MEPRA
AN EXPERT SYSTEM FOR AVALANCHE RISK FORECASTING

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ABSTRACT

This paper describes the current state of MEPRA, an expert system for avalanche risk forecasting. The author presents the system characteristics (knowledge base architecture, inference engine) and a ponctual validation at the location of a snow weather station. The last part shows the new MEPRA which was used during the winter olympic games of Albertville (FRANCE) connected with a meteorological analysis system ,SAFRAN, (Durand and alii, 1992) and a numerical model to simulate the snow cover ,CROCUS (Brun and alii, 1992).

INTRODUCTION

The avalanche risk forecasting in its principles as in its organisation has been described in precedent papers (Lachapelle, 1980 or Pahaut,1985). In this field, most of the knowledge is based on scientific theory (meteorology, thermodynamics, mechanics...) but other knowledge comes from forecasters' personal experience. During many years of work, the direct observation of avalanches has allowed the forecaster to complete his education by empirical knowledge, formalized or vague. This type of information, in fact temporary, is destined to be specified or invalidated and finally replaced by a deterministic knowledge of the problem when the research is completed. The expert system is the computer tool which enables these different types ofinformation (deterministic, statistic or heuristic) to be assembled. It is possible to integrate it very easily into the forecaster's dayly work and the system can justify their reasoning. This last function is essential because the system must not replace the forecaster but help him in his work. The advantage of the expert system appeared as soon as the feasability study began. The objective was to analyse the forecaster's intellectual approach, to evaluate the expert opinion's model and to verify that the experts were able to transfer and formalize their knowledge.

THE MEPRA EXPERT SYSTEM

The expert system is a software computer, their objectives are to reproduce the expert human reasoning in a particular field. It consists of :

- a knowledge base representing the transfered learning and concerning only the field analysed. It is composed of production rules, an "if..then..else.." construction. The process of getting the rules is a difficult and time-consuming job.

- an inference engine (cognitive system) guiding the problem 's resolution, managing the knowledge base and explaining the system's behaviour.

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The MEPRA knowledge base

The knowledge base of the MEPRA prototype was built thanks to good collaboration between researchers, engineers, avalanche forecasters, teachers or people working on snow. This work allowed us to imagine a processing system for 2 of the most important problems in avalanche risk forecasting :

- keeping track of the snowcover representation
- evaluating avalanche risk forecasting.

As the knowledge base architecture shows (figure 1), the expert system, using the meteorological data, the morphologic and energetic state of the snowpack (CROCUS results or observed data) :

- completes the snowpack representation by other characteristic estimations, particularly mechanical, of the snow layers (shear strength, ram resistance, type of grain...)
- adds other information on the state of the snow cover in the area (wind slab, snow accumulation)
- deduces 3 natural avalanche risks (surface, partial and bottom) on a 4 level scale (nil, low, moderate, high) after classifying the ram and stratigraphical profiles and only as a function of the fresh or wet snow depth.

The writing of this knowledge base, approximatively 350 rules, allowed for the definition of new concepts for the fresh snow (dendricity, sphericity), new classification of grain types, typology of ramtest and stratigraphical profiles. However, this knowledge base uses models in terminal phases of development. The formalization of expert knowledge being inadequate, it has been necessary to put forward some assumptions for the use of new elaborated numerical data. This assumptions are then tested and will become knowledge, easily introduced into the base.

The inference engine (cognitive system)

The inference engine's principal task is to reproduce the expert's reasoning. One of the main MEPRA characteristic being the control of the evolution of the snow meteorological situation, the "Centre d'Etudes de la Neige" (C.E.N.) of METEO-FRANCE has chosen PILOTEX software developed by I.T.M.I.(French society). This software allows us to put into words and to communicate the knowledge to the system which will be used by an inference engine. The working mechanism of this engine is equivalent to a traditional backward-chaining.

A local test of the model

During the winter 1988-1989, a first validation was carried out using the twice-daily snow meteorological data at the location of the snow weather station FLAINE in "Haute-Savoie" department. This winter was characterized by snow precipitation from the end of November to the middle of December, followed by 2 months of warm and dry conditions. The snowpack was mostly built during the storm period from the end of February to the beginning of March. From the end of March to the middle of April, the weather was mostly warm and fair. The second half of April was characterized by heavy snowfalls followed by rapid snowmelting at the beginning of May. The varying weather conditions, from 15 February to 15 March, were perfect to test the expert system.

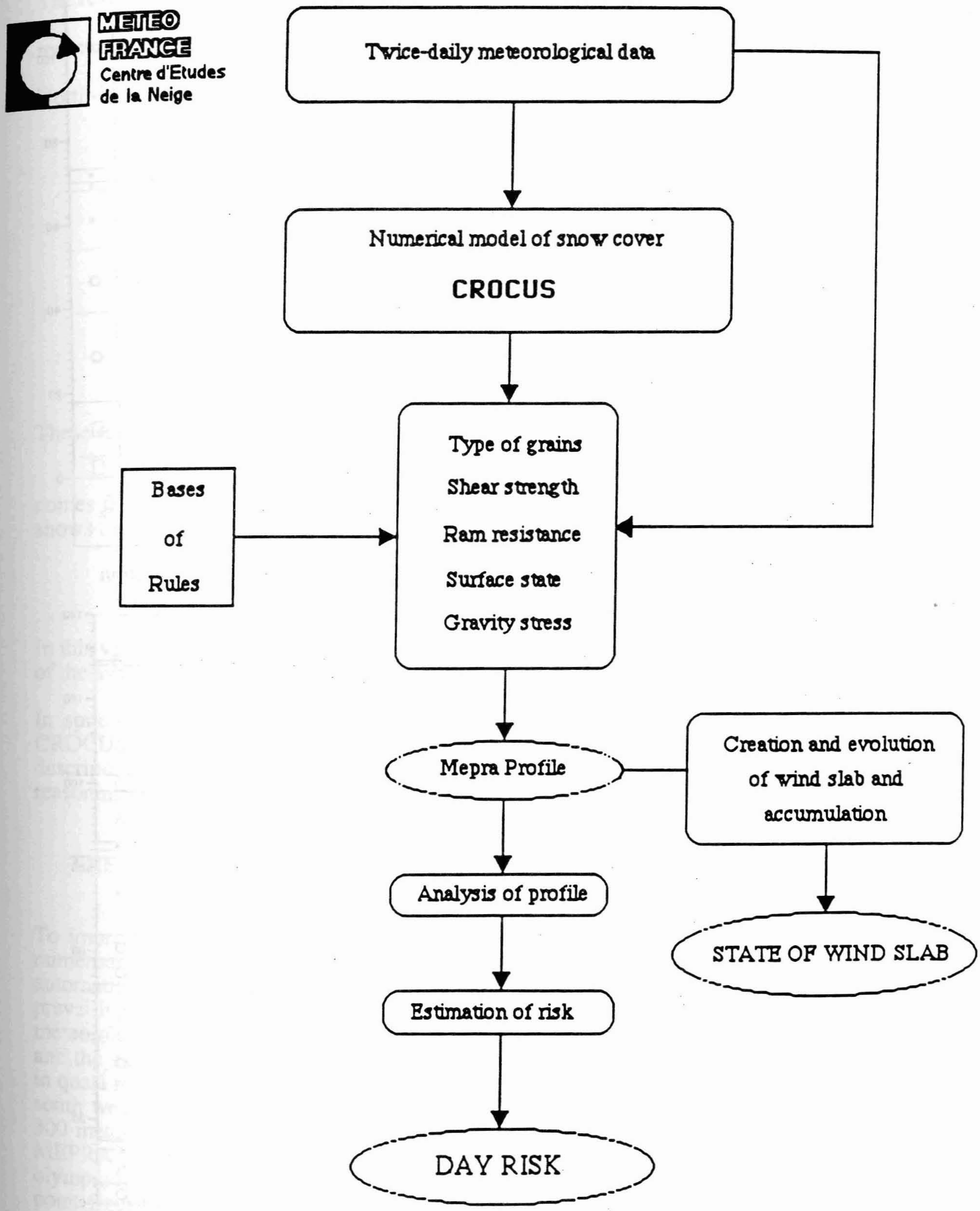

Figure 1 : Architecture of knowledge base

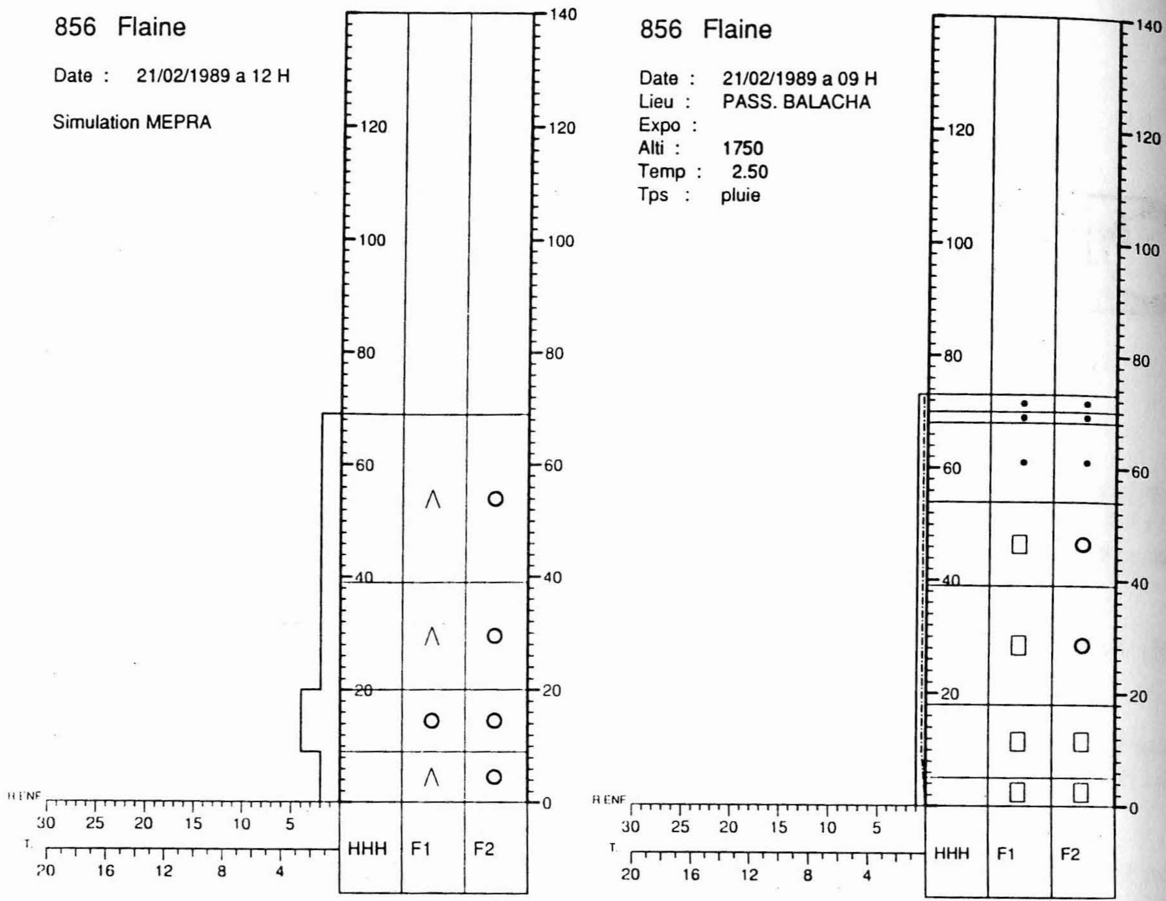

Figure 2 : Comparison between real and Mepra snow pit after one week of simulation

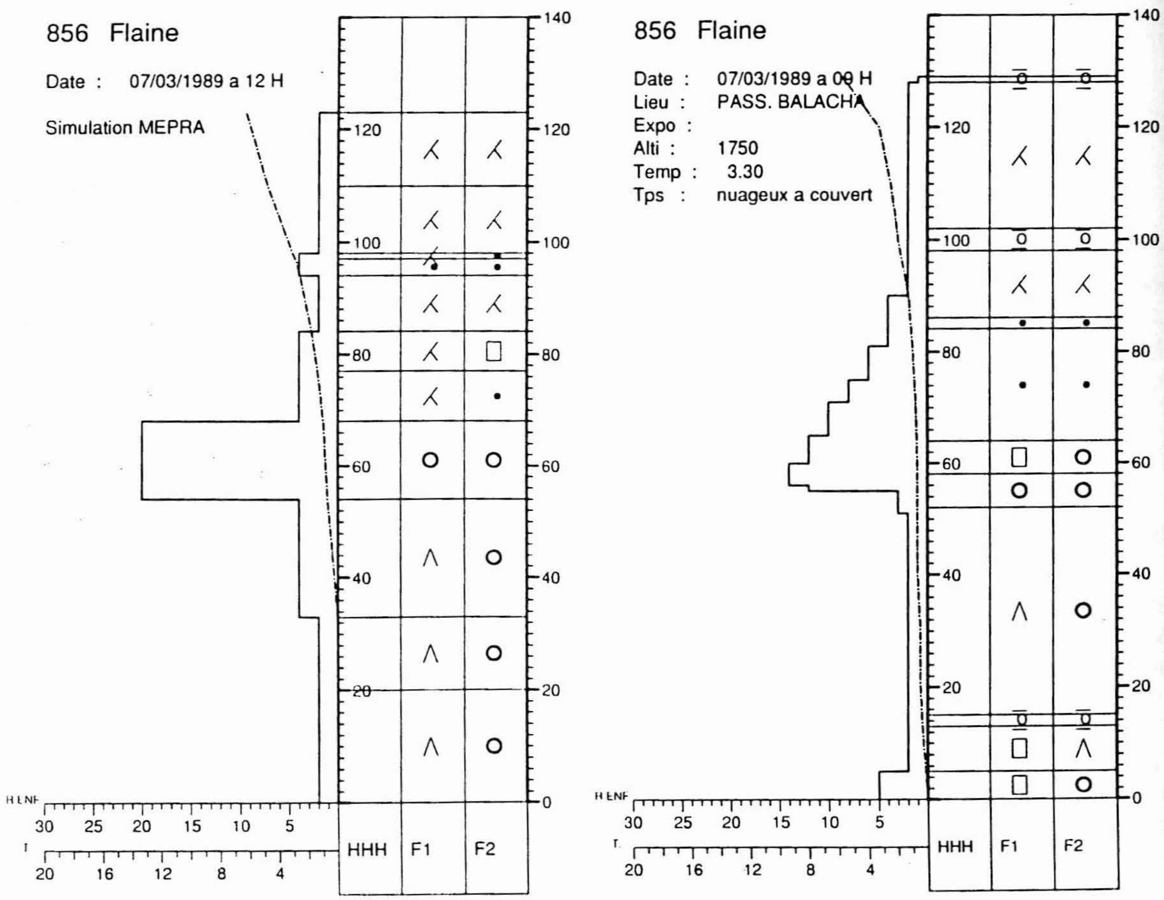

Figure 3 : Comparison between real and Mepra snow pit after three weeks of simulation

The result analysis is consisted of comparing:
- the MEPRA ramtest and snow cover stratigraphy with the same weekly measured parameters ,(figures 2 and 3, results after 1 and 3 weeks of simulations)
- the daily MEPRA avalanche risk with the daily observed avalanche activity in North-West to North-East exposition (figure 4).

AV.ACT. / MEP. R.	NIL	OBS.
LOW	15	0
MOD.OR HIGH	3	7

Figure. 4 : Board of MEPRA risk and observed avalanche activity

These results lead us to make the following observations :

- a difference between the ram profiles in the last simulation which probably comes from a bad value of the exposition masks. Furthermore, the resemblance of the graphics shows the quality of the simulations

- any wrong valuation (Avalanche activity not equal to zero with risks)

- only 3 false alerts (moderate or high risk with avalanche activity equal to zero). In this version of the knowledge base, the decreasing hazard of avalanches depended on the state of the avalanche activity.

In spite of this successful test, the first MEPRA knowledge base didn't use completely the CROCUS model results and the snowpack mechanical stability reasoning. It didn't allow for the description of the great spacial variability of the snowpack and the avalanche risk in a massif, the reasoning based only on one ramtest and snowpack stratigraphy being too local.

THE NEW MEPRA, THIRD LEVEL OF AVALANCHE FORECASTING TOOLS

To improve this and allow for the simulation of the snow cover and the avalanche hazard at numerous locations from differents orientations and altitudes, the C.E.N. has developed an automatic weather analysis system which computes everywhere in the French Alps the prevailing weather conditions at hourly intervals. This system, named SAFRAN, uses meteorological model outputs, the meteorological data of the snow-weather avalanche network and the automatic station network. It enables automatic running of the French model CROCUS in quasi real time in different locations with different orientations (North, east, south east, south, south west, west and flat), slopes (15, 30 degrees) and altitudes with a vertical discretisation of 300 meters without reinitialisation since the 1 August of the current year . Then, every day, a MEPRA expert analysis is carried out on every typical snowpack (140 simulations for an olympic massif like "Vanoise" in "Savoie") giving an estimation of the avalanche risk for every point(figure5).

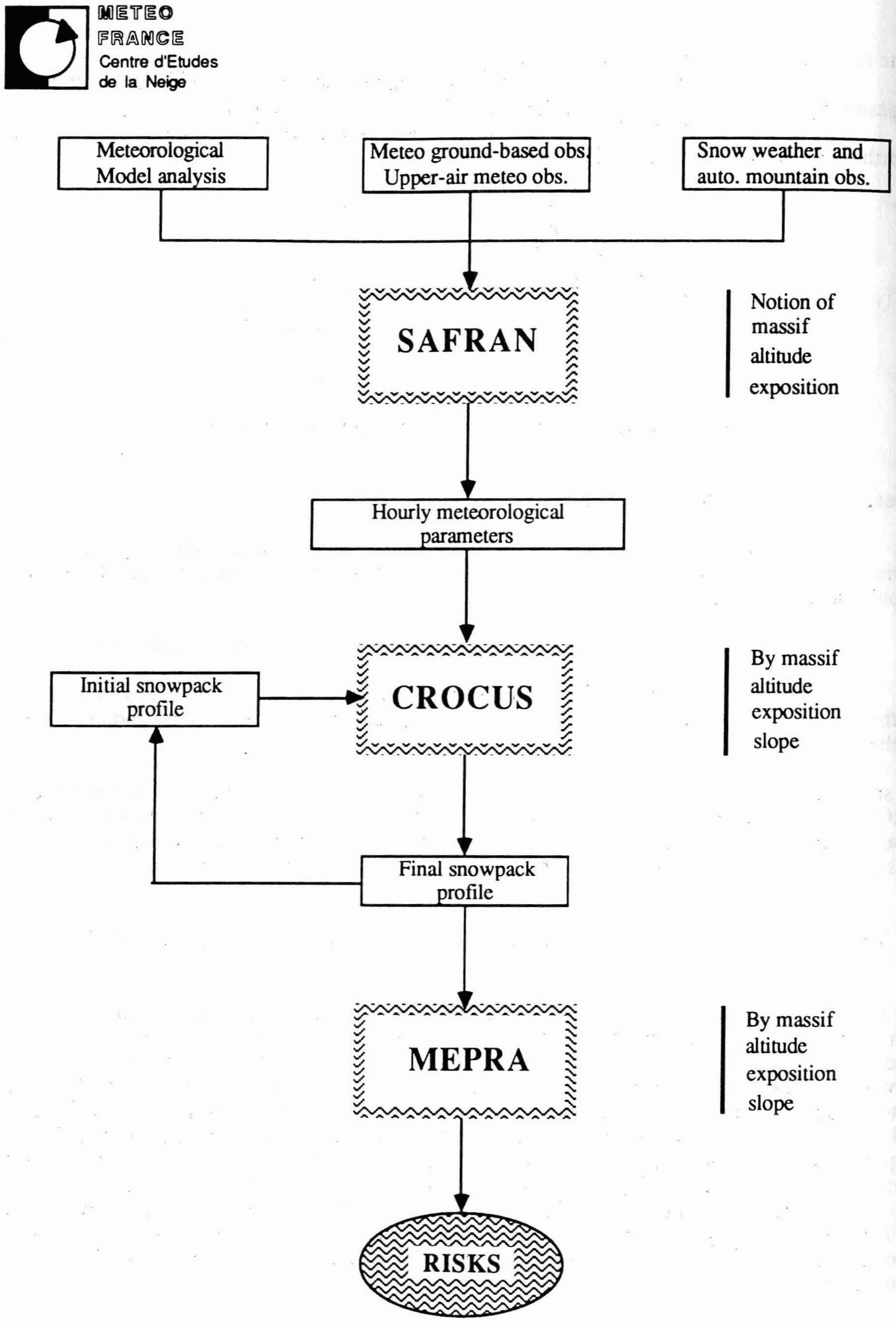

Figure 5 : Architecture of avalanche risk forecasting tools

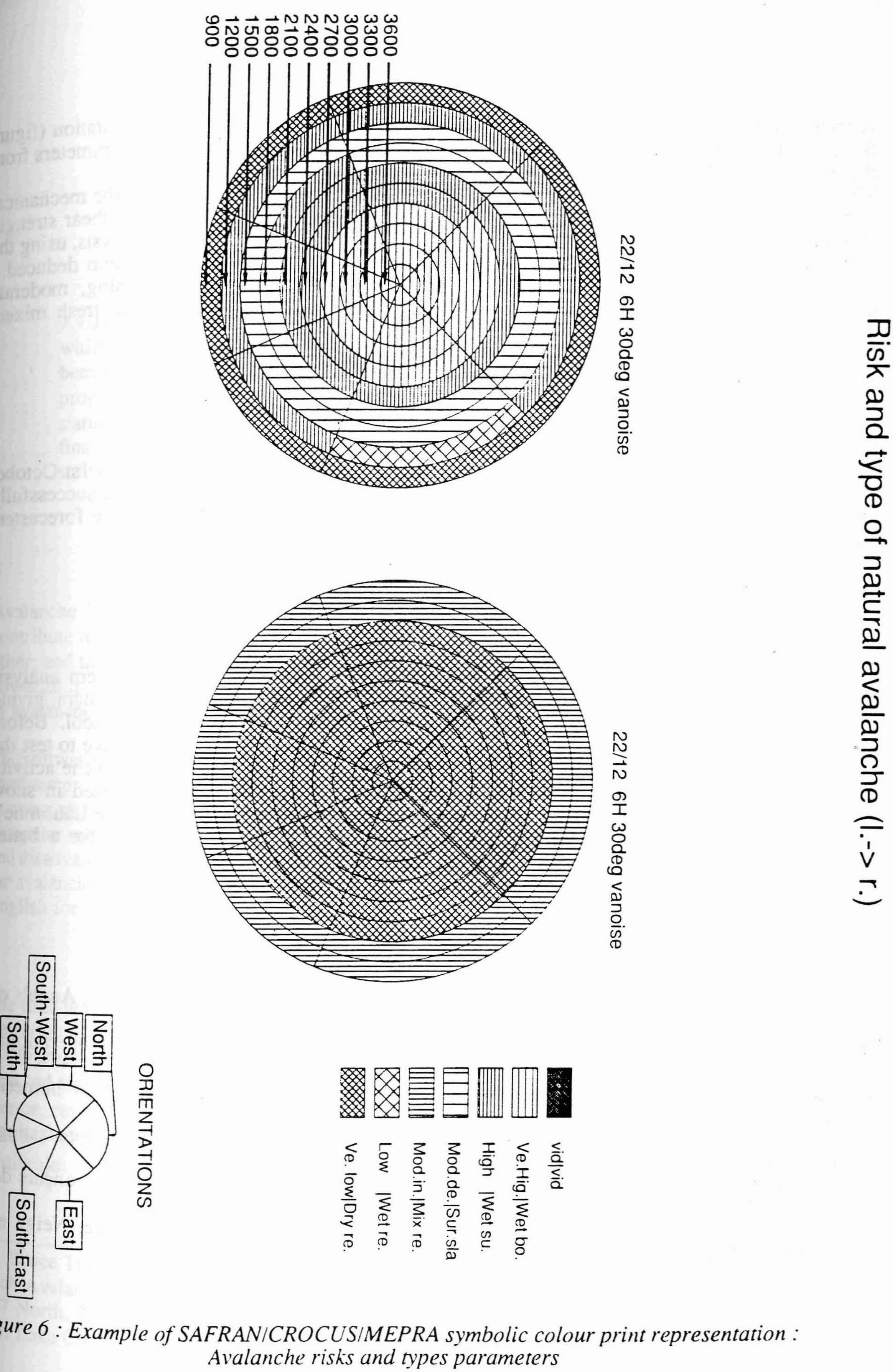

Figure 6 : Example of SAFRAN/CROCUS/MEPRA symbolic colour print representation : Avalanche risks and types parameters

A sophisticated colour display software allows us to visualize a symbolic representation (figure 6) or to project on a ground numerical model (75 meters mesh) some elaborated parameters from the model results (avalanche risk, avalanche type, surface temperature...).
The elaboration of this complete automatic chain has allowed for the analysis of the mechanical stability of every snowpack in detail by comparison betweeen gravity stress and shear strength (Navarre and alii, 1990) for all the layers. Then, with this mechanical stability analysis, using the depth of the unstable snow and the temporal stability evolution, the expert system deduced a natural avalanche risk on a 6 level scale (very low, low, moderate increasing, moderate decreasing, high and very high) and the avalanche types (fresh dry, fresh wet, fresh mixed, surface slab, surface wet, bottom wet).

Preliminary operational runs

This complete automatic chain (SAFRAN+CROCUS+MEPRA) was initialised on 1st October 1991 and has run daily since that date without reinitialisation. Its results were used successfully during the 91/92 winter especially during the olympic games of Albertville by the forecasters who were in charge of avalanche risks.

CONCLUSION

The global correspondance between the forecaster's analysis and the expert system analysis particularly during the olympic games seems to prove that this complete automatic chain, giving information where observed data don't exist, will be an interesting objective tool. Before installing this chain in the meteorological station in charge of avalanche risk, we have to test the MEPRA results by comparing the MEPRA avalanche risk with the observed avalanche activity during the 10 last winters. Then, in collaboration with two laboratories specialized in snow research C.EM.A.G.R.E.F. (Buisson L, 1989) and "Ecole Polytechnique fédérale de Lausanne", we should develop a local account of this tool to integrate field characteristics for a better description of local phenomena like wind slab or snow accumulation.

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