena based on a detailed field analysis led by an expert. However, the CLPA remains a very important component of these hazard maps.

IMPROVE AND RENEW THE CLPA

Why renew the CLPA?

Several decades after the definition of the CLPA, confirmation of the government mandate and the mission entrusted to the ONF and Cemagref became necessary. After the 1999 avalanche of Montroc (Chamonix), feedback was requested of the General Inspectorate of the Environment. The resulting report (Glass et al., 2000) proposed improvements in the CLPA in terms of data collection and diffusion. The Ministry for the Environment contracted with Cemagref and the ONF for the 2002–2006 period (Bélanger et al., 2002) in order to modernize the CLPA in its quality approach, database structuring, and data diffusion.
The main improvements were as follows.

Adopting more fully adapted data processing methods

The current name of the CLPA is "Localization Map of Avalanche Phenomena" to better reflect the data recorded in the maps.
The standards of the document’s graphics were also improved, clarifying the symbols used (fig. 7). The CLPA does not project the intensity or the frequency of avalanche phenomena. It only takes into account various types of phenomena in their known maximum limits as recorded in eye witness accounts.

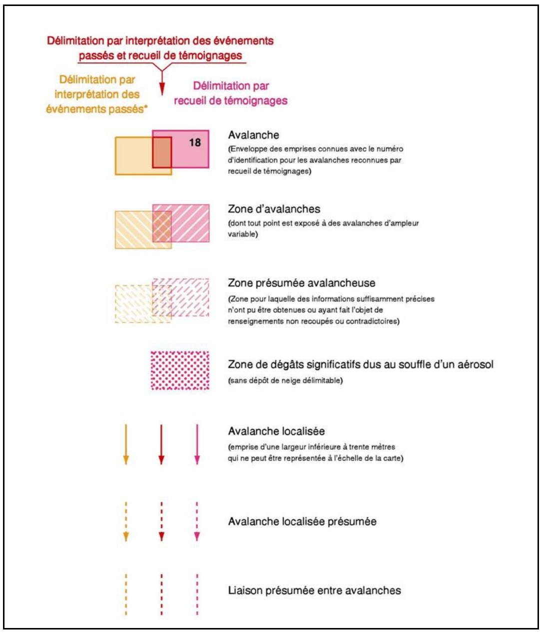

Fig. 7 The CLPA key

During the field investigation, zones undergoing significant damage due to an air blast are henceforth clearly discerned from avalanche snow deposit. In addition, the observed traces left by the avalanche run, which could not be reported during the field investigation with eye witnesses, are included in the photo-interpretation layer in orange.
Finally, data collection and management were standardized and are now underway in the implementation of a quality approach.

Regular data updating

Since the creation of the CLPA, the mapped area has grown and the data have been updated as allowed by the current funding. The data are now updated regularly.

Indeed, new avalanche limits based on new or larger events are recorded every year by the ONF. The maximum of information is recorded as quickly after the events as possible. Furthermore, any eye witness account brought to Cemagref is also integrated into the CLPA once a year. The CLPA is updated 20–30 times every year.

Winter 2008–2009 was particularly rich with more than 80 major modifications recorded. The last avalanche cycle in December 2008 was a reminder of the vulnerability of humans in the mountain environment and the need to keep such events activated in current memory.

Every zone studied is also updated every 10 years. This is the opportunity to check and complete the annual updating, to find possible new avalanche limits that may not have been recorded in the annual updating, and to consistently renew all the CLPA areas. This updating has taken place since 2003 on every zone bounded and studied until then and will occur in 2011 for every municipality one by one.

New avalanche limits are rapidly integrated into the database in order to make the most recent data available to all users. These are then made accessible on a web site (www.avalanches.fr), managed by Cemagref for the Ministry of the Environment.

Wider and more appropriate data dissemination

The CLPA is distributed as an atlas assembling several documents on a 1:25,000 scale map, with the confirmed limits of the largest historic avalanche events, a user key, and a collection of identification sheets concerning every avalanche numbered on the map. The map is presented as a set of A3 (297 per 420 cm) sheets, referenced according to a regular and unique grid for the Alps and Pyrenees (fig. 8), to facilitate future updating. The atlas includes a departmental organization map of sheets, a user guide on how it was compiled, its use and its limitations, and a descriptive note of the avalanche context in the studied areas, for each massif as defined by Météo France for avalanche risk forecasting (PRA) (33 of these "massif notes" were drawn up).

The atlas is widely disseminated in the municipalities concerned and their technical departments in charge of avalanche risk management.

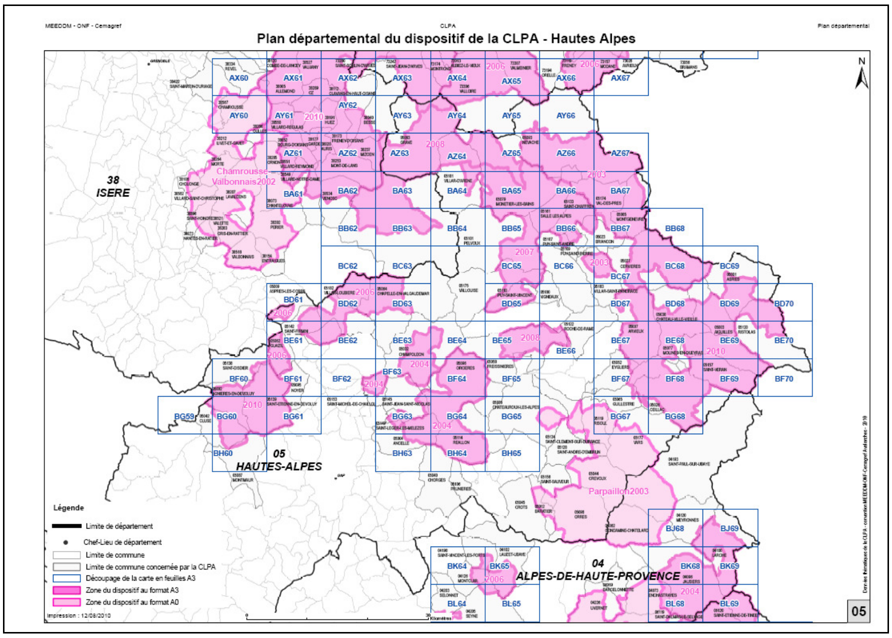

Fig. 8 A departmental organization map - extract of the regular and unique grid

The CLPA contains geographical data geolocalized and arranged according to a single reference topographic map, and tables standardized which contains further information on the simple geolocalized objects.
The content of the identification sheets has been specified and is at present digitized and the information contained has been integrated into the document's new presentation.
All the maps and identification sheets are available as images and GIS data on the web site www.avalanches.fr. Other documents (user guide, user key, massif notes, and organization maps) are also available on the site.

INCREASE THE STUDIED AREA TO IMPROVE THE LAND USE KNOWLEDGE OF THE DANGER ZONES

The updated maps currently cover 556,000 ha out of 725,000 ha of the CLPA, which will be entirely updated before 2011 (fig. 9).

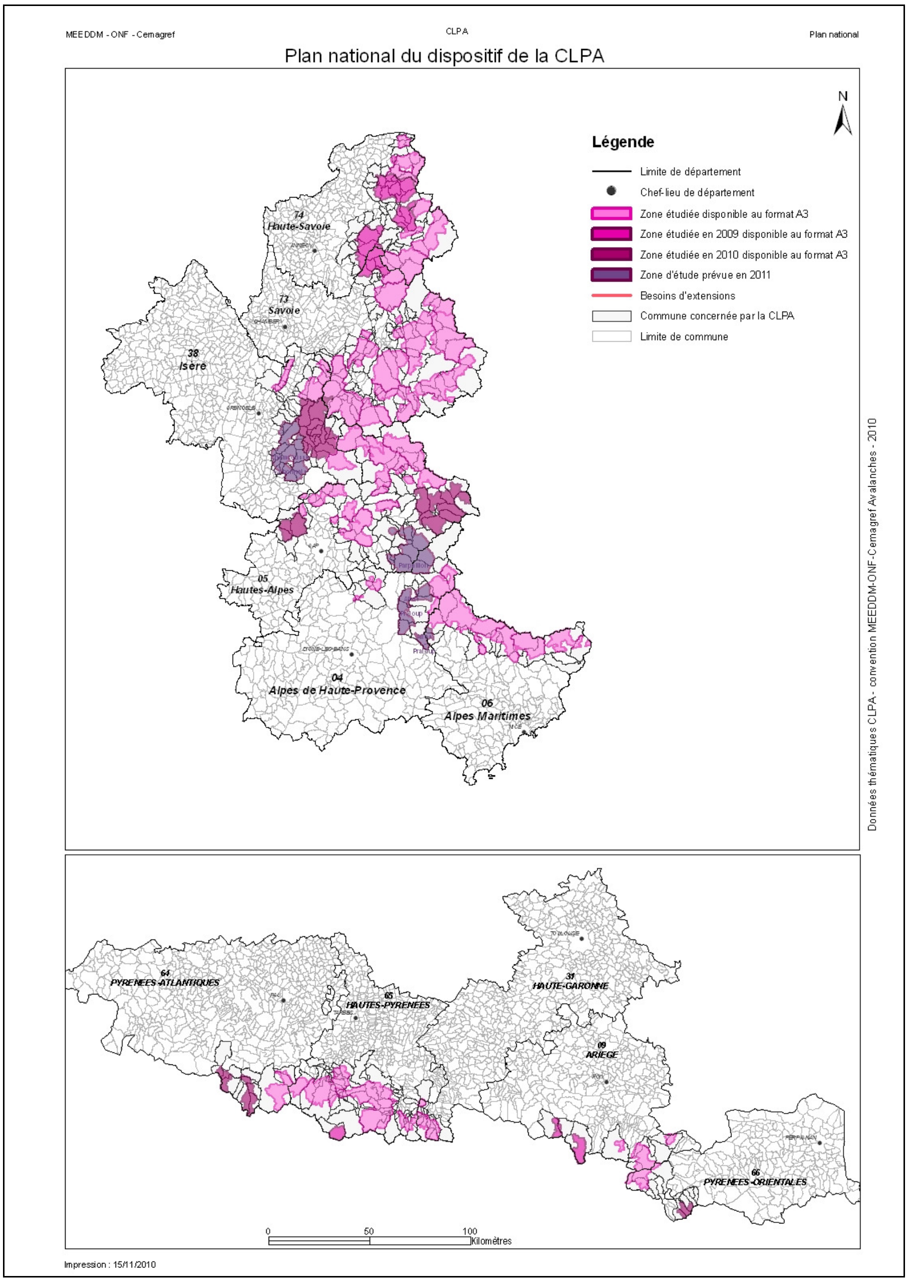

Fig. 9 Map of CLPA studied areas in the Alps and Pyrenees in 2010

Changes in land use have created new needs in terms of avalanche knowledge. Approximately 93,000 ha have already been studied, through to financial participation of communities in the Alps and Pyrenees.
Finally, 380 municipalities of the Alps and Pyrenees are concerned by the CLPA. It accounts for more than 25,000 recorded avalanches and more than 13,000 eye witness accounts.
In the future, each of the A3 sheets will be updated every 10 years. Studies on other massifs including human and property stakes (Massif Central, Corsica) will also be envisaged.

APPLICATIONS AND PERSPECTIVES

The objective of improving and widely distributing current avalanche data was to facilitate the work of technicians and make the data available to all actors so as to ameliorate avalanche prevention. However, the informative nature of the data excludes any avalanche forecasting, the aim of yet more detailed analysis of the avalanche phenomenon.

At the technical level

These data are used for the most part to make decisions on avalanche risk prevention and management: town planning (natural risk prevention plans, evacuation plans, etc.); communication routes (road closures and openings, construction permits, etc.); as well as infrastructures (dams, retention dams in ski resorts, electric lines, development of ski resorts, etc.). However, the geographical data and textual data have not yet been digitally linked to improve data traceability. Finally, other complementary databases are being developed and it would be useful to associate the reflections undertaken in the current project to improve public information.

At the scientific level

The skills acquired since the implementation of the CLPA today allow our research teams to reflect upon an expert approach of avalanche event recording. Besides continuous improvement of the data, this reflection will contribute to the elaboration and the improvement of decision-making tools.

The CLPA database is unique in the world. It covers a large part of the French mountainous urbanized areas and it contains rich spatially integrated information. If we manage to extract and to formalize this information, it can be exploited to transfer the information to avalanche passes not covered by the CLPA and to compare CLPA avalanche limits within a given area and detect any potential abnormalities. That can be done with one of the products of our research on the dynamics of avalanches. These are distribution models simulating an avalanche flow over its entire route, providing the maximal extension of the avalanche and the limits of the deposit. The application of these models on a given avalanche path requires detailed knowledge of its topography (e.g., as a digital field model or numerical field model), the identification of the limits of the start zone, and knowledge of the thickness and the rheologic properties of the mobilized snow. Analyzing all the CLPA avalanche limits would require defining the initial conditions and comparing the model's avalanche releases with the CLPA avalanche limits.

As the CLPA avalanche limits correspond to rare to extreme events, we can choose to set the start zone to its maximal extension and the thickness of snow in a rare reference such as the centennial reference. We can translate the existing expert rules as algorithms in a geographical information system, which will provide an automatic definition of the start zone limits from the digital field model.
According to the results, the start zone limits contained in the CLPA can refine or force the expert rules. The following inference stage will consist in using an iterative process to determine the friction parameters that minimize the difference between the historic influence and the influence obtained by models. This procedure should be applied to climatologically homogeneous sectors and, to estimate the predictive capacity of this method, to a learning phase on a section of the CLPA while keeping certain avalanche paths for testing. The statistical distribution, the spatial variability within a massif

and between massifs, and friction parameters will be used and possible climate correlation parameters will be researched.

This research project will allow us to extract and formalize part of the knowledge contained in the CLPA (model + statistical distribution of its parameters), which could be used to the predetermination of avalanche limits on paths situated out of zones studied for the CLPA.
All this research based on the CLPA data requires knowledge, implementation of geographical object tools, and the development of a specific mathematical environment allowing the manipulation of spatial objects.

This project will certainly take several years to carry out. In the meantime, the CLPA data are already being used by the RTM services to predetermine start zone limits as well as internally for the study of buildings concerned by the CLPA avalanche limits. The CLPA gives numerous applications and developments for the expert assessment of risks and in town planning, in avalanche risk zoning and in economic evaluation of risk.

CONCLUSIONS

The multiple applications improve the available tools used for gaining knowledge on avalanches. They continue the observation activity, begun more than a century ago, as for the EPA, and confirmed over the last few years with the CLPA. In the meantime, the renovation of the CLPA allows the technical departments and now the public access to essential data for avalanche risk prevention.

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