VEÐURSTOFA ÍSLANDS

Report
05012

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CrocusMepra PC - Guide

An example from Iceland

VÍ-VS-06
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PARTLY REWRITTEN, PARTLY TRANSLATED BY SVANBJÖRG HELGA HARALDSDÓTTIR

FROM

GIRAUD, G. 2001. CROCUSMEPRA VERSION PC. METEO FRANCE INTERNAL REPORT

THE PUBLIC ROADS ADMINISTRATION SUPPORTED THE PROJECT

AVALANCHE HAZARD - SNOWDRIFT

MODELS TO FORECAST AVALANCHE HAZARD ADJUSTED TO ICELANDIC CONDITIONS

(SNJÓFLÓÐAHÆTTA - SKAFRENNINGUR LÍKÖN TIL AÐ SPÁ SNJÓFLÓÐAHÆTTU AÐLÖGUÐ ÍSLENSKUM AÐSTÆÐUM)

VEGAGERÐIN

METEO FRANCE

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Introduction

This document is partly translated from French (Giraud, 2001), and partly rewritten, shortened and adjusted to Icelandic examples. More details can be found in Giraud (2001).

The project was supported by the Public Roads Administration in Iceland as well as the Jules Verne program for cooperation between Iceland and France.

The snow department, CEN (Centre d'Etudes de la Neige), of Meteo France in Grenoble has developed models to simulate the evolution of the snowpack (Crocus) and analyse its stability and avalanche hazard (Mepra). Crocus calculates the evolution of energy, mass and morphology of the layers of the snowpack and Mepra analyses the stability of the snowpack and avalanche hazard. The models are in daily operation with Safran, a mountain weather model, on computing servers (the operational system is UNIX) in France and Iceland. The input to Safran is weather observations, weather analysis and forecast from large scale weather models. The input to Crocus is the mountain weather from Safran and finally Mepra analyses the stability of the snow profiles from Crocus. In the late 90's Crocus was developed without Mepra for PC.

A more recent version of Crocus for PC has been developed using the object oriented language Visual C++, and Mepra was included, resulting in CrocusMepra PC.

The models simulate the evolution of the snowpack and the avalanche hazard using an initial snow-profile and weather forecast as input. By changing the weather forecast or snow profiles, tests can be made for various scenarios.

CrocusMepra PC has the following features:

- A user-friendly Windows driven user-interface
- Crocus-Mepra simulations in local mode by
  a) inserting an initial snow profile and meteorological conditions
  b) running Crocus and Mepra
  c) viewing the results on screen
- Scenarios in analysis and forecast mode, for testing as well as comparing with real occurrences in nature
- A portable utility to assist the snow observers

The architecture of CrocusMepra PC

The models read the initial characteristics of the station or site chosen for the simulations, a snow profile and weather forecast. The initial snow profile includes the dates of formation of each layer, date of the profile, number of hours to simulate as well as the meteorological conditions during the simulation.

PARAM_CROCUS is an initial file with parameter setup for Crocus. It can be modified during the application and saved with the modifications. This file should only be modified for special tests and a **backup copy should be kept.** A knowledge of the relevant parameters is necessary.

The evolution of the snow profile is simulated hour by hour with information about the layers and energy fluxes at the surface of the snow cover.

The program **MepraPC.exe** is an expert system, i.e. a knowledge based system, which analyses the stability of the simulated snowpack. The results show the natural and accidental avalanche hazards, i.e. caused by overload or traffic.

Several views are available:

- Snow profiles from the simulations showing the natural and accidental avalanche hazard as well as the level of the instable layers causing natural or accidental avalanche hazard if they exist
- Evolution of the surface temperature
- Runoff at the ground surface

Three other choices are available:

- Evolution of meteorological parameters during the simulation
- Hourly energy flux
- List of actions of the simulation

Selected profiles may be saved and used as initial snow profiles in a later simulation.

Application of CrocusMepra PC

The application is started using an icon, linked with

CROCUS.exe

Figure 1. *Toolbar: Station, initial snow profile, meteorological parameters.*

At the top of the first view the menu in Figure 1, you can select three forms which you need to fill in before running the simulations. They are figures on the toolbar indicating, from the left:

1. Station (far left: station, see Figure 2)

2. Initial snow profile (second from the left: form, see Figure 3a and b)

3. Meteorological conditions, with three views (third from the left: sun, see Figure 6, Figure 7 and Figure 8).

In (1) above you may choose an already saved station or add a new one, in (2) you may choose an already saved profile as an initial profile or make a new one. The meteorological data in (3) is necessary too. The view can be modified by inserting new data.

The best way is to experiment with these forms on screen.

Station - geographical characteristics

A view with characteristics of the station (site, Fr. poste) needs to be filled in for a new station or a previously defined station can be selected from a list. The following figures are from a test run, only shown as an example, and not with real data.

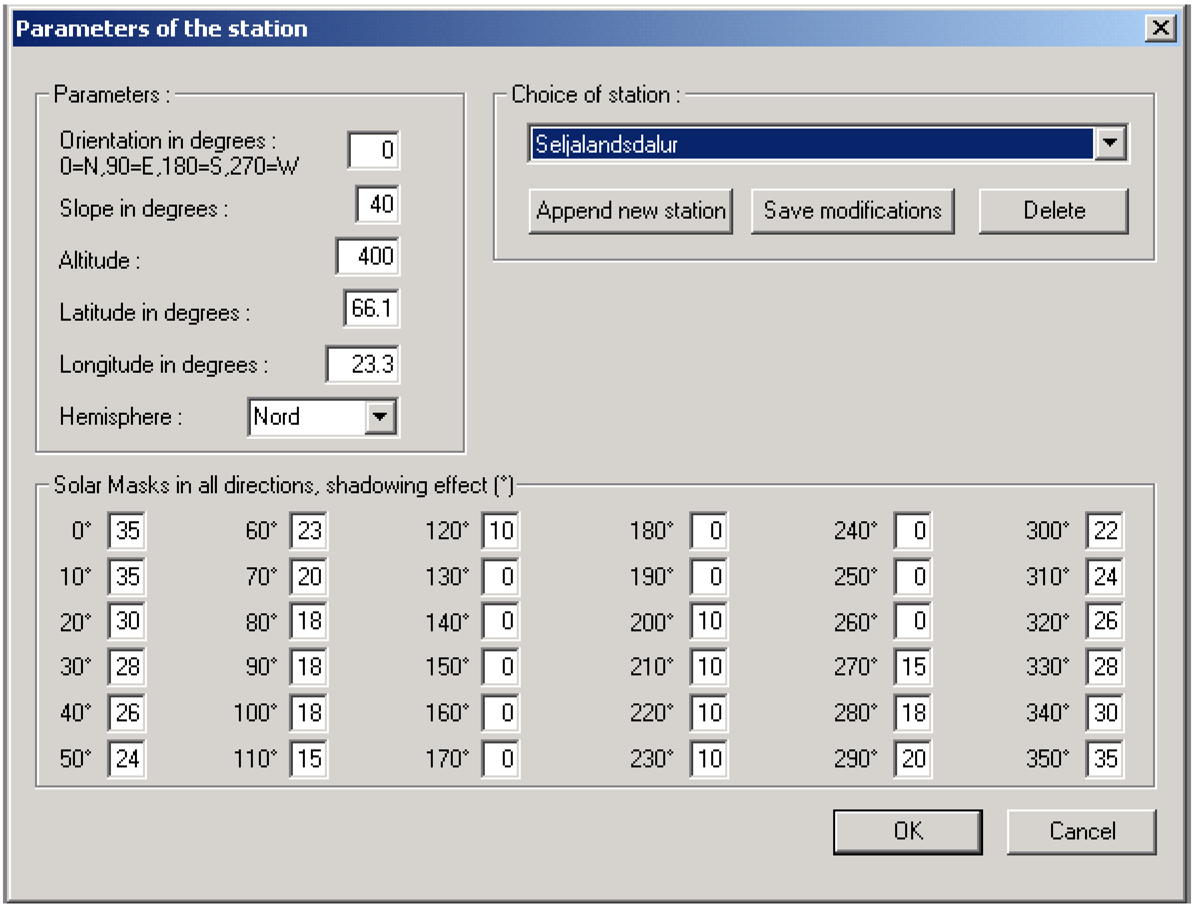

Figure 2. *The characteristics of a station.*

Each station needs some of the main geographical parameters describing its location and characteristics (Figure 2), such as: name, orientation (°), slope in degrees or inclination (°), altitude (m), latitude (°), longitude (°), location (N/S hemisphere) and solar masks for its orientation (°).

Most of the parameters for a new station are probably known or easy to fill in. The solar masks are used for the effect of solar radiation on the surface. In case you do not fill in anything, 0 in all fields, the effect of the solar mask is neglected. To fill in the solar mask properly the elevation angle of the "horizon" is written in degrees from horizontal, for every 10° from N to E, S, W (270) and N. Large angles indicate that you are looking uphill from the relevant station to a steep mountainside. If, for a station at 400 m a.s.l. you want to fill in the angle looking to the ocean, the angle might seem negative, in which case the correct value is 0°.

Initial profile and simulation period

Before starting the simulation it is necessary to define the starting date and hour of the simulation and the number of days to simulate (see top of Figure 3a). The period of simulation is limited to 10 days. If you want to simulate for a longer period of time, you may do that in steps, by saving the last profile and using it as an initial profile in the next simulation.

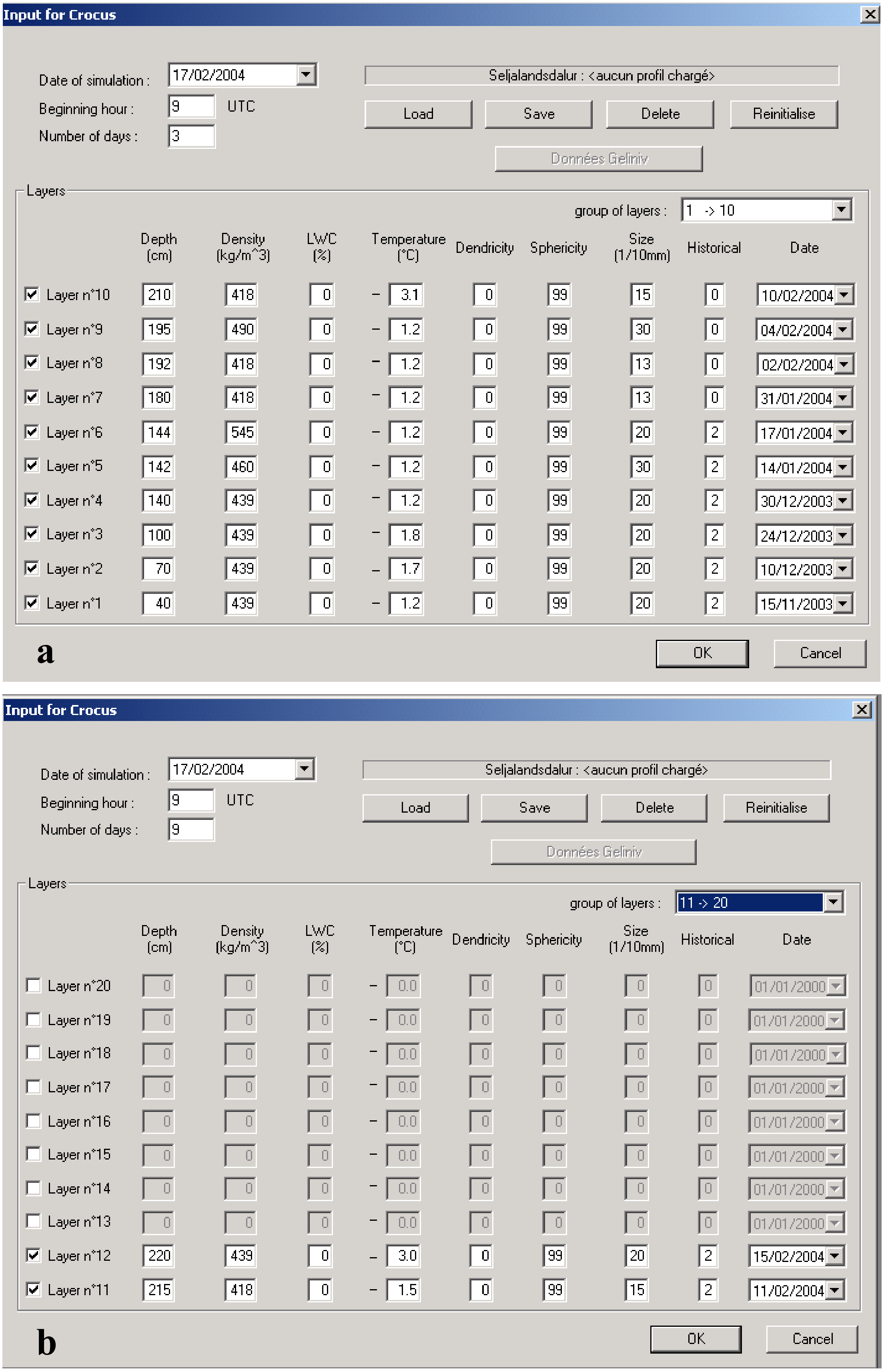

Figure 3a and b. *Initial date of simulation and number of days, profile showing 10 layers at a time. The limit is 50 layers. The height from the ground surface of the top of the layer (Depth). The parameters will be explained in the text.*

The profile is defined by the parameters in the table (units in brackets Figure 9). The bottom layer is number 1.

Note that "Depth" here should be height above ground-surface.

The next parameters are density, liquid water content (LWC), temperature and dendricity. The parameter dendricity describes how branchy the crystals are in the layer. The parameter ranges from 99 for fresh star-formed snow grains to 0 for grains without branches (far from the original fresh star-formed snow). The next field represents sphericity of the grains (how round the grains are, 0 for faceted crystals and 99 for fully rounded grains or wet grains), then diameter of grains (e.g. 15=1.5 mm), history (depends on the past or present evolution of layer, from 0 to 3 (Appendix 4. Structures of the grains), where 0=fresh snow, 1=if the crystals grow in high temperature gradient, 2= if the crystal growth is affected by the presence of water, 3=if the crystals grow first in high temperature gradient and are later affected by the presence of water), and date (original date of layer). In Snowpro Figure 4 shows an example of a snow-profile In Figure 5 the columns after height/depth are between the cm from ground surface, representing the layers, e.g. at the bottom of the Figure 142-144 cm.

To see the effect of different scenarios on the evolution of the modelled snowpack the layers can be modified as well as the weather parameters (see below).

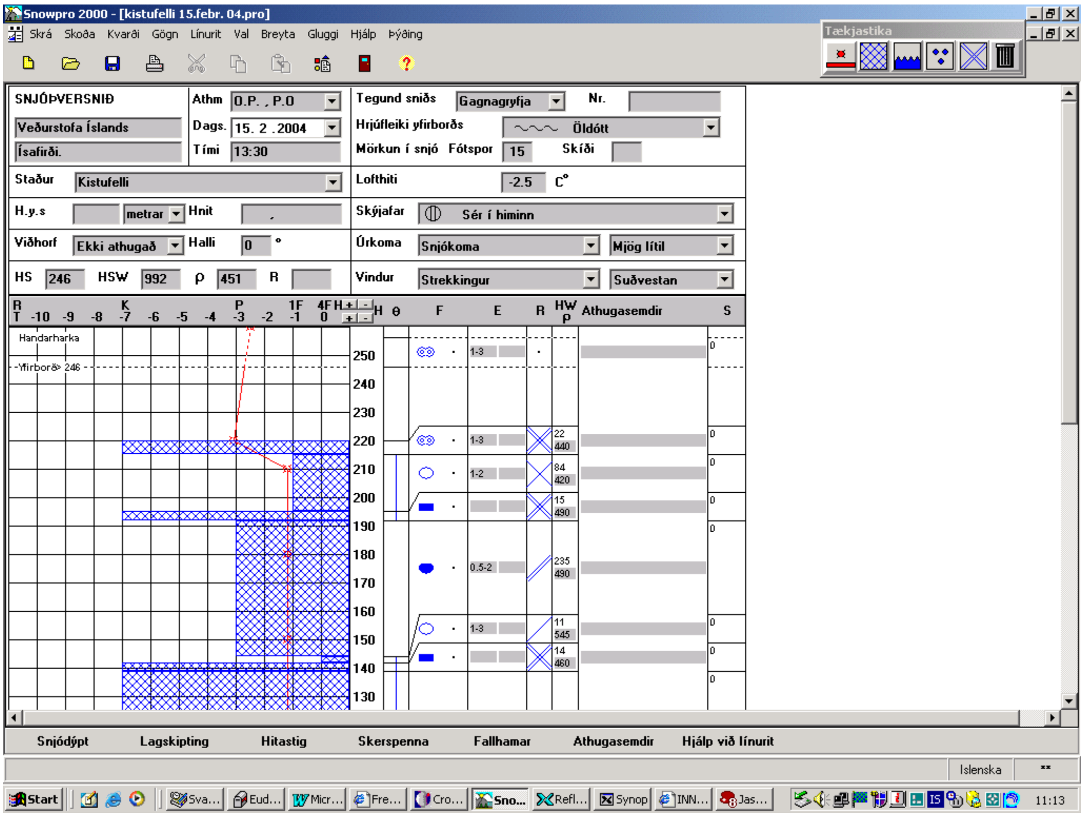

Figure 4. *The snow profile used as an example, here as presented in Snowpro.*

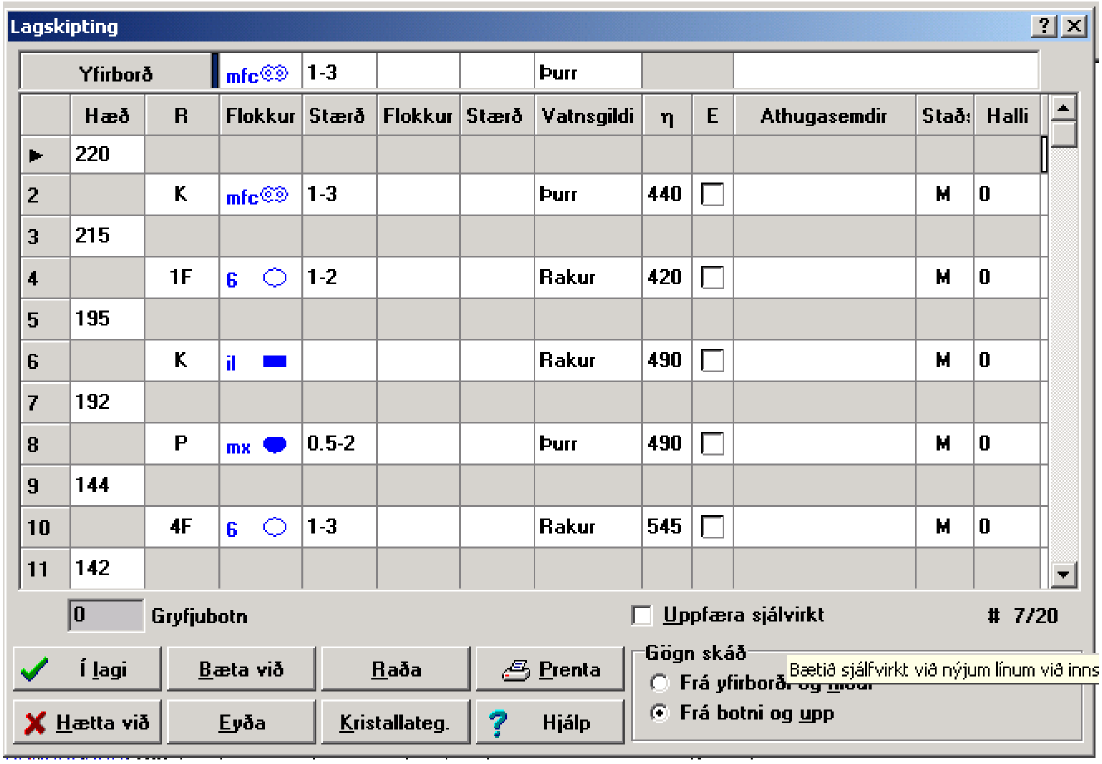

Figure 5. *Layers of the snow profile from Snowpro.*

Some of the information needed in CrocusMepra PC is the same as in Snowpro. The dendricity and sphericity parameters depend on the snow crystals. For further explanation see Appendix 4. Structures of the grains.

The maximum number of layers is 50, but only 10 at a time are shown on the screen.

Meteorological conditions

It is necessary to fill in the meteorological conditions before running the simulations. With the <sun> icon you get access to the forms to fill in. They are self-explaining, three views.

1. Meteorological parameters: temperature, humidity, wind and clouds (Figure 6)
2. Precipitation: rain in mm during a selected period (Figure 7)
3. Snow precipitation: snow in cm during a selected period (Figure 8)

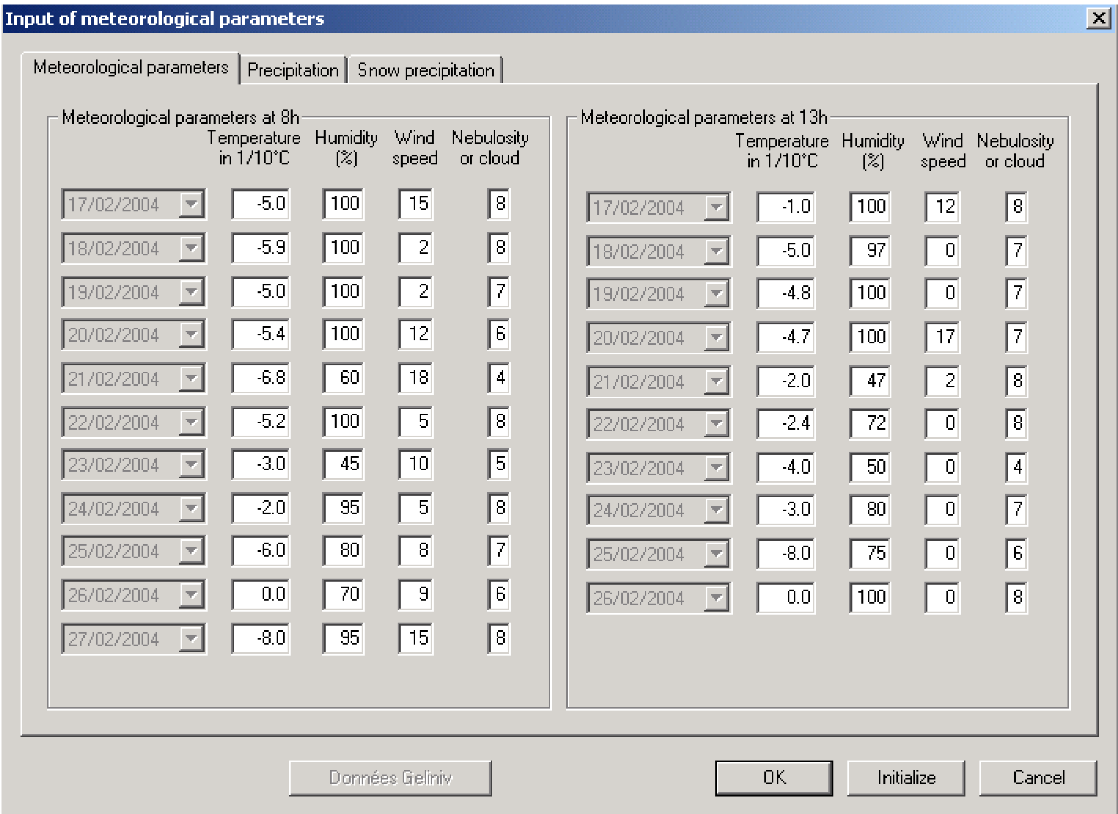

Figure 6. *Meteorological parameters: temperature, humidity, wind speed and nebulosity.*

The calculation could be based on observations from Bolungarvík at 9 and 12 UTC, bearing in mind that the snow pit is at 600 m a.s.l. These are not true values, but were modified for playing around with the software. The general rule would be to set the temperatures at 600 m a.s.l. lower than the sea level forecast and the precipitation higher. In the input data for the model the values for precipitation should be inserted as liquid precipitation for rain in mm (Figure 7) and snow precipitation in cm (Figure 8), where each of them can have 3 periods recorded for precipitation per day.

The most practical use might be to use the weather forecast as background and estimate the values at the elevation of a snowpit, e.g. 600 m a.s.l. It is possible to compare the results of simulations with the evolution in nature. The results from simulations, starting with an initial snow profile from a snowpit and already known weather, can be compared with a later snowpit. In some areas mountain weather stations can give valuable information for back calculations, filled in with a "guess" of the missing values as precipitation, or new snow depth.

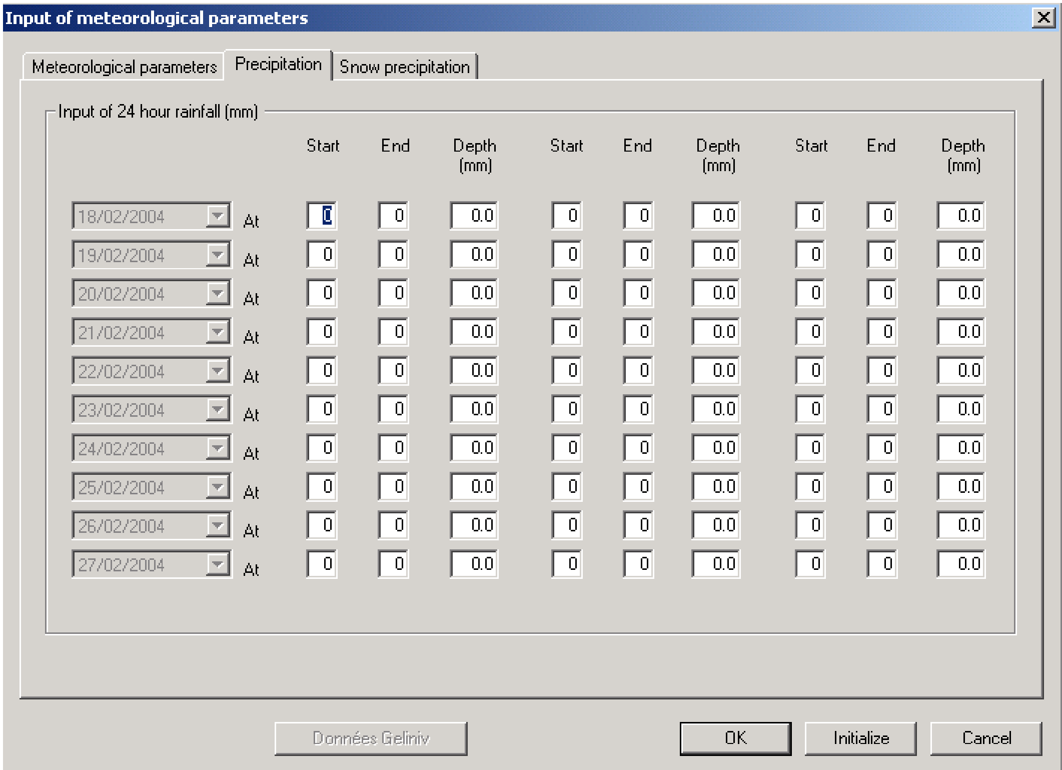

Figure 7. *Liquid precipitation (mm) in 3 intervals per day, from 8 a.m. to 8 a.m.*

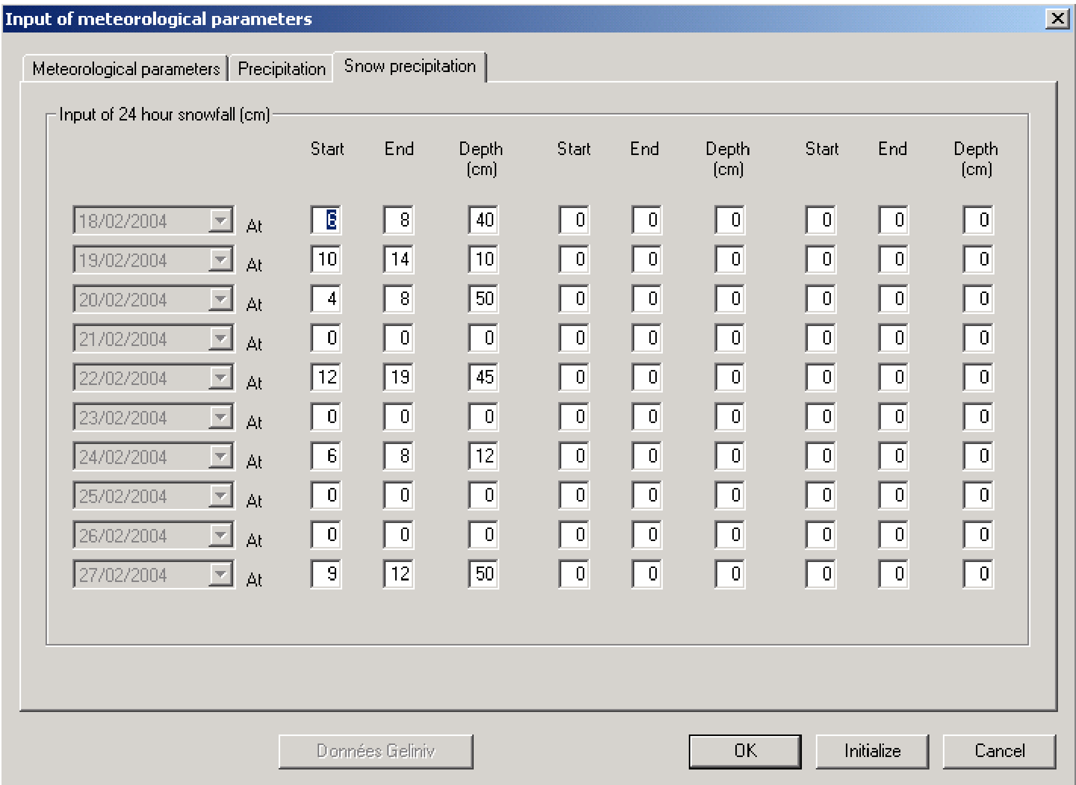

Figure 8. *Snow precipitation or new snow (cm), three periods possible per day.*

The density of the new snow is calculated as a function of temperature and wind speed.

The simulation and results

After filling in the previous forms, you can start the simulation by pressing the <Start> button (Figure 9).

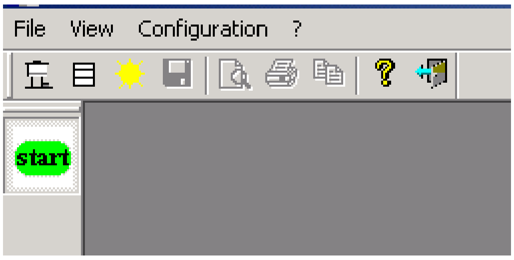

Figure 9. *Start button to start the simulation.*

During the simulation the text, Models running, appears on the screen, after which the first snow profile appears (Figure 10).

Viewing the results

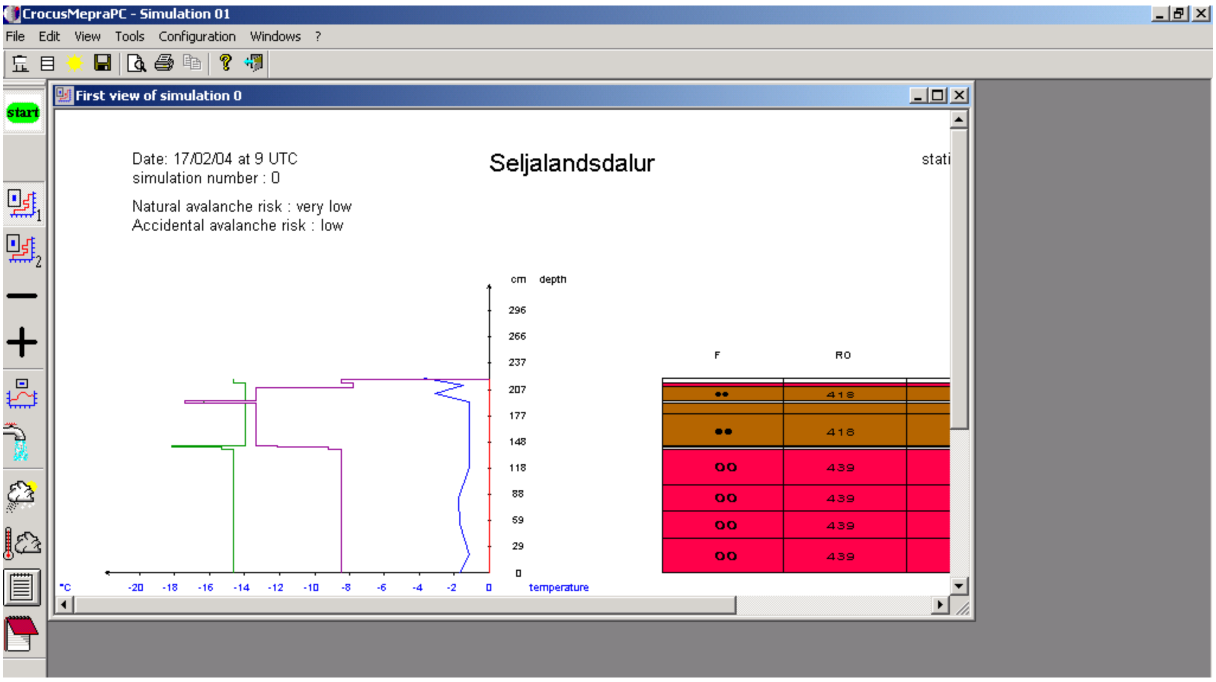

Figure 10. *The first snow profile of the simulation.*

On the left of the screen, the buttons are for showing the first profile (1), the last profile (2), a time step (1 hour) backwards (-), a time step forwards (+), snow surface temperature (a graph), hourly and total runoff (water tap), wind, rain and snow (cloud and sun), air temperature, humidity and nebulosity (cloud and thermometer), fluxes of the simulation (table) and finally a log of the process. Most of this is self-explanatory in the figures.

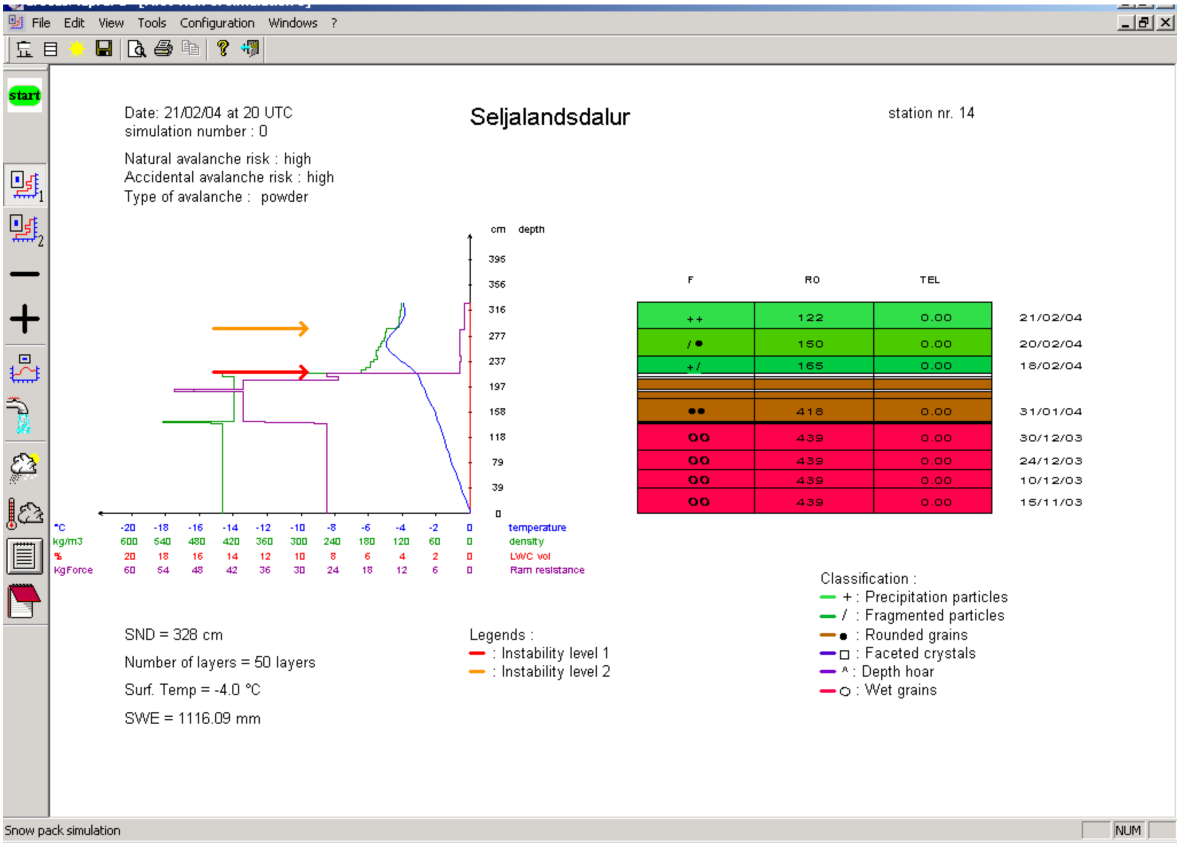

Figure 11. *An example of a snow profile with analysed avalanche hazard (red arrow).*

Figure 11 shows a resulting snow profile where avalanche hazard was analysed. It shows two levels of instability and both natural and accidental (due to overload, such as skiers) avalanche hazard. Temperature of the snowpack (blue), density (green), LWC (liquid water content, red) and ram resistance (purple), or how "strong" the layer is are all shown in the graph. Under the graph the values of the total snow depth, number of layers, surface temperature and SWE or snow water equivalent are given.

The crystals of the snow profile are in the table on the right in the Figure. The classification of the crystals is below the table, explained with colours and shapes. In the table of crystals the green layer with ++ at the top of the profile is fresh snow with unbroken crystals, green with +/ denotes fresh snow with partly broken crystals, and between them the greenish layer with /• shows broken and rounded crystals. Below the brown layers, • • shows round crystals and farther down, the oldest layers are red with open circles showing round refrozen crystals. These do not show wet grains here since the temperature in all these layers is below 0°C.

In the table on the right in Figure 11 the density is shown under RO, where, as could be expected, the fresh snow or green layers have lower densities than the brown and red snow layers deeper down. TEL is the water runoff, which is 0 in the present example. The original dates of each layer are farthest to the right in the Figure.

By pressing the right mouse button on a layer in the table, more detailed information appears in a box, as shown in Figure 12. The selected layer is a dense layer (418 kg/m3) of refreeze wet grains (dendricity=0 and sphericity=99 and historical=4) with a very high value of shear strength/Shear stress which is a stable layer.

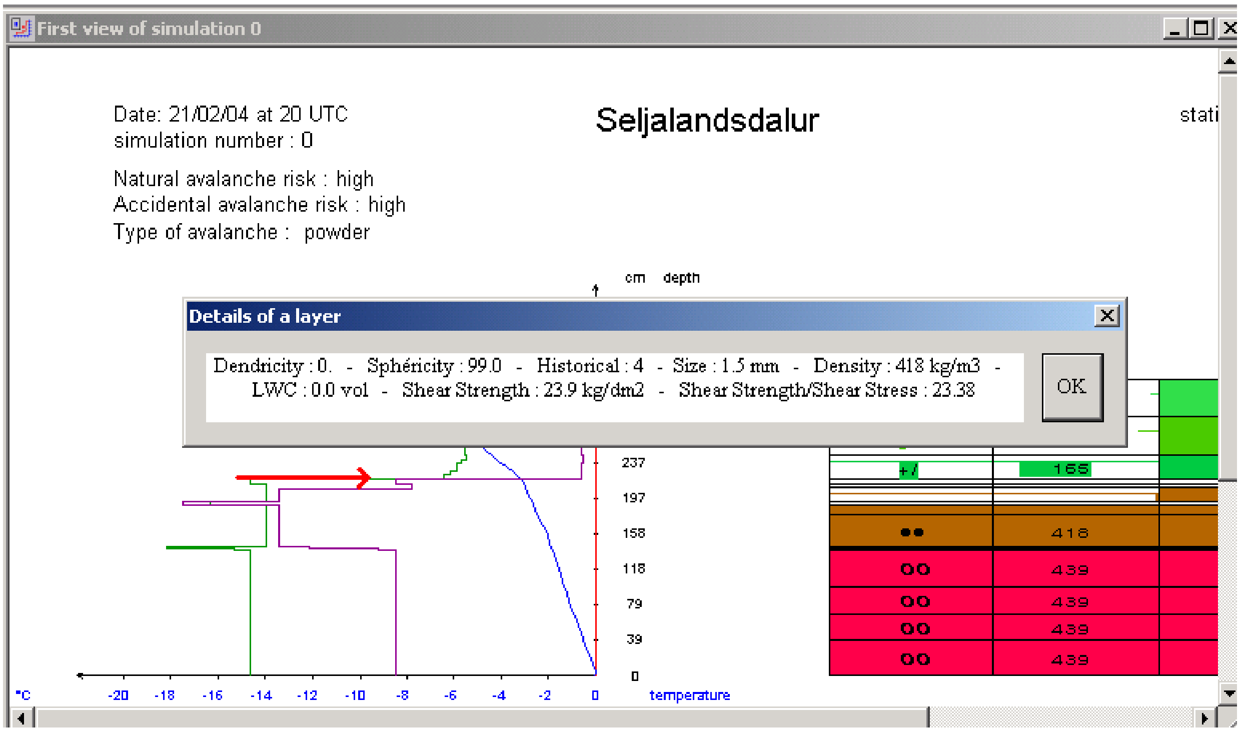

Figure 12. *By clicking the right mouse button on the weak layer (red arrow), this information appears.*

The default is to show the first profile (profile button 1) at the beginning of the simulations and the last profile (profile button 2) of the simulations. The <+> button shows a profile +1 hr. from the present one, and the <-> button shows -1 hr. from the present one, given the present view is not the last or first one. A selection of hours does not work correctly, so it should not be used at present.

The fluxes shown in a table (press the second icon from the bottom on the far left on the screen), include:

SolR:	Net solar radiation (W/m^2)	HFG:	Heat flux from ground (W/m^2)
IrR:	Net infrared radiation (W/m^2)	SMF:	Freezing mass at the surface (kg/m^2)
SHF:	Sensible heat flux (W/m^2)	SCS:	Solid condensation at the surface (kg/m^2)
LHF:	Latent heat flux (W/m^2)	SS:	Sublimation at the surface (kg/m^2)
HFR:	Heat flux due to rain (W/m^2)	ES:	Evaporation at the surface (kg/m^2)
HFS:	Heat flux due to snow (W/m^2)	Rain:	Rain (mm)
COR:	Correction due to sublimation and freezing (W/m^2)	NSWE:	Water equivalent of fresh snow (mm)
		WRO:	Water runoff (mm)

Save a profile

When finishing, the program asks if you want to save a profile (Figure 13).

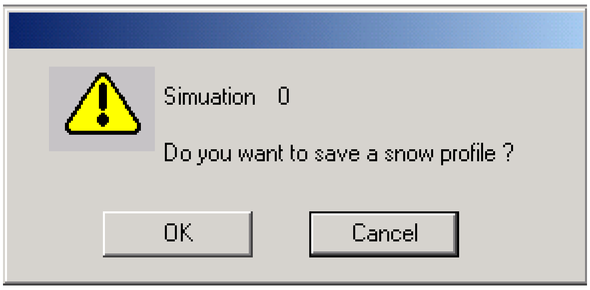

Figure 13. *Safe a profile before closing the session?*

You may e.g. select some special hour of the results or the last profile to keep to continue the simulation for 10 more days. Here the hour of the detection of two weak layers is selected.

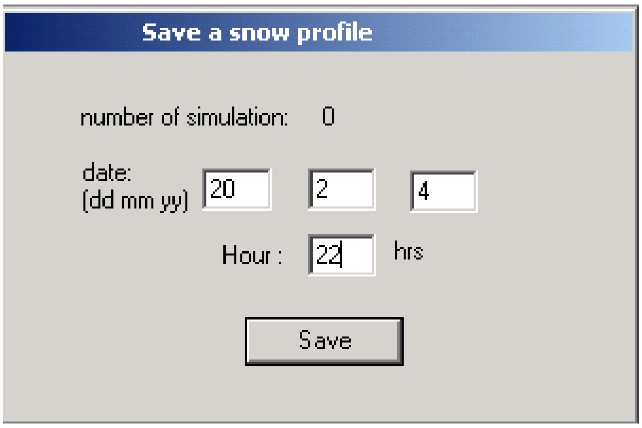

Figure 14. *The time of a stored profiles in the example.*

For starting again with the saved profile, the initial steps are as before, until pressing <Load> in Figure 3 and the next Figure.

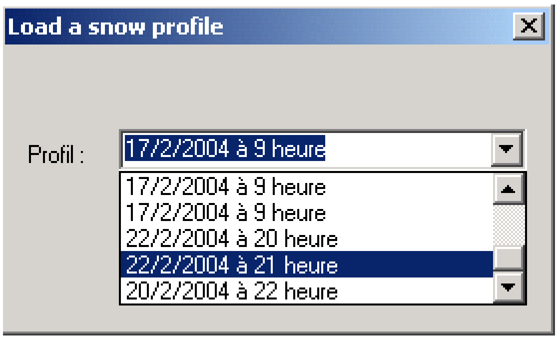

Figure 15. *Selecting an already saved profile.*

The new "initial profile" includes, as a consequence of the previous simulation, 50 layers (Figure 16) which in turn replace the initial 12 layers (Figure 3). The first 12 layers probably have changed as well, since they have matured through the days of simulation to 22 February.

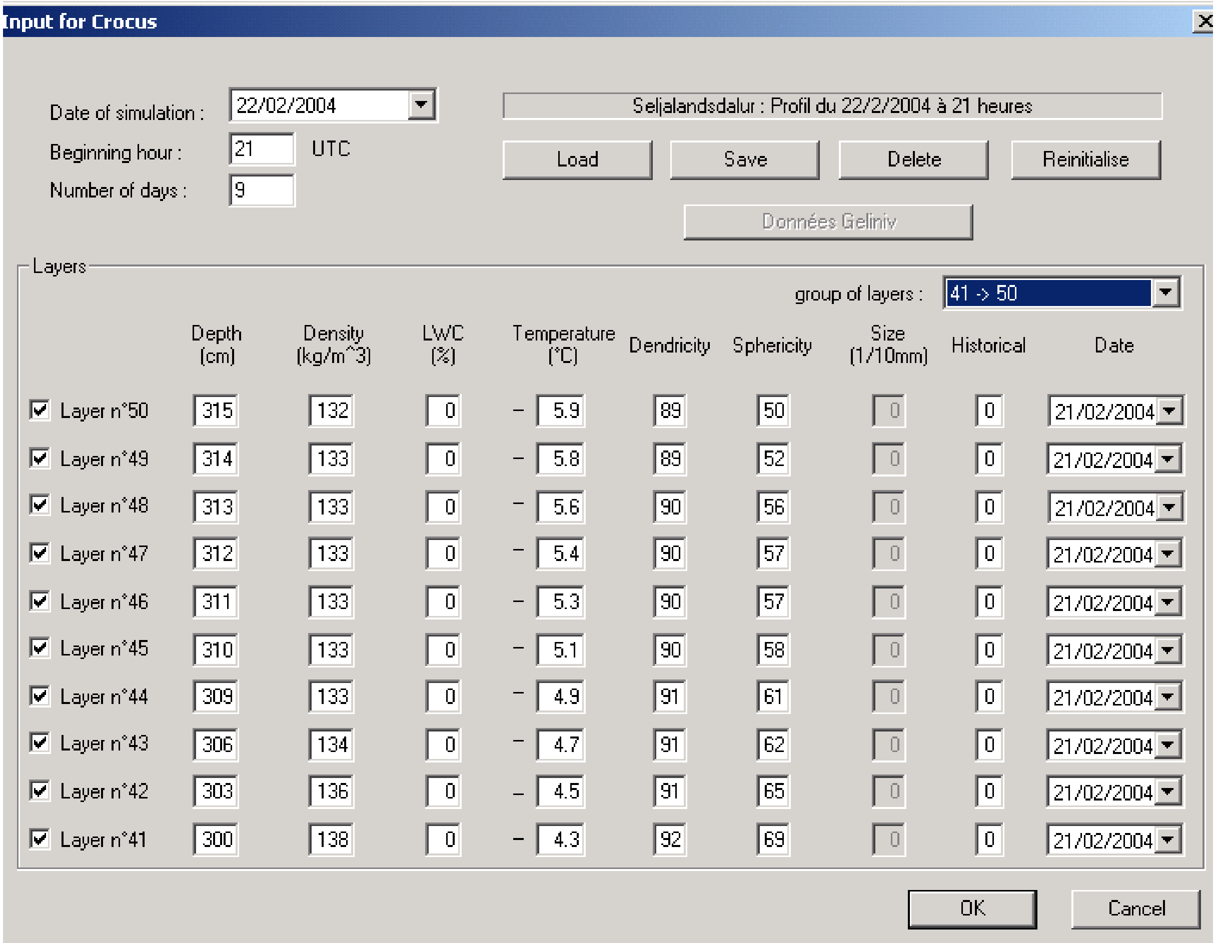

Figure 16. *The profile which was saved in the first example can be the initial profile of the next simulation.*

Multiple simulations

The results of the simulation may be left on the screen and modifications made to some of the parameters, such as station, initial profile and meteorological conditions. The user then has access to all the windows and can easily compare the results of the different simulations. The different windows are accessible by the icons or menus. It is easy to play with the scenarios of variations in weather or snowpack. NOTE: Do not exceed the capacity of your PC.

Configuration

The menu allows the user to modify the model parametrisation Crocus and Mepra and to set the UTC hour instead of local hour.

Under Configuration (Figure 1) the parametrisation of Crocus or Mepra may be modified by changing the file PARAM_CROCUS (Figure 17). NOTE: The file includes all the parametrisation for Crocus and the changes need to be made with great caution. As noted earlier, make a backup of your initial file.

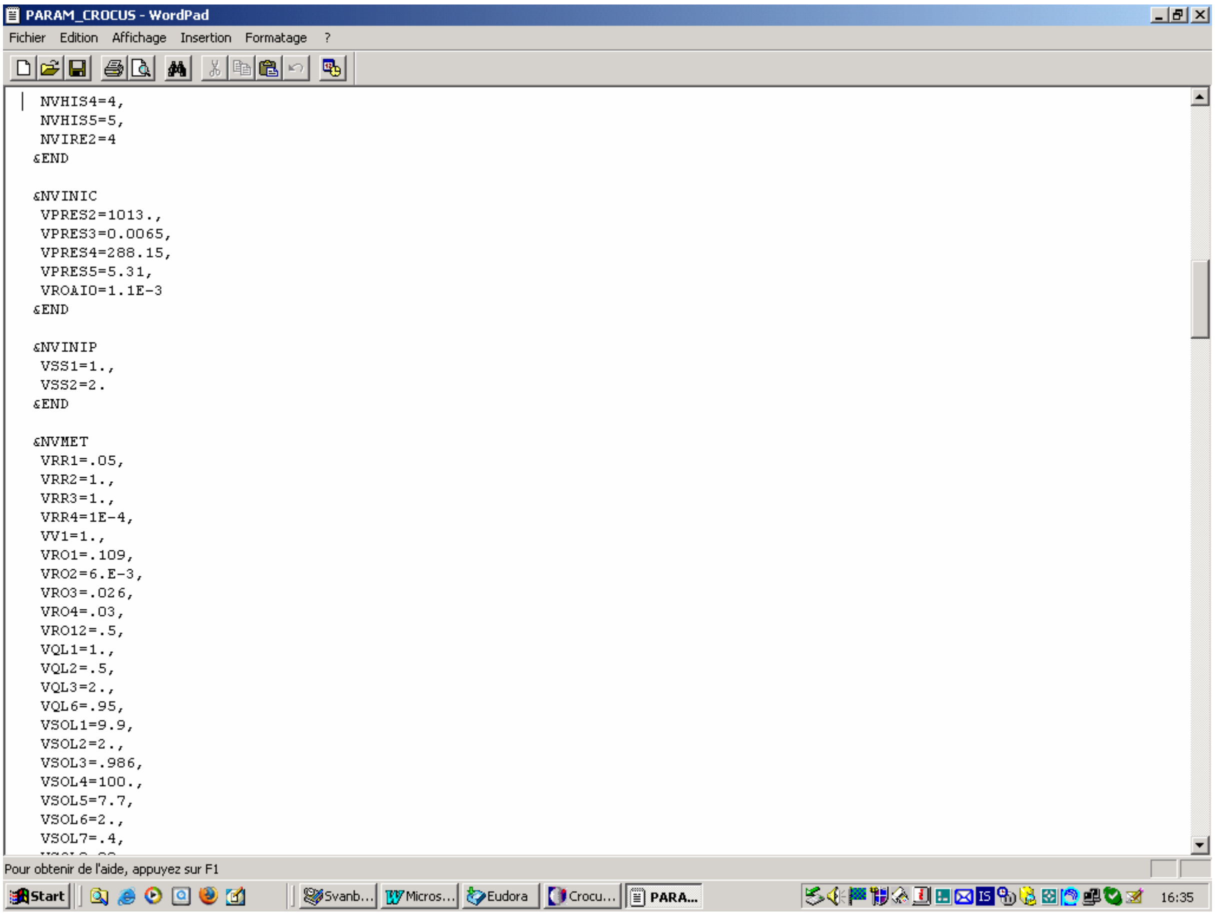

Figure 17. *Configuration - parmetrisation of Crocus*.

The time zone can be changed with respect to difference from UTC and summer/winter time, as for France. It is not necessary for Iceland (Figure 18), which uses UTC during the whole year.

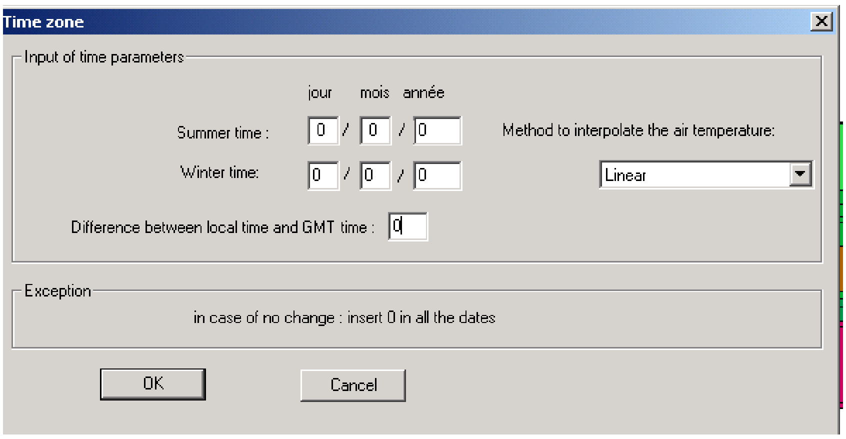

Figure 18. *Modifying the local time zone with respect to UTC (0 for Iceland).*

Online help

Help is available in the French version (F1), but only in French as well for the English version (? in Figure 1).

Conclusions

This version of CrocusMepra PC has gone through various means of validation. Crocus has been validated with data from Col de Porte near Grenoble, during periods of accumulation of snow, melting and metamorphism. CrocusMepra has been validated with occurrences of avalanches in nature as well as snow profiles. In spite of validation there are some problems in all software. Do not hesitate to contact the email adress given below in case of errors or if you have difficulties in getting started.

The PC version has not been adapted for Icelandic conditions in a similar way as the SSCM-models that run daily.

These modifications were:

- Safran: Precipitation correction due to wind effect. The observations of precipitation are multiplied by a coefficient which depends on wind speed and temperature. In the PC versions this is not important since the increase in snow depth is in the input for snowfall, not in the precipitation as in the models for the daily runs.
- Parameters for calculating the density of new snow have lately been set to VRO3=0.04 and VRO12= 0.55 (instead of 0.26 and 0.5 in France. In previous tests we chose 0.04 and 0.75 in Iceland). After the installation, this can be set with Configuration as in Figure 17, where an example is shown.
- T_c, the temperature which discriminates between snowfall and rain depends on location (0.8°C for Hveravellir up to 1.8°C for Bolungarvík). The temperature, T_c, does not affect the PC-version since the user inserts snow depth increase in cm when the precipitation is snow, and rainfall in mm when it is raining.
- Mepra: The criteria for the stability analysis of the snowpack was modified in the Icelandic version of the models, but the present PC version uses the French criteria.

  In the future the PC version and the SSCM-daily version need to be compared and probably adapted better.

Acknowledgements

The project was supported by the Public Roads Administration in Iceland as well as the Jules Verne program for cooperation between Iceland and France. We are grateful to Halldór Björnsson, who read the report and gave comments. Haraldur Ólafsson and Yves Durand have also contributed with good comments and cooperation, as well as Lauernt Mérindol and Gilbert Guyomarc`h. Last but not least are we grateful to Barði Þorkelsson for his good omments.

In case you need assistance, please contact:

svana@vedur.is or leifur@vedur

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Further reading

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Appendix 1. Glossary of snow terms

dendritic grains (Fr. grain dendritique) : the grains are characteristic for new snow, with branches. This kind of grains will disappear gradually during metamorphism.

round grains (Fr. grain sphérique): the grains are characteristic for snow which has gone through metamorphism during not very high temperature gradient or if the snow is or has been wet.

history (Fr. historique): a variable which allows the user to distinguish between different past evolution of the grains.

TEL (Fr. Teneur en **E**au **L**iquide de la neige): Snow wetness. If TEL=0, the snow is dry, if TEL>0, the snow is wet or humid.

Appendix 2. Diagrams

Sorry, the text in the diagrams is in French.

Crocus

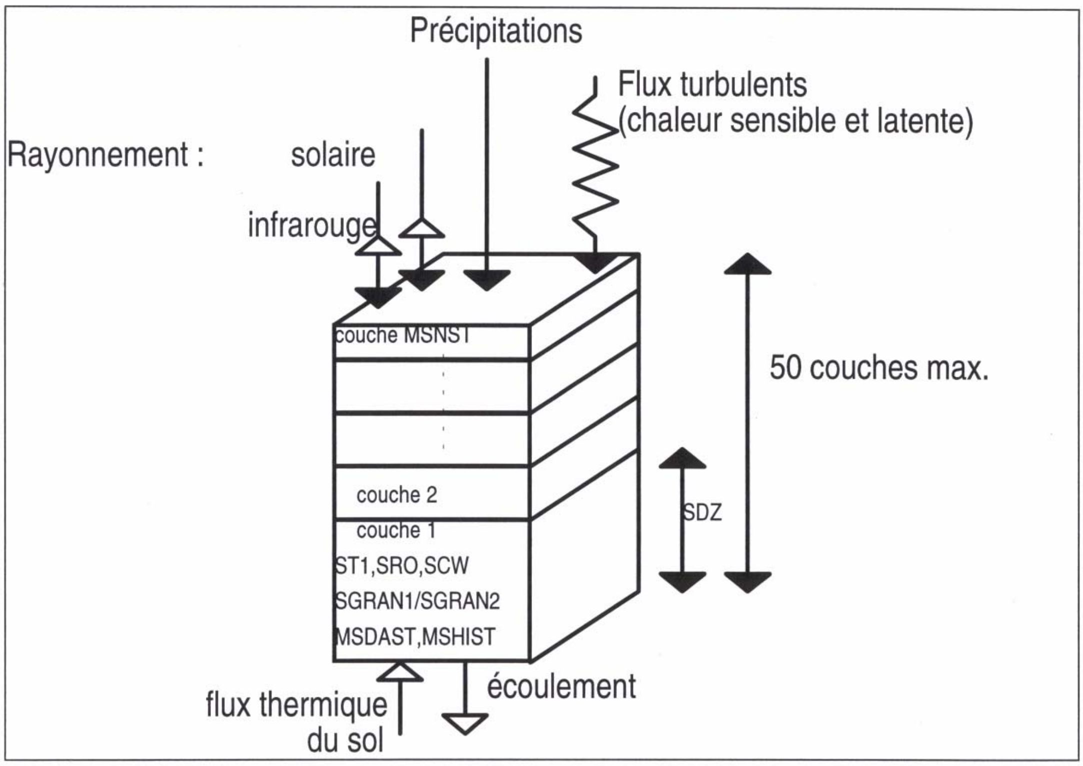

Figure 19. *A diagram of the Crocus-model. Radiation, precipitation, turbulent fluxes (sensible and latent heat), thermal flux from the ground to the snowpack, water dripping into the ground. A maximum of 50 layers.*

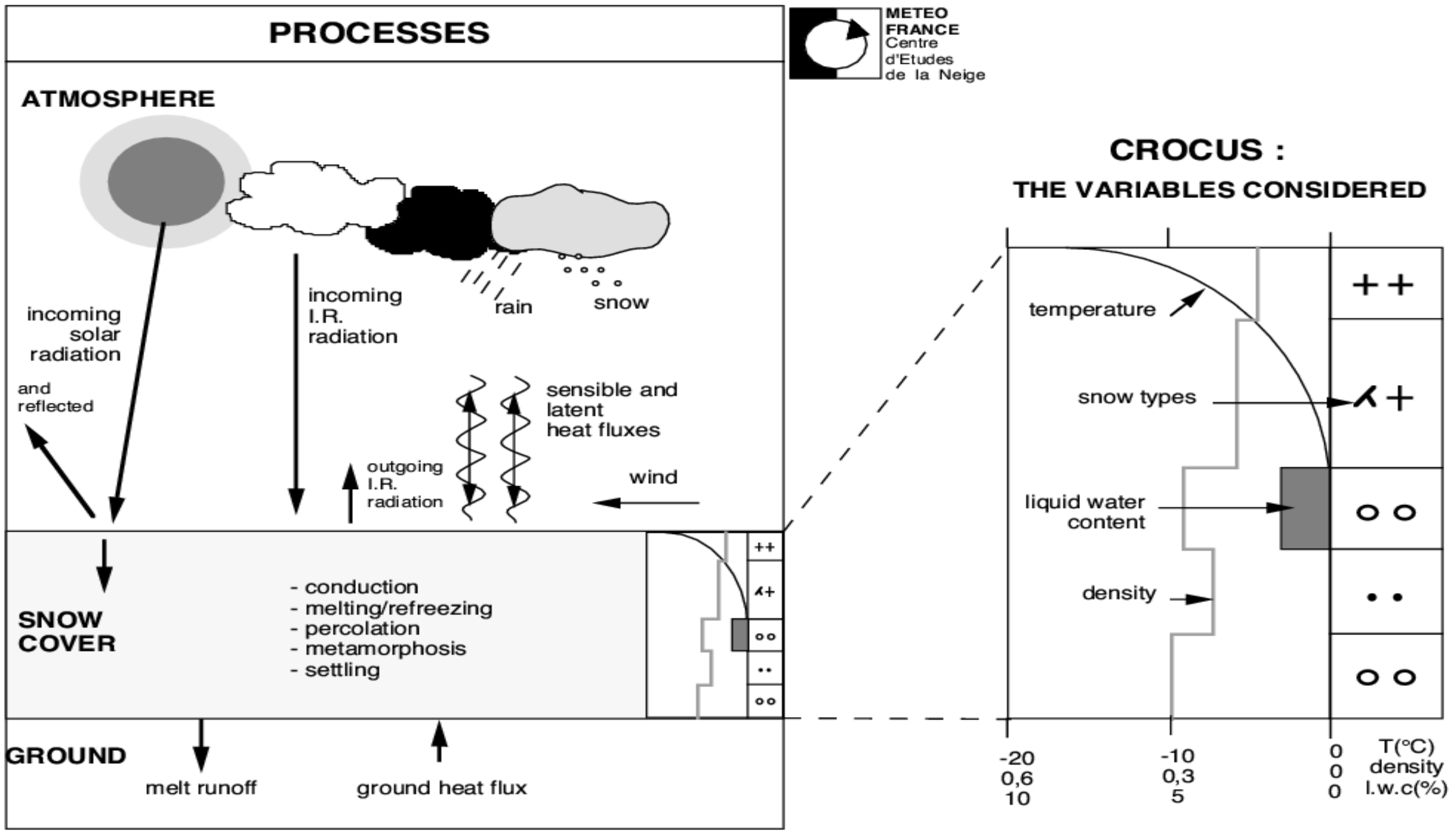

Figure 20. *The working process of Crocu. Initial snowpack and weather observations for the day are read by Crocus, which calculates the evolution of energy, mass and morphology of the layers of the snowpack. The results are snow profiles (right) showing temperature, types of grains, liquide water content and density.*

Mepra

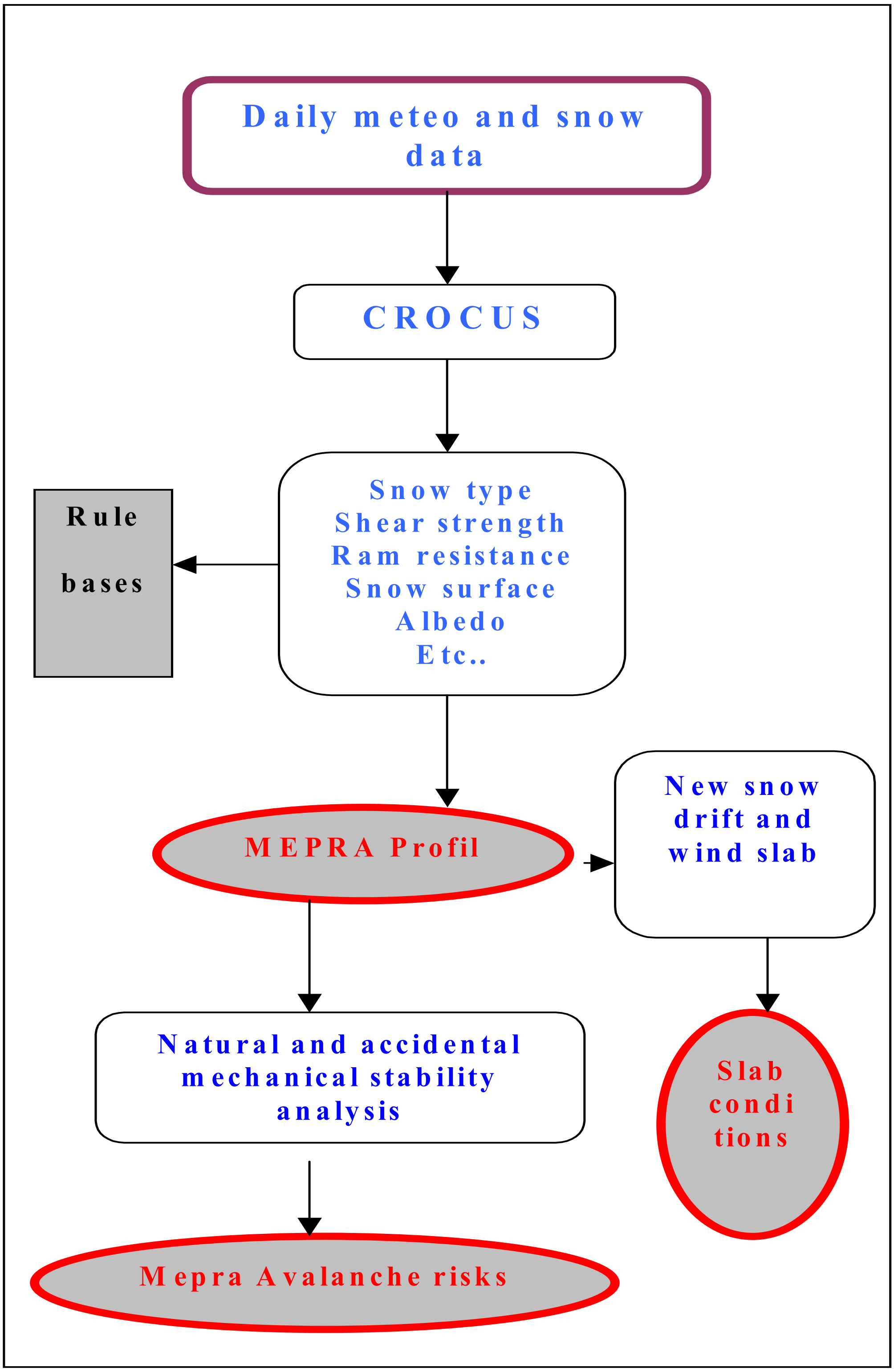

Figure 21. *Diagram of Mepra. Mepra reads the various snow profiles from Crocus for different elevations and aspects, analyses their stability and evaluates the avalanche hazard for each of them.*

Appendix 3. Characteristics of the files

Most of the terminology has been translated in the software, but the help is still in French. In case assistance is needed contact the authors.

The file PROFIL.MSO:

The details of the file profil.mso or resul*X*.mso (where X represents the number of the station in the simulation), a total of 1581 characters:

0-7:	Date and hour of the profile (year, month, day and hour, each one represented by 2 characters).
8-11:	Number of hours in the simulation (4 characters).
12-15:	Pressure in the level of the site (station) in hPA (4 characters).
16-17:	Inclination of the site (station) in degrees (2 characters).
18-217:	Thickness of the layers (DZ) in 1/100 cm (up to 50 layers).
218-467:	Temperatures (T1) of the 50 layers in 1/100 K, the temperature of each layer is recorded with 5 characters.
468-667:	Density (RO) of the 50 layers in kg/m^3, each coded with 4 characters.
668-867:	Wetness, or water content (teneur en eau liquide volumique TEL) of the 50 layers in 1/100 (% volume), each coded with 4 characters.
868-872:	Total snow depth (HTN) in 1/100 cm coded with 4 characters.
873-1072:	Dendricity or sphericity of the 50 layers in 1/10, coded with 4 characters.
1073-1222:	Sphericity in 1/10 or diameter in 1/10 mm for the 50 layers, each one coded with characters.
1223-1272:	History (historique) of the 50 layers (ISTORI), coded with 1 character for each layer.
1273-1276:	Drainage (ecoulement ECS) at the bottom of the snowpack during the last hours in (1/100) g/cm^2.
1277-1278:	Number of layers in the snowpack (NST).
1279-1580:	Date of the 50 layers, each one coded with 6 characters (2 for the year, 2 for the month and 2 for the day).

The file METEO.MSO

The file «meteo.mso» has 8 columns and n lines (with n number of records).

1. Temperature of the air [1/100K].
2. Wind speed [1/10 m/s].
3. Humidity of the air [%].
4. Nebulosity (from 0 to 1).
5. Infrared radiation [W/cm²].
6. Precipitation of rain [mm].
7. Precipitation of snow in [cm] of snow.
8. Density of new snow [kg/m^3] (not used).

The file FLUX.MSO

The file «flux.mso» includes 11 columns and n lines (with n = number of records).

1. Temperature of the air [1/100K] coded with 5 characters.
2. LWC (Liquid Water Content) of the surface [% volume] coded with 4 characters.
3. Daily runoff [mm] coded with 7 characters.
4. Albedo [1/1000] coded with 3 characters.
5. Net solar radiation [W/m²] coded with 7 characters.
6. Infrared radiation [W/m²] coded with 7 characters.
7. Sensible heat flux [W/m²] coded with 7 characters.
8. Latent heat flux [W/m²] coded with 7 characters.
9. Heat flux due to rain [W/m²] coded with 7 characters.
10. Heat flux due to snow [W/m²] coded with 7 characters.
11. Ground heat flux [W/m²] coded with 7 characters.

The file MEPRA.MSO

A field contains 995 characters (Fr. octets/caractères). It contains the fields of hourly simulations.

Description:

1-7: Day, month and year of the profile. (day and month with 2 characters, the year with 4 characters).

8-9: Hour of the simulation.(two characters).

10-11: Number of layers of the snowpack (two characters).

12-16: Temperature of the earth surface (five characters).

17-20: Type of the upper and lower profile (four characters, two for each).

21-22: Number of layers of the lower profile.

23-24: Natural avalanche hazard.

25-26: Type of avalanche.

27-28: Accidental avalanche hazard (caused by traffic).

29-32: Height of upper profile (four characters).

33-36: Height of instability level number 1.

37-40: Height of instability level number 2.

41-44: **Height of unstable snow** (four characters).

45-245: Thickness of layers (4 characters each, maximum 50 layers, 50*4).

246-496: Resistance of each layer (50*5 characters).

497-647: Shear strength of each layer (50*5 characters).

648-898: Tangential gravity stress (50*5 characters).

Appendix 4. Structures of the grains

Most of the terminology has been translated in the software, but the help is still in French. In case assistance is needed contact the authors.

Classification of dendritic snow (i.e. snow with dendricity > 0)

Type of grains (diameter if available in mm)	MSHIST History (Historique)	SGRAN1 Dendricity	SGRAN2 Sphericity
+ +	0	-99.0	50.0
+ /	0	-75.0	50.0
/ /	0	-50.0	50.0
/ □	0	-25.0	25.0
/ •	0	-25.0	75.0
□ □ (d < 0.4)	0	-5.0	0.0
• • (d < 0.3)	0	-5.0	99.0

Figure 22. *Dendritic crystals, i.e. with branches (many or few), broken or not broken*.

Classification of non-dendritic crystals

Hist. / Spher.	0	1		2/4		3/5
	□ □	d < 0.5	□ □	∀d	○ □	○ □
		0.5 < d < 1.0	□ ∧			
		d > 1.0	∧ ∧			
0.2	□ ●	d < 0.5	□ ●	∀d	○ □	○ □
		0.5 < d < 1.0	□ ∧			
		d > 1.0	∧ ∧			
0.5	● □	d < 0.5	● □	d < 0.5	● ○	(1)
				0.5 < d < 1.0	○ ○	
				d > 1.0	○ ○	
0.8	● ●	d < 0.5	● ●	d < 0.5	● ○	(1)
				0.5 < d < 1.0	○ ○	
				d > 1.0	○ ○	

Figure 23. *Non dendritic grains*.

History: The situation depends on the presence of water and the growth and size of the crystals.

- If the growth of the grains is affected by the presence of water MSHIST=2
- If the grains grow in high temperature gradient MSHIST=1
- If the grains grow first in high temperature gradient and after is affected by the presence of water MSHIST=3

Symbols of the crystals

The grain symbols are according to the international classification (Colbeck and others, 1990).

Basic Class	*Explanation*	*Symbol*
1	Precipitation particles	+
2	Decomposed and fragmented precipitation particles	/
3	Rounded grains (monocrystals)	●
4	Faceted crystals	□
5	Cup shaped crystals and depth hoar	/\
6	Wet grains	○

Appendix 5. Colour of the crystals

For Figure 24 compare codes with Figure 22 and Figure 23.

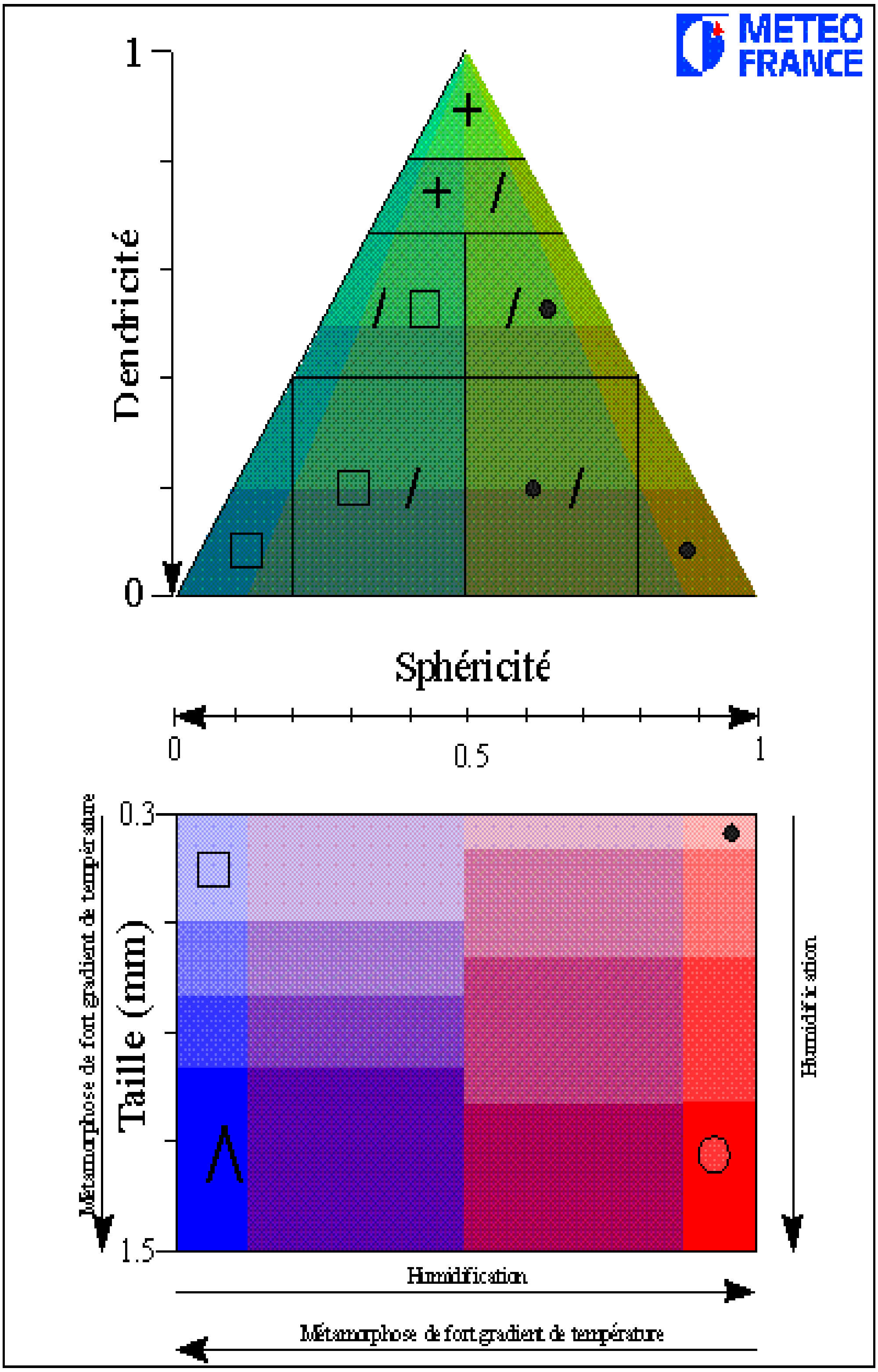

Figure 24. *Colour codes for types of crystals.*

Appendix 6.

Files in the system:

carsim.mso

mepra.mso

meteo.mso

nto.mso

num.mso

posgeo.mso

profile.mso

resul14.mso

mepra.mso