provides a fast and efficient decision support (Fig.2.6). Even so these models made good progress in the last years, they cannot fulfil all wishes of precision in space and time (Buser 1989, Föhn 1998).

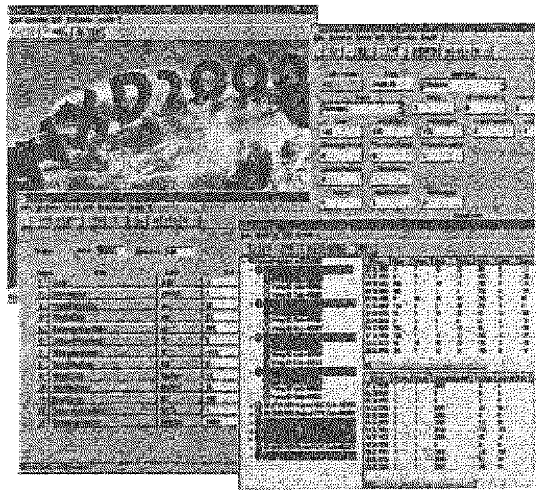

Fig.2.6 Input and output window of NXD2000, the Swiss local avalanche forecasting software tool.

While the web is the main information channel for the general public, a service called *InfoBOX* was set up by the SLF three years ago. This service links together national, regional and local avalanche specialists in Switzerland. So far, about 140 specialists, i.e. people who are in charge of avalanche safety in villages or towns, in ski areas or on highways, are using the SLF InfoBOX service. Via this service, snow and weather data from automatic stations or weather forecasts can be accessed 24h a day (Fig.2.7).

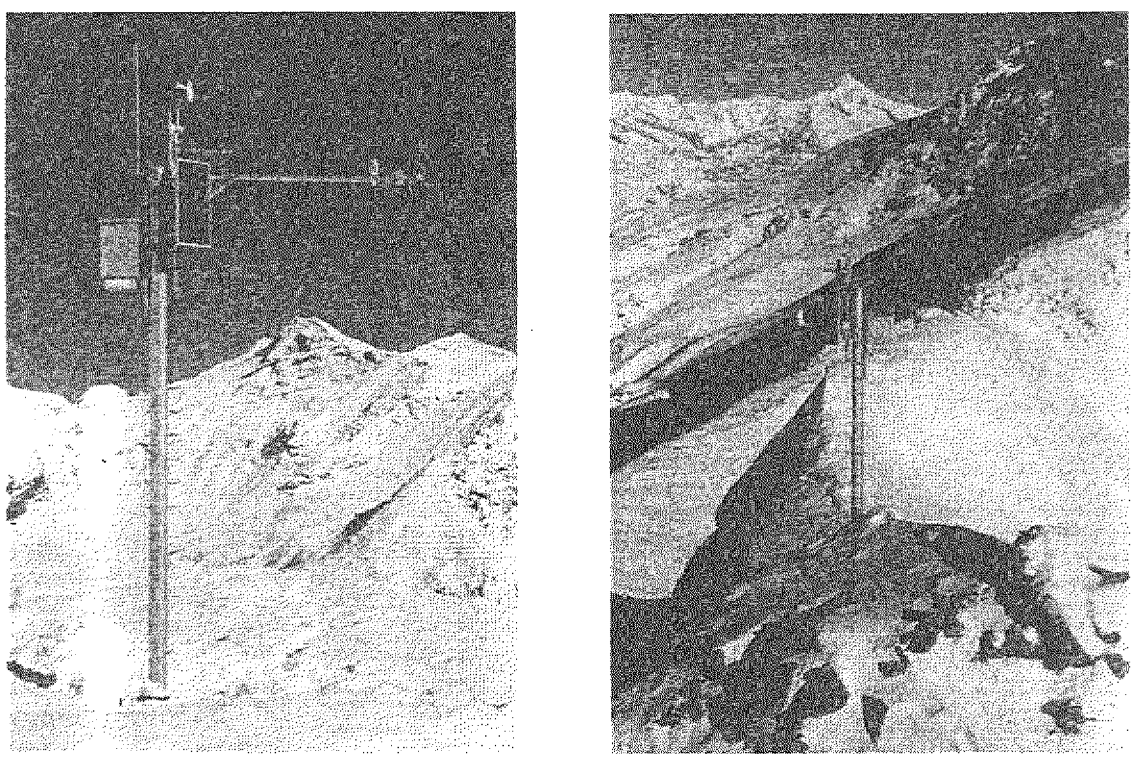

Fig.2.7 IMIS network. Automatic snow (left) and weather (right) station at Simplon Pass/VS Switzerland.

All other short-term, *temporary measures* like artificial release, traffic closure, evacuation of people and cattle are subsequent measures in critical periods. Stoffel (1996) discussed the different techniques for artificial avalanche release. Evacuation has to be based on well defined evacuation procedures to prevent additional hazardous situations for the people involved. In such critical situations the local government supported by avalanche experts has to take responsibilities.

2.3.3 Avalanche hazard mapping

Hazard maps serve as basic document for avalanche risk evaluation, especially with respect to land-use planning (for a more detailed overview see Margreth and Gruber 1998). In Switzerland hazard mapping begun after two catastrophic avalanche periods in January and February 1951. The first avalanche hazard maps in Switzerland were elaborated for Gadmen and Wengen in the Canton of Bern, 1954 and 1960, respectively. Dangerous zones were designated according to occurred disastrous events in a more qualitative way without taking into account climatic factors or quantitative avalanche calculations. In course of time the methods were improved and avalanche models introduced to calculate the dynamic behaviour. This development led for example to the *Swiss guidelines for avalanche zoning* (BFF 1984) and the *Guidelines for the calculation of dense flow avalanches* (Salm et al. 1990). The two publications are today the most important tools for the elaboration of avalanche hazard maps in Switzerland. In recent years numerical simulation, GIS and DTM tools led to substantial improvements (Gruber et al. 1998a,b). Two parameters were chosen to quantify the potential hazard for a given site:

- Expected *frequency* of an avalanche reaching a given site (frequency is normally expressed by the return period),
- *Intensity* of an avalanche (intensity is expressed by the avalanche pressure exerted on a wall of a building. As this pressure is assumed to increase with the square of speed and proportional to density, the kinetic energy of snow masses is also included).

To be able to distinguish variable hazard intensities and run-out scenarios, several *hazard zones* are defined:

Red zone: Pressures of more than 30 kN/m^2 for avalanches with a return period of up to 300 years, and/ or avalanches with a return period up to 30 years independent of pressure,

Blue zone: Pressures of less than 30 kN/m^2 for avalanches with return periods between 30 and 300 years,

Yellow zone: For powder-snow avalanches with pressure less than 3 kN/m^3, and return periods more than 30 years. For dry-snow avalanches with pressure unknown, and return periods more than 300 years,

White zone: No avalanche impacts to be expected,

Gliding Snow: Area of pronounced danger for gliding snow at locations without avalanches or with impacts larger than by avalanche effects.

The elaboration of hazard maps must strictly follow scientific criteria and methods including expert knowledge. The goal is to determine the *extreme avalanche* on a reliable basis. Field visits to assess the avalanche terrain, the examination of the avalanche cadastre as a map with all known avalanches in history, including their extent and date, additional information from competent local people or from old chronicles, the check of local climatic conditions and dynamic avalanche calculations are important tools. The *dynamic calculations* are used for:

- Predicting an extreme event, probably not registered in a cadastre,
- Delimiting the hazard zones for the different return periods,
- Calculating run-out distances and pressures as a function of avalanche frequency.

In Switzerland the *Voellmy-Salm model* is used since more than 20 years for estimating avalanche speeds, flow heights and run-out distances of dense flow avalanches (Salm et al. 1990). The use of the Voellmy-Salm model requires a careful estimation of its input parameters as fracture depth, friction parameters or avalanche size (Margreth et al. 1998). To check the sensitivity the calculations have to be made with different input parameters. Critical assessment of the results is important. It has to be pointed out that dynamic calculations are just one part of hazard assessment. In recent years, many such dynamic calculation methods have been proposed, some of which are routinely and effectively used by practitioners (Salm et al. 1990). *Numerical methods* using FE- or FD- techniques have set new standards in the use of avalanche dynamics models (McClung et al. 1995, Bartelt et al. 1997). User-friendly GIS- and DTM-tools are additional assets to complete and facilitate avalanche hazard mapping (Gruber et al. 1998a, 1998b).

2.3.4 Technical measures

Technical, long-term avalanche defense measures are used in the starting zone to prevent the release of avalanches (supporting structures) and in the avalanche track and run-out zones (avalanche sheds, deflecting and catching dams) to reduce the damaging effect of descending avalanches.

Supporting structures

The wide application of supporting structures had its beginning after the severe avalanche winter 1950/51. Since then the technology has reached an advanced stage. More than 500 km supporting steel bridges and snow nets have been built over the last 50 years. All experience gathered through these decades is summarised in the Swiss Guidelines (1990). The aim of supporting structures is to prevent the start of large avalanches or at least to *limit* snow motions to an harmless extent. Fully developed avalanches can not be stopped and retained by supporting structures (Margreth 1996).

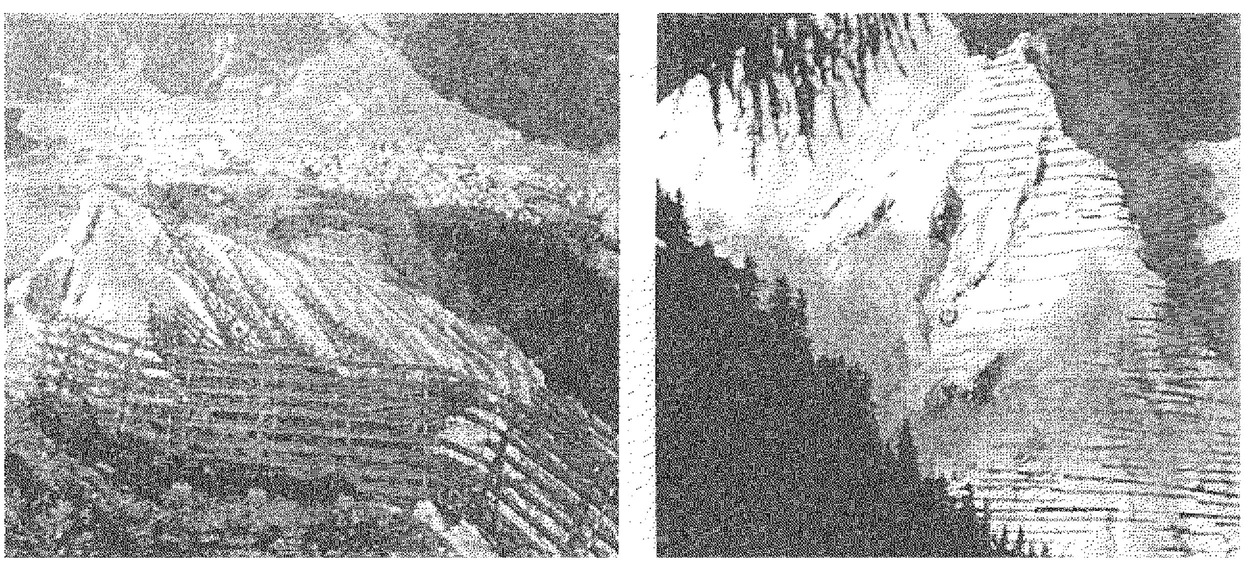

Fig.2.8 Steel supporting structure above Davos/Switzerland (Schiahorn).