Journal of Nepal Geological Society, 2000, Vol. 22, pp. 393–398

Glacier disasters in the French Alps

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ABSTRACT

In France, an extensive inventory of glacier-induced disasters was started by LGGE-CNRS and CEMAGREF-ETNA in 1998 for the French Alps. Inquiries, archives, and field visits made it possible to register more than a hundred events during the past two centuries. Results are synthesised in specific cards for each glacier with its geographic description (location, parameters, picture) and a short summary of the event. The French Alps are divided into four massifs and the example from the Mont Blanc Range is presented in this paper. Three main types of hazard associated with the glaciers are: outburst of glacier lakes, fall of ice (repetitive serac falls or glacier tongue ruptures), and draining of internal water pockets. Temporal distributions are analysed for each hazard based on the past French and Swiss glacier disasters. It is also proposed to create a "French glacier observatory" as well as to seek an extensive co-operation at the scale of the whole Alps.

INTRODUCTION

The main objective of this work is detection and mitigation of the hazard induced by glaciers in the French Alps. During the last century, several authors have worked on this subject (Mougin 1925; Lliboutry 1971; Tufnell 1984; Haeberli et al. 1989; Haeberli 1983). A first synthetic work for the French Alps was presented recently with the support of the French Government (Valla et al. 1999).

More than a hundred disasters related to glaciers or their surroundings were recorded during the last two centuries just from the French Alps (Buisson et al. 1999). Consequently, a large database was created and will be updated in the future. The collaboration of numerous specialists and organisations (Services RTM-ONF, Mountain Rescue PGHM) was required to achieve this aim. The investigation of archives also provided inestimable detailed information.

RECORD OF DISASTERS

Fig. 1 presents the temporal distribution of recorded 88 events from France and 46 cases from other European countries, mainly from Switzerland. We have to notice that many events of secondary importance may have been unnoticed, especially those of the 19th century and war periods owing to lack of witnesses. The analysis of this historical distribution shows three picks: 1) at the beginning of the 19th century, 2) between 1890 and 1914, and 3) for the present period. We have to be very careful while interpreting such peaks.

During the first period (1810–1830), the glaciers were still quite active (Little Ice Age) and they disturbed widely human activities in the Alpine valleys with the creation and outburst of glacier lakes. During the summer of 1818, two huge lakes (with about ten million cubic metres of stored water), formed

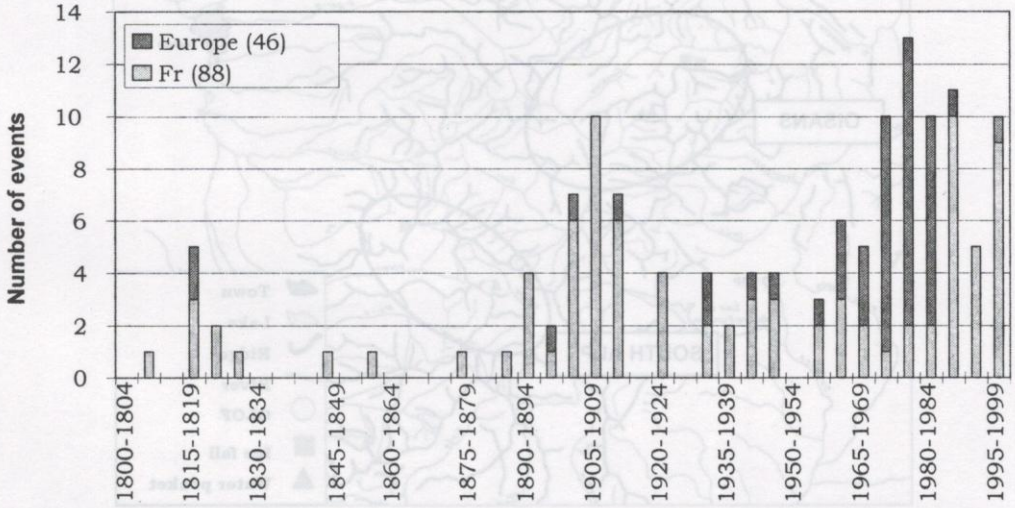


Fig. 1: Historical distribution of the French and European recorded glacier disasters

recently by the collapse of advancing glaciers, broke their ice dams and caused dramatic and lethal floods in France (Chapoutot 1998) and Switzerland (Musée de Bagnes 1988). Hence, the first peak corresponds to those severe disasters, which were well recorded in memories.

In the second period (1890-1960), French Office "Eaux et Forêts" was strongly involved in observation of glaciers, and many second-order facts were also incorporated except during the First and Second World Wars.

During the third period (1960-1999), the recent reclamation of the Alpine territory combined with the crucial need of collective security has led to an almost complete record of glaciological events including the secondary ones (Marnezy 1981). Some general remarks on these records are the following:

- collection of more detailed information will increase the magnitude of the third peak;
- the loss of information depends on the importance of the event or disaster. Even if remote, a disaster with a dozen of victims is still present in the memories;
- a systematic investigation of the archives is long, difficult, and expensive; and
- a good network of technical specialists is indispensable for the future monitoring of glacier disasters.

We present the spatial repartition of records from the French Alps (Fig. 2), according to the three types of studied hazard (circles for the outburst of glacier lakes, squares for icefalls, and triangles for draining of internal water pockets).

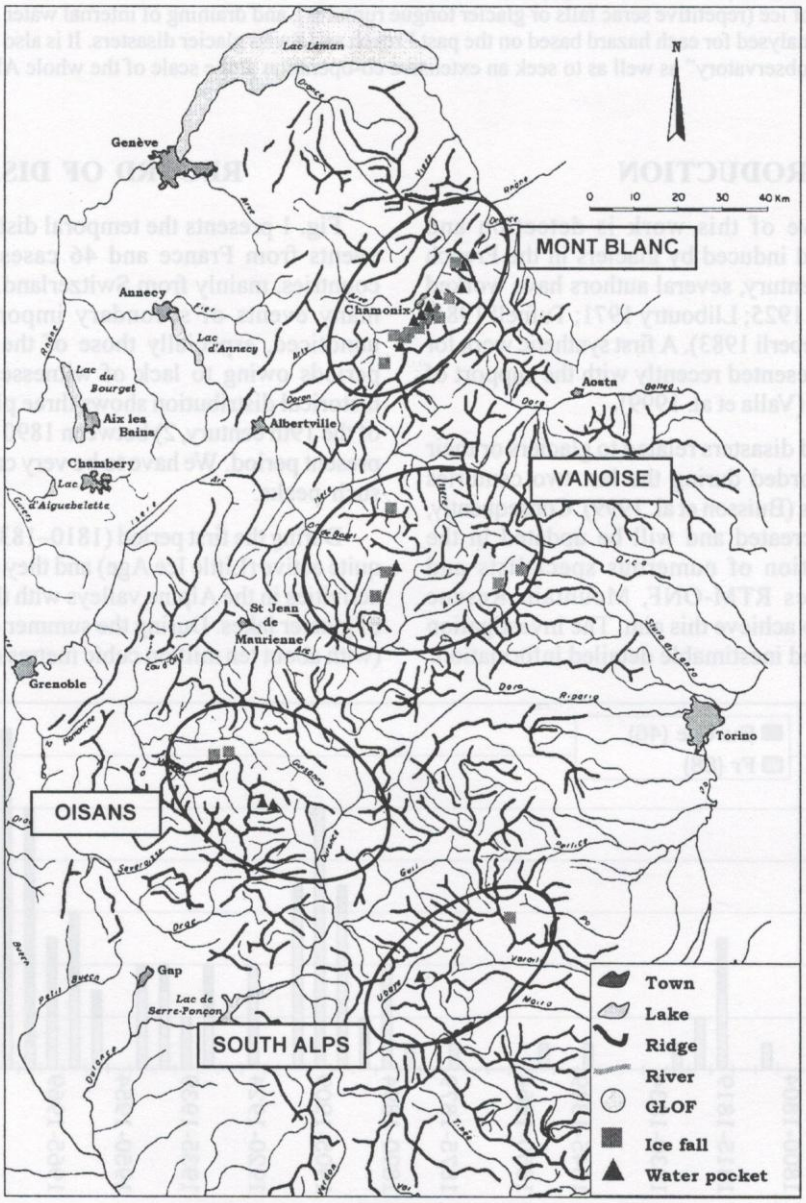


Fig. 2: Location of the recorded events in the French Alps

For this purpose, the French Alps are divided into the following four massifs.

- The Mont Blanc Range, with more than 70 detected events, has the most exposed valley (Chamonix). We will present it in detail below.
- The Vanoise Massif (national park) with less than two dozen events.
- The Oisans Massif (another national park), which is smaller than the Mont Blanc, experienced fewer events, probably due to low human activity.
- The South Alpine Range is poorly glaciated but presents some quite significant problems like the outburst of the Plan Chauvet glacier (Assier and Evin 1998) or the collapse the Coolidge glacier of Mont Viso (Dutto et al. 1991).

THE GLACIER FILE

For each glacier with detected disaster or event, we prepared a complete document or "Glacier File" (Fig. 3). Its morphological characteristics are specified in terms of geographic co-ordinates, surface area, length, maximum altitude, average slope, exposure, and type of glacier. A location map and a photograph of the glacier illustrate the dossier, and all the recorded events are listed with the morphological details, information sources, and some notes. A coloured pictogram specifies the type of phenomena. Fig. 3 depicts the example of the Mer de Glace, the largest glacier of the French Alps, which experienced the outburst of water pockets in 1878, 1920, and 1969.

THE MONT BLANC RANGE

With more than seventy detected glacier events, the French side of the Mont Blanc (the Chamonix Valley) appears for the last two centuries the most vulnerable place for glacier disasters in the French Alps. Fig. 4 is the recapitulation of all the collected information and the numbers written in the symbol indicate the number of events. Our investigations revealed 4 outbursts of glacier lakes (shown as circles), 36 icefalls or collapses (squares), and 31 breaching of glacier water pockets (triangles).

We suspect quite many glaciological events from the central part of the Mont Blanc Range were not detected in the past due to their remoteness and insignificant economic losses in the 19th century Chamonix Valley. It is clear that available archives had mostly preserved information of perturbing disasters with significant damage of lives, land, and property.

SOME EXTREME DISASTERS IN THE ALPS

In some historical cases, glaciological disasters had a huge magnitude, with uncommon volume of water or ice. Here are some examples of them.

The outburst of Lake Giétroz, Switzerland (1818)

Massive icefalls coming from the hanging Gietroz glacier produced an ice dam with estimated volume of 1.7 million m^3. The meltwater was stored during the spring season (27.5 Mm^3). Venetz, the famous engineer involved in glaciology, was in-charge of draining the lake by civil works. An artificial channel was evacuating about half of the water volume when the dam collapsed at 4 p.m. of 16 June 1818. In a few hours, about 18 Mm^3 of water washed away the Swiss Bagne Valley, damaging villages and killing more than 50 people. Mitigation of such a disaster is possible (Vallon 1989) and channels were recently excavated in that area in order to control such hazardous alpine lakes.

The draining of Tête Rousse glacier water pocket, France (1892)

On the night of 12 July 1892, a terrific mudflow engulfed several houses of the well-known Saint Gervais thermal buildings, at 600 metres of elevation. Some 200,000 m^3 of water stored in the small Tête Rousse glacier ran down from 3150 metres with a velocity estimated at 14 m/s, scrapping half a million cubic metres of moraine. The disaster was so quick that nobody could escape. Out of 200 victims, only the bodies of 175 people were recovered (Reynaud and Valla 1999). This accident, the most disastrous one in France, is an example of the most critical hazard hidden under the glacier.

The collapse of Allalin glacier, Switzerland (1965)

This accident occurred on 30 July 1965 during the Mattmark dam construction, when a glacier tongue slipped on the bedrock. An estimated volume of 0.5 to 1 Mm^3 of ice wrecked the construction housings of the dam workers, killing 88 people (Vivian 1966).

SEASONAL DISTRIBUTION OF THE DISASTERS

For this study, we used the data from France and Switzerland (Haefeli 1966, Aelen 1985). Four histograms are presented, the icefall hazard being split into tongue collapse and serac fall.

GLOF (Glacial lake outbursts floods)

In France, 12 outbursts of glacier lakes are recorded and in Switzerland, Haeberli (1983) recorded 36 cases. Fig. 5 confirms the apparent fact – outbursts occur essentially in summer season, when the snow melting has filled up the glacier lakes. At the same time, moraine dams are more fragile due to the water percolation and the possible melting of icy terrain (Marnezy 1981). Only one outburst occurred in winter.

Icefalls and glacier tongue collapses

The studied examples of icefalls (45 cases) include all the major ones recorded in France (41 cases) and Switzerland (4 cases). Generally, such an event is known when the disaster had killed victims or the fall was important.

Massif concerné : *Mont-Blanc*

Ruptures de poche d'eau

La Mer de Glace

✱ *Détail des événements recensés :*

↳ **Date** : le 16 août 1878
➢ **Phénomène :** une rupture d'une poche d'ea
➢ **Conséquences :** une crue de l'Arveyron t
Les champs et une maison furent inondés.

↳ **Date :** le 25 septembre 1920
➢ **Phénomène :** suite à de violentes précip
vidange de poche d'eau s'est produite, avec char
➢ **Conséquences :** une violente crue de l'Ar
caves et rez-de-chaussée dans Chamonix (1,5 m
de glace de près d'un mètre cube ont été retrouv

↳ **Date :** le 25 juillet 1969
➢ **Phénomène :** on enregistre une crue sul
barrage dû à un éboulement en rive gauche, l
importante poche d'eau sous-glaciaire, située à
Blanc.
➢ **Conséquences :** l'inondation a été évitée g
Les informations relatives à ces événements sont réd
l'aval. Le phénomène en lui-même n'est absolument pas
ni de la durée des épisodes.

✱ *Sources d'information :*

↳ **P.G.H.M. de Chamonix.**
↳ **Danguy, J.M.**, (Montenvers Chamonix). Témoignage
↳ **Mougin, P.,** 1925. *Avalanches, débâcles et érosion*
Imprimerie nationale. Paris, p. 167 et 172.
↳ **Vivian, R.**, 1975. *Les glaciers des Alpes occidental*
p.349 (d'après Poirel, J., 1969).

✱ *Commentaires :*

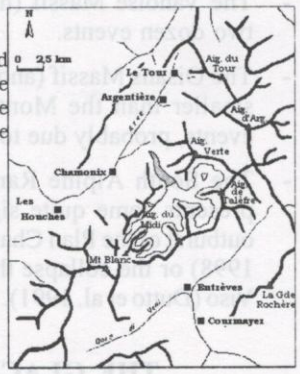
Il arrive fréquemment que les glaciers soient tenus pour
pas immédiatement. Ainsi la Mer de Glace a-t-elle été soup
1996, puis le 13 août 1997, mais ces hypothèses ont été éc
qui se sont produites à ces périodes. Il semble plus probab
d'écoulement intra-glaciaires habituels ait conduit à plus
ruptures de poche d'eau.

Depuis peu, un lac se développe au front du
d'évaluer le danger potentiel qu'il représente, il est nécessaire d'estimer le volume
d'eau qu'il contient. Il est ensuite tout à fait envisageable d'entailler la moraine pour
provoquer une vidange artificielle et faire disparaître le risque. Quoi qu'il en soit, il
faut en surveiller l'évolution.

✱ *Localisation :*

↳ Coordonnées :45°55'15'' / 6°55'45''
↳ la Mer de Glace est le plus grand appareil glaciaire français (~40 km²); il se compose de plusieurs glaciers. Mais ici, le terme " Mer de Glace "" désigne seulement la langue terminale de ce grand glacier.

✱ *Surface :* ~ 3,5 km²
✱ *Longueur :* ~ 4,7 km
✱ *Altitudes extrêmes :* ↳ 2200 m
↳ 1400 m
✱ *Pente moyenne :* ~ 9° (17%)
✱ *Exposition :* Globalement NW.
✱ *Type de glacier :* Glacier de vallée (langue terminale de l'appareil glaciaire " Mer de Glace ").



Extrait de : "Mont Blanc, jardin féerique" - 1996. Chuba - G. Rebuffat - 1996.

Extrait de : "Mont Blanc, jardin féerique" - 1996. Devan - P.Vittet - 1952.

✱ *Événements recensés :*

↳ Le16 août 1878
↳ Le 25 septembre 1920
↳ Le 25 juillet 1969

Fig. 3: Glacier File (recto and verso)

We discover that every month is present in this histogram with a higher representation during spring and summer and a few cases in autumn (Fig. 6). Nevertheless, no trend seems evident.

There were 34 records of glacier tongue collapse in Europe, with only one case detected in France (Glaister 1951). The time distribution (Fig. 7) shows clearly the essential influence of flowing water in the process of the glacier tongue collapse. Almost all the accidents occurred in late summer, when the wet bedrock helps to accelerate the glacier velocity. It would be interesting to check the average air temperature during the period preceding the tongue collapse.

DRAINING OF WATER POCKETS

There are recorded 51 events, generally of small magnitude (20 in Switzerland and 31 in France). As for the glacier lakes, the outburst occurs generally in summer (70%) after the thawing season (Fig. 8). We note just one case in February, the earliest one being in May. It is clear that the meltwaters quickly replenish the glacier water pockets at the end of spring (May or June in higher altitudes).

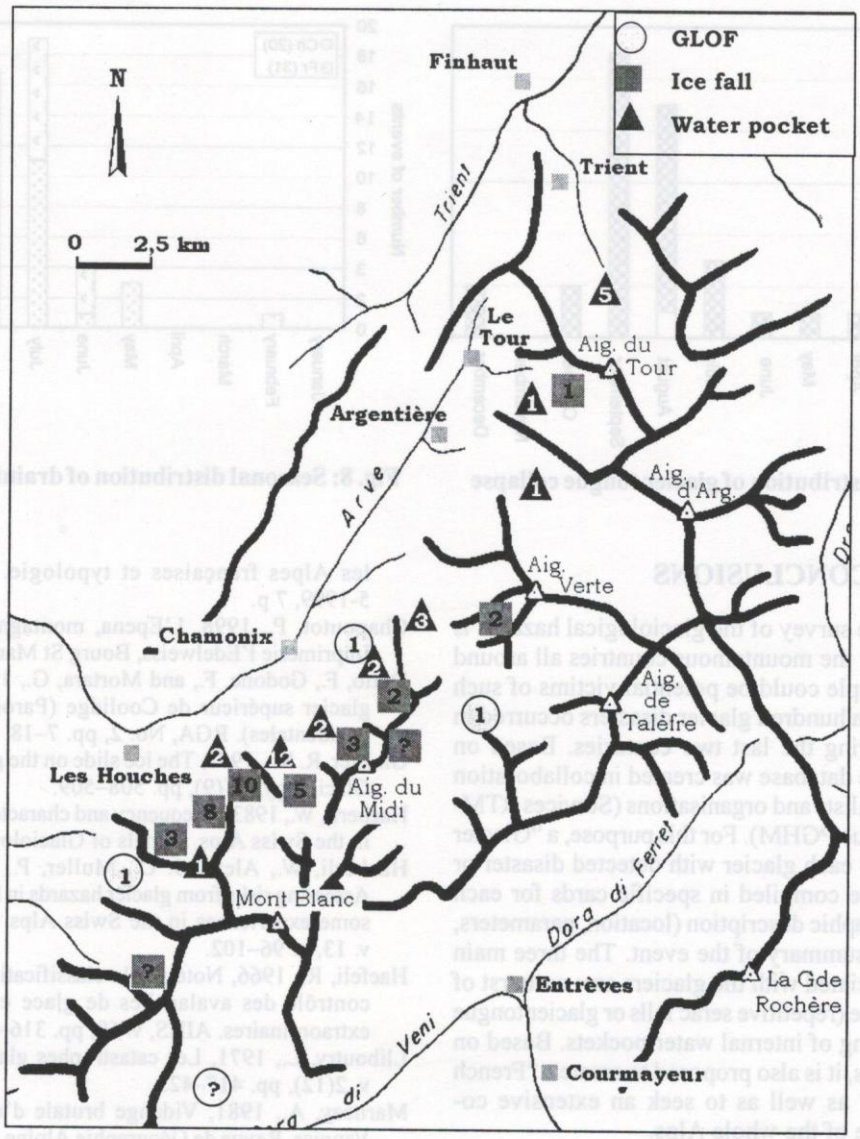


Fig. 4: Details of the recorded events, French Mont Blanc Range

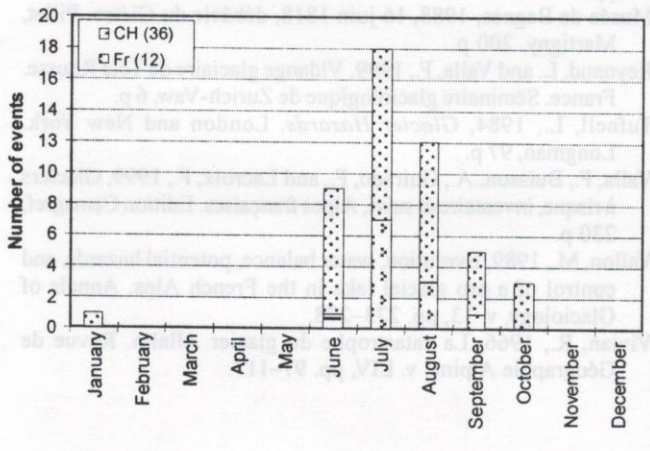


Fig. 5: Seasonal distribution of glacier lake outburst flood

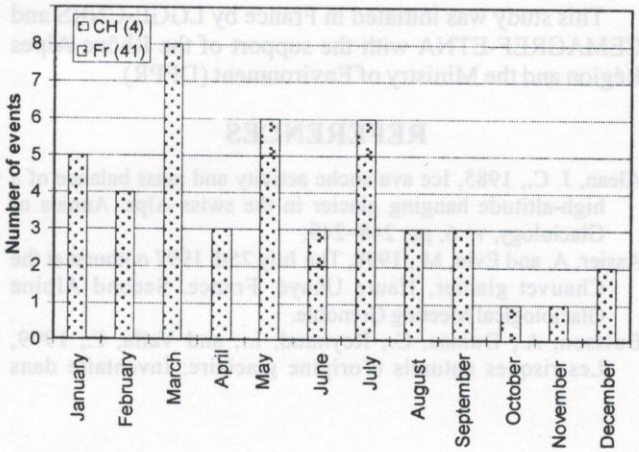


Fig. 6: Temporal distribution of icefalls

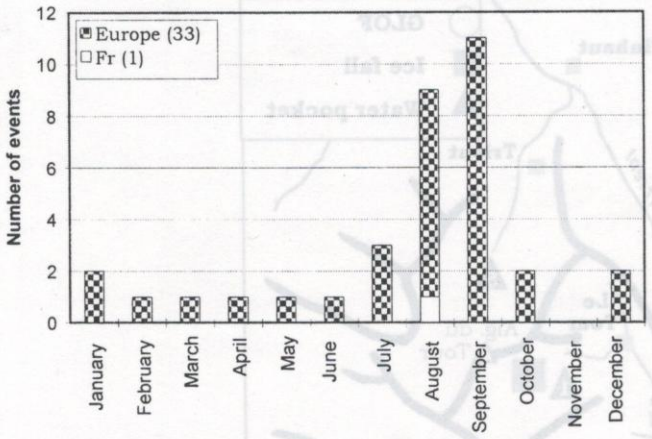


Fig. 7: Temporal distribution of glacier tongue collapse

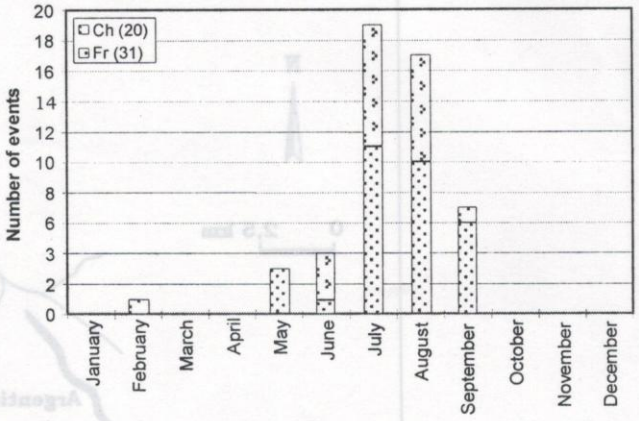


Fig. 8: Seasonal distribution of draining of water pockets

CONCLUSIONS

The study and the survey of the glaciological hazards is an important task for the mountainous countries all around the world. Many people could be potential victims of such disasters. More than a hundred glacier disasters occurred in the French Alps during the last two centuries. Based on those records, a large database was created in collaboration with numerous specialists and organisations (Services RTM-ONF, Mountain Rescue PGHM). For this purpose, a "Glacier File" was created for each glacier with detected disaster or event. The results are compiled in specific cards for each glacier with its geographic description (location, parameters, picture) and a short summary of the event. The three main types of hazard associated with the glaciers are: outburst of glacier lakes, fall of ice (repetitive serac falls or glacier tongue ruptures), and draining of internal water pockets. Based on the above experiences, it is also proposed to create a "French glacier observatory" as well as to seek an extensive co-operation at the scale of the whole Alps.

ACKNOWLEDGEMENTS

This study was initiated in France by LGGE-CNRS and CEMAGREF-ETNA with the support of the Rhône Alpes Région and the Ministry of Environment (DPPR).

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