SLF Expert report G2012.27

Hazard caused by ice avalanches from the Planpincieux Glacier, Val Ferret, Courmayeur, Italy

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Davos, 17 January 2013/mar

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CIG: 440168408C

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Davos, 17 January 2013/mar

Content

1 Mandate

The WSL Institute for Snow and Avalanche Research SLF in Davos, Switzerland was mandated on 25 July 2012 by the Fondazione Montagna Sicura in Courmayeur, Italy to analyse the hazard caused by ice avalanches from the Planpincieux Glacier. In accordance with Contract Nr. CIG: 440168408C the main objectives of the study are to investigate the hazard for different scenarios in relation to ice volume and snow stability. The following scenarios will be investigated:

a) Ice volume:
   - 20’000 m^3 (icefall of a small part of the glacier front)
   - 200’000 m^3 (icefall of the part currently separated by the largest crevasse)
   - ca. 1’000’000 m^3 (icefall of a larger part of the glacier)

b) Snow stability:
   - No snow (summer situation)
   - Rather stable snowpack (approximately corresponding to danger level 1 or 2 as forecasted in the avalanche bulletin)
   - Rather unstable snowpack (approximately corresponding to danger level 3 or higher as forecasted in the avalanche bulletin)

Based on the findings of the investigated scenarios safety measures will be proposed.

Stefan Margreth (Senior Consultant, SLF, Davos) visited the area on 29 February 2012 together with Martin Funk and Pierre Dalban (VAW ETHZ, Zurich) and with representatives of the Fondazione Montagna Sicura in Courmayeur.

2 Basic conditions and limitations

We point out that it is not possible to calculate for any ice volume and avalanche situation the “precise” consequences. There exists no approved calculation model to simulate ice or snow-ice avalanches. The calculations performed in this expert report give a certain order of magnitude of possible consequences that have to be interpreted very carefully. The main goal of the calculations is to compare the consequences of the different scenarios to each other and not to calculate “precise” runout zones for a single scenario. The interaction of ice avalanches with the snowpack and the assessment of the consequences are scientifically largely unknown. We had to make a series of assumptions based on expert judgement. We tried to work out the safety concept on a realistic base with a reasonable level of safety. A certain margin of safety is included in the hazard assessment. However, if the avalanche danger level is “high” or “very high”, avalanches may follow different tracks which are not considered in the presented safety concept. These situations need to be assessed based on the actually prevailing conditions.

Finally, it must be accepted that situations exist that are unpredictable and consequentially cannot be fully covered in the safety concept.

3 Overview

3.1 Glaciological and topographical situation

In November 2011 the separation of an ice mass in the lower part of the Planpincieux Glacier was identified (Figs. 1 and 2; Appendices 1 and 2). The Planpincieux Glacier is situated below the Whymper Glacier. The ice mass which extends from about 2650 m to the front of the glacier at 2600 m, is separated by several wide open crevasse zone. The whole Planpincieux Glacier is heavily crevassed; however, the crevasse zone above the partly separated ice mass seems to be more strongly fractured than others. It was supposed that this ice mass moves faster than the remaining glacier. According to M. Funk (VAW ETH Zurich) the sliding ice mass is a steep glacier tongue which terminates on a bedrock cliff. Because the sliding movement is most likely induced by water flow at the bottom of the glacier the detachment and fall of a large ice mass (> 100'000 m^3) is considered to occur most likely in summer or autumn. Smaller ice masses (< 50'000 m^3) can detach also in winter. The dimensions of the sliding ice mass were assessed by F. Diotri (Fondazione Montagna Sicura, Courmayeur) by means of a photogrammetric model. The width of the ice mass is 150 m, the height is 32 m and the length is 60 m. The volume of the ice mass is estimated to be around 200'000 m^3. An ice volume of 1 million m^3 covers a much larger area and extends from the front of the glacier at 2600 m up to an elevation of 2780 m. An ice volume of 20'000 m^3 involves only a small part of the glacier front (Appendix 2).

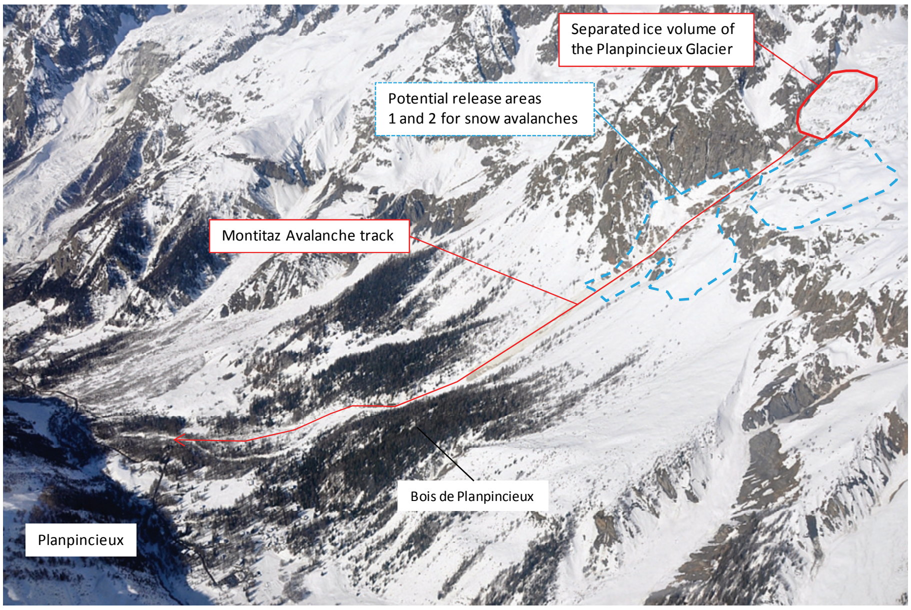

Fig. 1: View of the Planpincieux Glacier with the avalanche release areas, the Montitaz avalanche track and the runout area. The centre of the village of Planpincieux is protected by a forested terrain ridge. The main avalanche tracks are to the left and right of the forest.

The slope angle of the surface of the separated ice mass varies between 35° and 45°. If an ice mass detaches from the glacier an ice avalanche will form. Below the partly separated ice mass of the Planpincieux Glacier the avalanche track consist of a 100 m high and very steep cliff. The steep cliff can cause the formation of powder avalanches. The track is steeper than 30° until to an elevation of about 1950 m. Below an elevation of 1950 m the track follows the channel of the river Montitaz and gets more confined (Appendix 2). At the elevation of 1700 m the channel makes two well pronounced turns (Fig. 3). A fast flowing avalanche might leave the main track and follow a smaller secondary track into the direction of the village Planpincieux. Below the elevation of 1650 m the channel opens and several flow directions are possible. The slope angle decreases from about 13° to less than 10°. The main flow direction which can be easily recognized by the forest pattern is situated along the "Torrent de Montitaz" and into the direction of the switchback curves of the access road to Planpincieux.

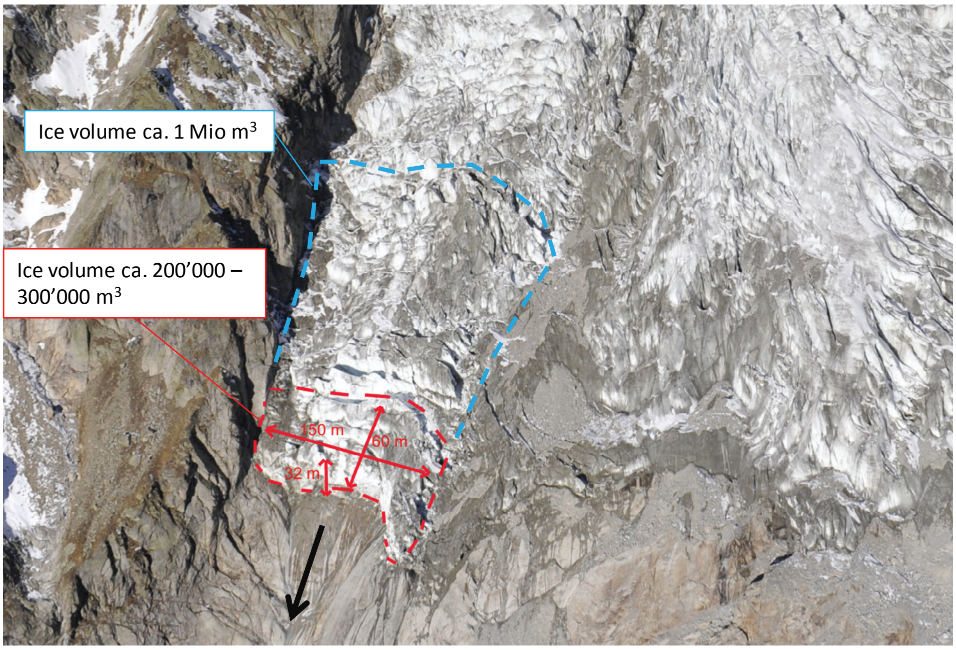

Fig. 2: View of the separated ice masses in the lower part of the steep glacier tongue of the Planpincieux Glacier. Below the front of the separated ice mass the track consists of a steep rock band.

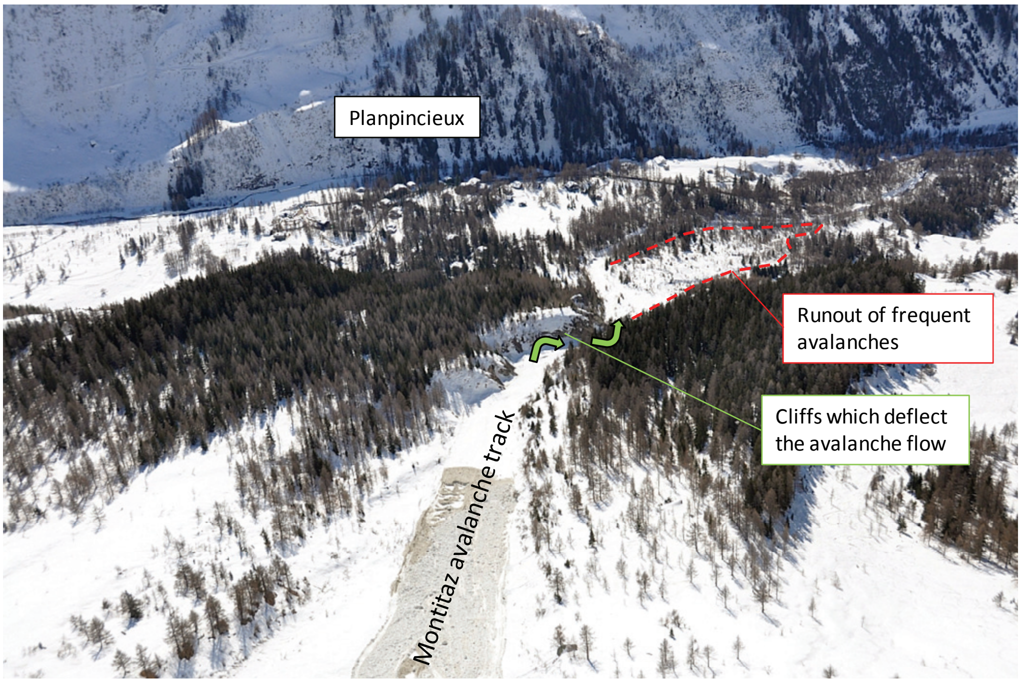

Fig. 3: View along the Montitaz avalanche track towards the bottom of the Val Ferret. A wet snow avalanche stopped at an elevation of ca. 1800 m (photo taken on 29 February 2012). Clearly visible is the sharp turn in the avalanche track which deflects the avalanching snow to the right. An avalanche can overflow the sharp turn if the velocity and flow depth is very high.

3.2 Avalanche situation and avalanche hazard map Planpincieux of 2001

The separated ice mass of the Planpincieux Glacier is situated in the middle of the avalanche path of the Montitaz avalanche (Nr. 66 in the avalanche hazard map). The main release area of the avalanche is situated in the upper part of the Planpincieux Glacier between 3650 m and 3500 m. E. Ceriani prepared a hazard map for the Montitaz avalanche (Ceriani 2001). He assumed for a return period of 100 years a fracture depth of 1.4 m and an avalanche volume of 58’800 m^3. The red hazard zone (impact pressure > 30 kN/m^2) ends at an elevation of 1600 m approximately 150 m above the access road to Planpincieux (Fig. 4). The yellow zone (impact pressure 5 to 30 kN/m^2) is situated between the elevation of 1600 and 1560 m and includes the last switchback curve of the access road. The blue zone (impact pressure < 5 kN/m^2) ends in the riverbed of the “Doire du Val Ferret” and includes most of the area of the village of Planpincieux. We think that the chosen fracture depth and avalanche volume is rather small in view of the huge avalanche path, but the extent of the hazard zones seems to be fine.

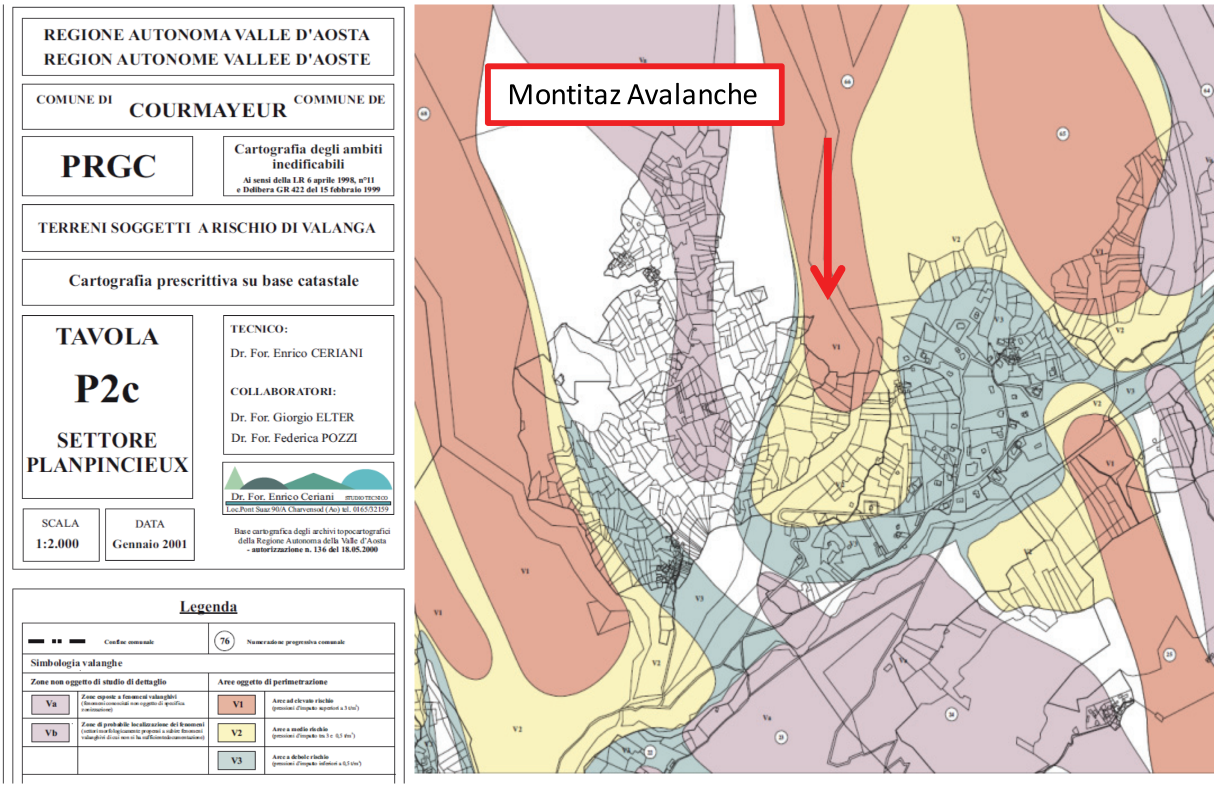

Fig. 4: Avalanche hazard map of Planpincieux (Ceriani 2001).

Below and east of the separated ice mass are large potential avalanche release areas which can be triggered by an ice fall (Appendices 1 and 2). The upper release area no. 1 is situated between the lower end of the Planpincieux Glacier and a cliff band. The mean slope angle is around 36° and the potential release area is around 11 hectares. The topography is rather uneven and consists of several depressions and ridges. The lower release area no. 2 is situated below the cliff band. The total release area is around 19 hectares and the mean slope angle is 36°. More than 50% of the release area no. 2 consists partly of small cliffs. We think that the break-off of large avalanches with volumes of more than 100’000 m^3 is rather unlikely in both release areas.

3.3 Avalanche history

15 events of the Montitaz avalanche were recorded in the avalanche cadastre (Fig. 5; codice valanghe V-18-009, Catasto Regionale Valanghe, 2012):

- The largest observed avalanche occurred on 21 December 1952 when 2 hectares of forest and the telephone line were destroyed. Parts of the avalanche flowed also along the avalanche track of Montitaz. That avalanche was most likely caused by an ice fall from the Whymper Glacier.
- The avalanche from 16 February 1982 stopped about 60 m in front of the first houses of Planpincieux and some meters in front of the access road to the Val Ferret. Most probably the avalanche was triggered by an icefall (Fig. 6).
- In summer 2005 an ice avalanche released which stopped above the access road.

- According to the avalanche history all documented avalanches stopped above the access road to Planpincieux. We assume that most of these avalanches released in the lower part or below the Planpincieux Glacier. Furthermore, we conclude that extreme snow avalanches which endanger the access road to Planpincieux and the village itself are quite rare (presumably more seldom than 50 years). In the avalanche cadastre no large ice fall from the Planpincieux Glacier was recorded.

Fig. 5: Avalanche cadastre with the maximum observed runout of the avalanches (Regione Autonoma Valle d'Aosta 2012). The Montitaz avalanche is shown in blue (codice valanghe V-18-009).

Fig. 6: Montitaz avalanche of 16 February 1982. The left arm of the avalanche stopped about 60 m in front of the first houses of Planpincieux.

4 Avalanche dynamics calculations

4.1 Fundamentals

Besides the analysis of the topographical situation, meteorological conditions and observed avalanche events, the results from avalanche dynamics calculations were used to quantify avalanche pressures and calculate run-out distances for different ice volumes and different snow conditions. Furthermore, the extent of extreme events, which were not observed yet, can be estimated with avalanche dynamics calculations. The model calculations with RAMMS (SLF 2012a) are based on the digital elevation model with a resolution of 10 m (MNT 2005) and on the ice and snow input parameters. The volumes and geometry of the falling ice masses, the degree of snow entrainment, the possible release of secondary avalanches, the loss of mass in areas with high ground roughness and the friction parameters must be defined based on expert judgement. We use the same approach as we applied for our investigations in 2009 (SLF 2009 and Margreth et al. 2011).

Ice volumes:
We performed the calculation for three different ice volume classes:
- 20'000 m^3 (icefall of a small part of the glacier front)
- 200'000 m^3 (icefall of the part currently separated by the largest crevasse)
- ca. 1'000'000 m^3 (icefall of a larger part of the glacier).

The glacier ice will be broken up during the fall and the density of the glacier ice will decrease from an estimated 850 to 900 kg/m^3 to about 400 to 500 kg/m^3. The initial ice volume was increased by a factor varying between 1.2 (maximum ice volume) and 2.0 (small ice volume) to compensate for the decrease in density which RAMMS does not consider, the poorly known mass distribution in the model calculation and the uncertainties in defining the scenarios. The chosen fracture depths were 20 m for an ice volume of 20'000 m^3 and 38 m for an ice volume of 1 million m^3. For these large fracture depths the RAMMS simulations showed a much too wide lateral spreading of the avalanche flow after the break-off. We corrected this deficiency by introducing so called "no flux cells" around the breaking-off ice mass which prevent a lateral spreading.

Avalanche fracture depth

In our reports of 1997 (SLF, 1997) and 2009 (SLF, 2009) we based the determination of the fracture depth for the avalanche dynamics calculations on snow data from the observation stations of Courmayeur (1920 m), Mont de la Saxe (2250 m), Simplon (2000 m), Lago Goillet (2526 m) and Pt. S. Bernard (1950 m). We determined a base value for the calculation of the fracture depth d_o of 115 cm for a return period of 10 years and 175 cm for 100 years for a slope inclination of 28° and an elevation of 2000 m. For the different starting zones we will adapt the fracture depth according to the return period, the slope angle and the elevation. The location of the investigated starting zones no. 1 and 2 below the Planpincieux Glacier are given in Appendix 2.

Friction parameters and simulation resolution

Combined snow-ice avalanches which break loose **in winter** were simulated with the same friction values as used for snow avalanches (SLF 2009 and SLF 2012). For small ice volumes and a rather stable snowpack this assumption is relatively pessimistic. However, if the ice avalanche triggers or entrains large snow masses this assumption is appropriate in our view. For ice volumes of 20'000 m^3 and a rather stable snowpack, the friction parameter values corresponding to medium volumes and a 10-year return period were used (for unchannelled topography μ = 0.225 and ξ = 2500 m/s^2). For extreme situations when an ice volume of 1 million m^3 triggers or entrains large snow masses, the most extreme friction parameters for large volumes and a 300 year return period (for unchannelled topography μ = 0.155 and ξ = 3000 m/s^2) were used. In general, for large avalanches smaller friction parameters are used than for small avalanches.

Ice avalanches which break loose **in summer** were simulated with increased friction values corresponding to small volumes and a return period of 10 years for an ice volume of 20'000 m^3 (for unchannelled topography μ = 0.26 and ξ = 2000 m/s^2) and corresponding to medium volumes and a return period of 30 years for an ice volume of 1 million m^3 (for unchannelled topography μ = 0.215 and ξ = 2500 m/s^2).

For ice volumes larger than 200'000 m^3 a simulation resolution of 20 m was applied. For the smaller ice volumes the chosen simulation resolution was 10 m.

Interaction between ice avalanche and snowpack

The largest uncertainty in the avalanche dynamics calculations is associated with the treatment of the impact of a falling ice mass on the snowpack. There exist no specific investigations on this topic. An ice avalanche will entrain only a part of the snow if the snowpack is very stable. A secondary avalanche release is unlikely. However if the snowpack stability is rather poor the falling ice avalanche can trigger a secondary snow avalanche in the release zone no.1 and possibly no. 2. We approached this problem with the RAMMS entrainment module where an erodible snow cover can be specified (SLF 2012a). This requires the definition of snow density, the erodible snow depth, the entrainment parameter K and the area where snow can be entrained. If the snowpack is rather stable we apply a small entrainment rate (K=0.2) and a small snow height, which can be entrained. If the snowpack is rather unstable an ice avalanche will entrain a 1.5 m thick snow layer by frontal plugging and the secondary release of snow avalanches is likely (Tab. 1). For such situations an entrainment parameter K=1 was chosen. The snow cover with an estimated density of 200 kg/m^3 is entrained instantaneously. The area with possible snow entrainment corresponds approximately to the release area Planpincieux no. 2 (Figs. 7.1, 7.2 and 7.3). We used the five danger levels of the European Avalanche Danger scale to quantify the snowpack stability and the release probability of snow avalanches (SLF 2012b; Appendix 4). Finally we will base the safety concept on the combination of ice avalanche volume and local avalanche danger level. The allocation of possible entrainment parameters to a certain danger level is based on expert judgement. Especially for the extreme scenarios (failure of an ice volume of 1 million m^3 in winter and summer) the uncertainty is very high.

Tab. 1: Entrainment parameters in relation to snowpack stability (K=0: no snow entrainment; K=1: the whole snowpack will be entrained)

Snowpack stability	Entrainment		Danger level European Avalanche Danger Scale
	Snow height	Parameter K	
Good	0.4-0.5 m	0.2	Level 1, Low danger
Fair	0.4-1.0 m	0.4-1	Level 2, Moderate danger
Fair to poor	0.6-1.0 m	1	Level 3, Considerable danger
Poor	1.5 m	1	Level 4, High danger Level 5, Very high danger

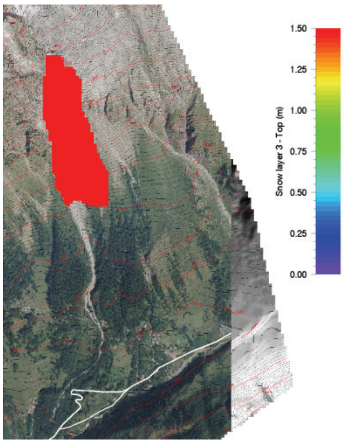

Fig. 7.1: Area of possible snow entrainment applied in the RAMMS simulations. The snow height varied according to the scenario between 0.4 and 1.5 m with a density of 200 kg/m^3.

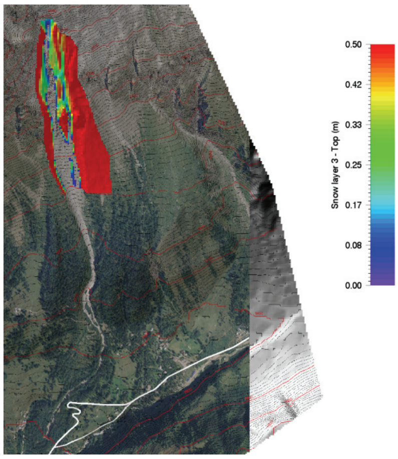

Fig. 7.2: Area of remaining snow after passage of avalanche. Simulation W2 with an entrainment parameter K of 0.2 and a snow height of 0.5 m. The total entrainment volume is 37'000 m^3.

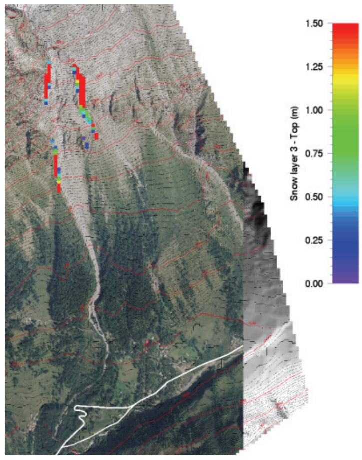

Fig. 7.3: Area of remaining snow after passage of avalanche. Simulation W7 with an entrainment parameter K of 1.0 and a snow height of 1.5 m. The total entrainment volume is 314'000 m^3.

Powder snow avalanches

Because the ice masses fall at the beginning of the track over a steep rock face the formation of a powder snow avalanche is likely (in the present report we name powder avalanches caused by an icefall as a powder "snow" avalanche). The formation of a powder snow avalanche is particularly relevant for ice volumes of more than 200'000 m^3. A reliable simulation of this process is not possible. We assess the consequences of the effect of powder snow avalanches with AVAL-1D (see below) and by expert judgment. The powder part of large avalanches with volumes of more than 1 million m^3 will endanger large areas and be decisive for the hazard to people (not protected in e.g. houses) outside of the areas hit by the dense part of the avalanches. An impact pressure of more than 0.5 kN/m^2 (corresponds to a strong storm with 100 km/h) is assumed to be dangerous for unprotected persons.

4.2 Investigated ice avalanche scenarios in summer

The results of the simulations are given in Appendix 6, Table 2 and Figures 8 and 9.

- **Simulation S1:** An ice avalanche with a volume of 20'000 m^3 is considered to be unproblematic for the access road to Planpincieux and the village itself.
- **Simulation S2:** According to the simulations, an ice avalanche volume of 200'000 m^3 is considered to be the threshold that the access road and the eastern part of the village are endangered especially if the formation of a powder snow avalanche is likely. The simulations show that the dense flow part will not reach the old access road to Planpincieux which is partly sheltered by a terrain ridge. The extent of the endangered area corresponds to the yellow zone of the hazard map of 2001.
- **Simulation S3:** An ice avalanche with a volume of 1 million m^3 strongly endangers the access road to Planpincieux and the village. A huge powder avalanche will form which might spread laterally in both direction over a distance of more than 1 km. The extent of the endangered area by far exceeds the hazard zones of the hazard map of 2001.

Tab. 2: Simulations results from ice avalanches from Planpincieux Glacier in summer

Scenario	Danger level European Avalanche Danger scale	Release volume (m^3)	Simulation volume (m^3)	Entrainment h (m)	Entrainment K (-)	Total entrainment volume (m^3)	Friction value category	Runout ratio (%)	Interpretation of simulation results	Output file
S1	-	20'000	40'000	-	-	-	Small, 10y	55	Avalanche stops in the channel at an elevation of 1700 m, 700 m above the access road.	Plamp1_20K_S10_Summer_Noflux_1.out.gz
S2	-	200'000	300'000	-	-	-	Medium, 30y	43	Avalanche stops at an elevation of 1515 m and endangers the upper switchback curve of the access road.	Plamp1_200K_M30_Summer_Noflux_1.out.gz
S3	-	1.0 M	1.2 M	-	-	-	Medium, 30y	40	Avalanche stops at an elevation of 1485 m and reaches the riverbed of the "Doire du Val Ferret". The access road and parts of Planpincieux are hit with intensities > 30 kN/m^2.	Plamp1_1Mio_M30_Summer_2_10m_noflux.out.gz

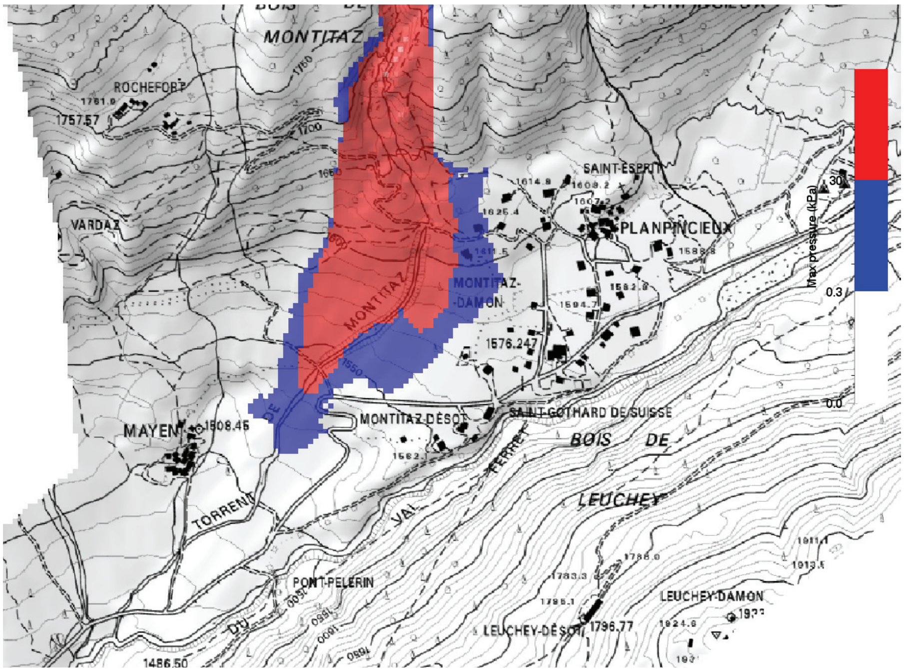

Fig. 8: Maximal pressure for scenario S2 with an ice volume of 200’000 m^3 in summer (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

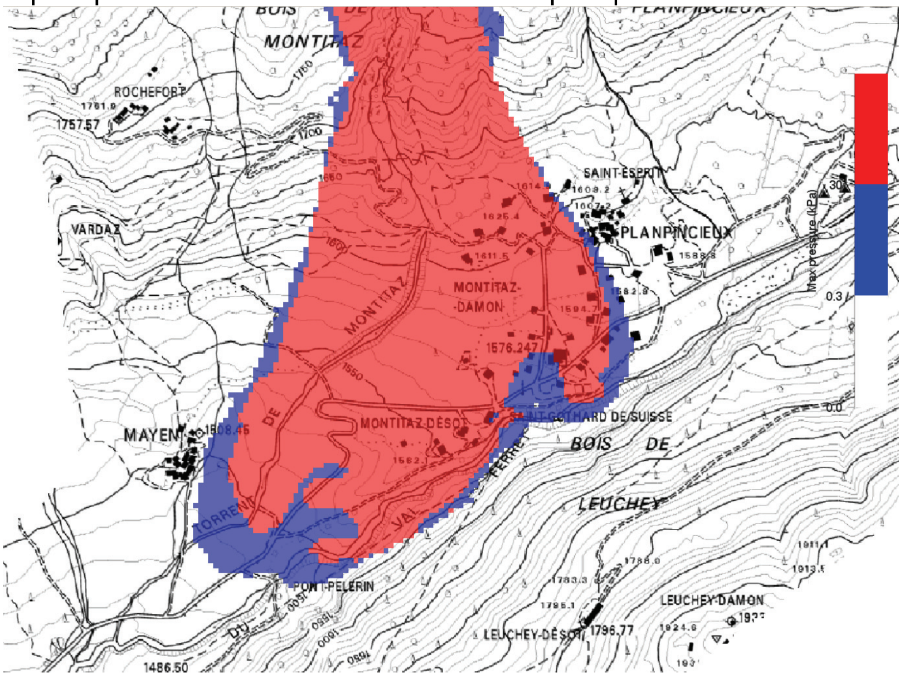

Fig. 9: Maximal pressure for scenario S3 with an ice volume of 1 million m^3 in summer (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

4.3 Investigated ice avalanche scenarios in winter

4.3.1 Ice avalanche with a volume of 20’000 m^3 in winter

The results of the simulations are given in Appendix 7, Table 3 and Figures 10, 11 and 12.

- **Simulation W1 and W2:** We think that the consequences of an ice fall with a volume of 20’000 m^3 during time periods with a rather stable snowpack is comparable to the summer situation. The release of large snow avalanches and the formation of a powerful powder avalanche is rather unlikely. The access road to Planpincieux and the village itself are not endangered for that scenario.

- **Simulation W3:** The scenario with an ice avalanche volume of 20’000 m^3 combined with fair to poor snowpack stability is considered to be the threshold that the access road and the eastern part of the village are endangered. According to the RAMMS simulation a dense flow avalanche reaches the switchback curve of the access road with an intensity of less than 30 kN/m^2. The ice avalanche erodes and triggers a snow volume of 82’000 m^3. The dense flow avalanche reaches not the old access road to Planpincieux.
- **Simulation W4:** An ice avalanche with a volume of 20’000 m^3 which flows over a poorly consolidated snowpack will entrain a snow volume of up to 180’000 m^3. The avalanche hits according to the RAMMS simulation the access road to Planpincieux and the western part of the village with intensities of more than 30 kN/m^2. The formation of a powerful powder avalanche is likely. The extent of the endangered area exceeds the hazard zones of the hazard map of 2001.

Tab. 3: Simulations results for ice avalanches from Planpincieux Glacier in winter with a release volume of 20’000 m^3

Scenario	Danger level European Avalanche Danger scale	Release volume (m^3)	Simulation volume (m^3)	Entrainment h (m)	Entrainment K (-)	Total entrainment volume (m^3)	Friction value category	Runout ratio (%)	Interpretation of simulation results	Output file
W1	1	20'000	40'000	0.4	0.2	31’000	Medium, 10y	51	Avalanche stops in the channel at an elevation of 1580 m and 200 m above the access road.	P1_20K_M10_Winter_Noflux_1_Entr1_HD1.out.gz
W2	2	20'000	40'000	0.5	0.2	37‘000	Medium, 10y	48	Avalanche stops at an elevation of 1570 m and 160 m above the access road.	P1_20K_M10_Winter_Noflux_1_Entr1_HD2.out.gz
W3	3	20'000	40'000	0.6	0.5	82‘000	Large, 10y	42	Avalanche stops at an elevation of 1518 m and reaches the switchback curve of the access road with intensities < 30 kN/m^2.	P1_20K_L10_Winter_Noflux_1_Entr1_HD3.out.gz
W4	4 or 5	20'000	40'000	1.5	1.0	178‘000	Large, 30y	41	Avalanche stops at an elevation of 1496 m. The access road and parts of Planpincieux are endangered.	P1_20K_L30_Winter_Noflux_1_Entr1_HD45.out.gz

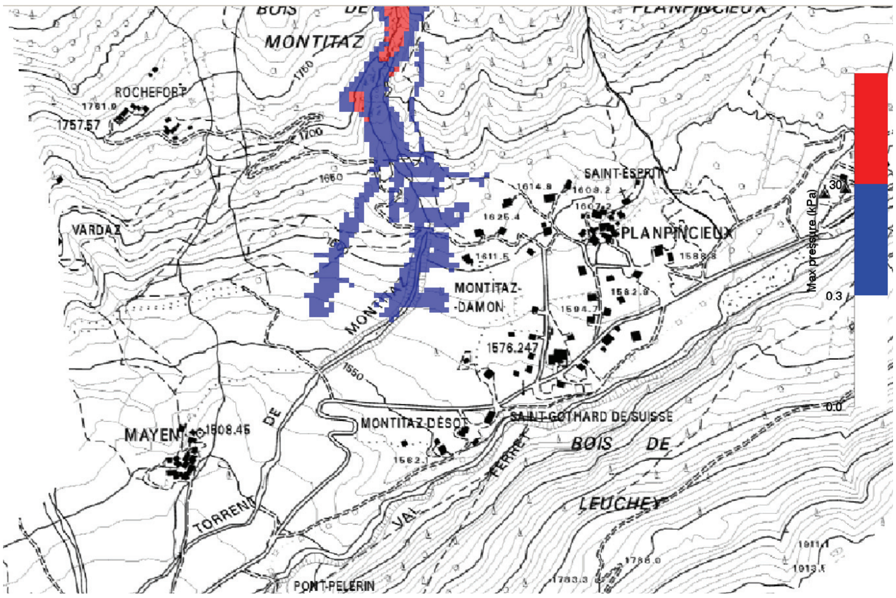

Fig. 10: Maximum pressure for scenario W2 with an ice volume of 20’000 m^3 in winter and avalanche danger level 2 (Moderate) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

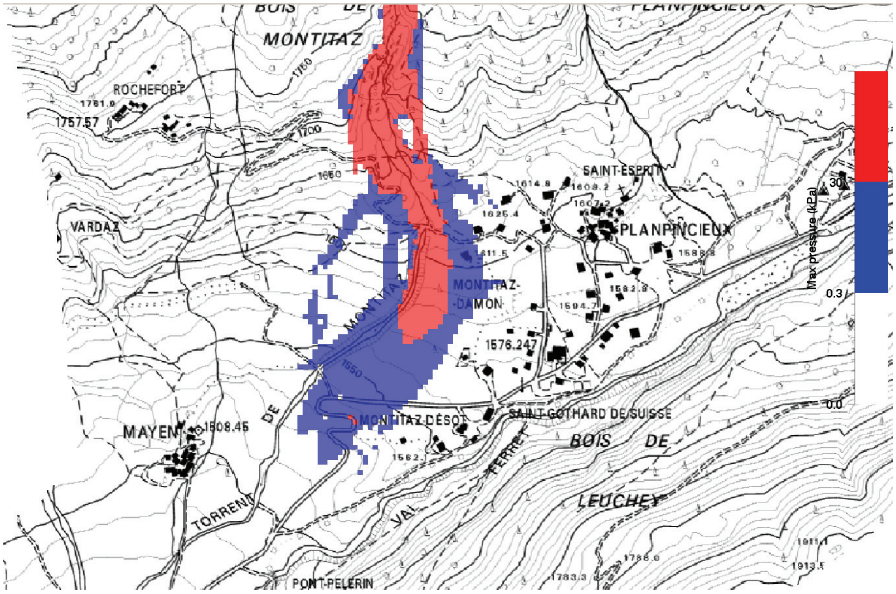

Fig. 11: Maximum pressure for scenario W3 with an ice volume of 20’000 m^3 in winter and avalanche danger level 3 (Considerable) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

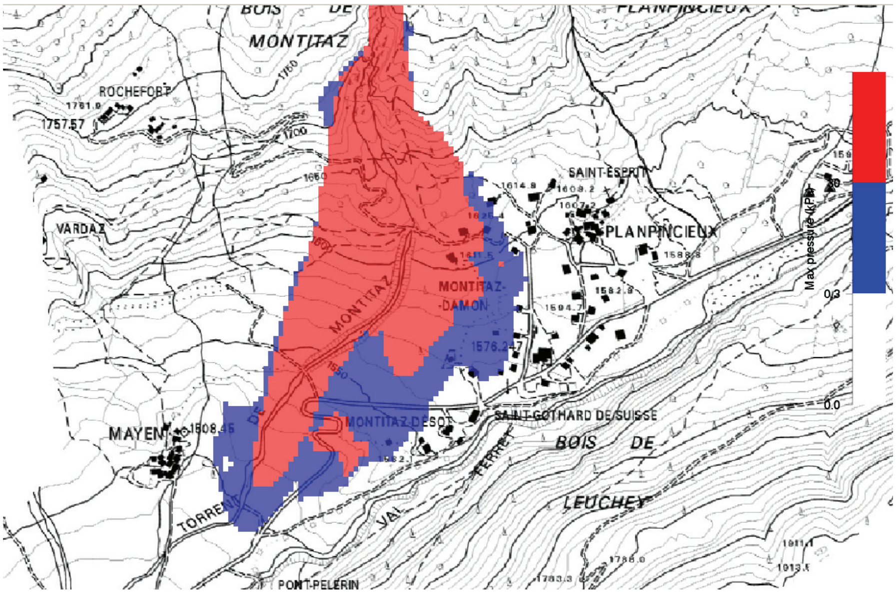

Fig. 12: Maximum pressure for scenario W4 with an ice volume of 20’000 m^3 in winter and danger level 4 or 5 (High or Very high) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

4.3.2 Ice avalanche with a volume of 200’000 m^3 in winter

The results of the simulations are given in Appendix 7, Table 4 and Figures 12, 13 and 14.

- **Simulation W5:** We think that the consequences of an ice fall with a volume of 200’000 m^3 during time periods with a rather stable snowpack is comparable to the avalanche scenario applied in 2001 by Ceriani for the elaboration of the hazard map. Compared to a snow avalanche an ice avalanche has a higher friction, but the mass is by a factor of 10 larger. Planpincieux is sheltered by a forested ridge so that a dense flow avalanche reaches only the peripheral area of the village. Planpincieux and the old access road will however be hit by the powder part.
- **Simulation W6:** The combination of an icefall with a volume of 200’000 m^3 combined with fair to poor snowpack stability results in an avalanche which entrains or triggers an additional snow volume of 128’000 m^3. The consequences of simulation W6 are comparable

with simulation W5. The dense flow avalanche also reaches the old access road to Planpincieux with a high intensity.

- **Simulation W7:** An ice avalanche with a volume of 200'000 m^3 which flows over a poorly consolidated snowpack will erode or trigger a snow volume of up to 314'000 m^3. According to the RAMMS simulation, the avalanche hits the access road to Planpincieux and the parts of the village with intensities of more than 30 kN/m^2. The formation of a powerful powder avalanche is likely. The extent of the endangered area by far exceeds the hazard zones of the hazard map of 2001.

Tab. 4: Simulation results for ice avalanches from Planpincieux Glacier in winter with a release volume of 200'000 m^3

Scenario	Danger level European Avalanche Danger scale	Release volume (m^3)	Simulation volume (m^3)	Entrainment		Total entrainment volume (m^3)	Friction value category	Runout ratio (%)	Interpretation of simulation results	Output file
				h (m)	K (-)					
W5	1	200'000	300'000	0.5	0.2	87'000	Large, 30y	43	Avalanche stops at an elevation of 1496 m and hits the access road with an intensity >30 kN/m^2. The old road is only partly hit.	P1_200K_L30_Winter_1_noflux2_HD1_20m.out.gz
W6	2 or 3	200'000	300'000	0.6	1.0	128'000	Large, 30y	40	Avalanche stops at an elevation of 1488 m and hits the access road and the old road with an intensity >30 kN/m^2. Planpincieux is hit with an intensity <30 kN/m^2.	P1_200K_L30_Winter_1_noflux2_HD23_20m.av2
W7	4 or 5	200'000	300'000	1.5	1.0	314'000	Large, 100y	39	Avalanche stops at an elevation of 1480 m. The access road and parts of Planpincieux are endangered with an intensity >30 kN/m^2.	P1_200K_L100_Winter_1_noflux2_HD45_20m.av2

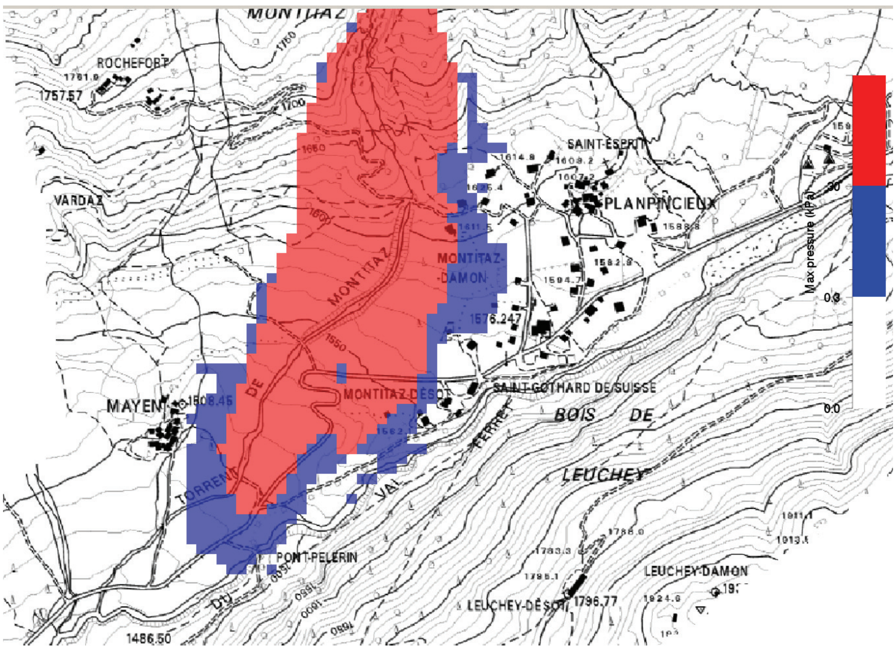

Fig. 13: Maximum pressure for scenario W5 with an ice volume of 200'000 m^3 in winter and avalanche danger level 1 (Low) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

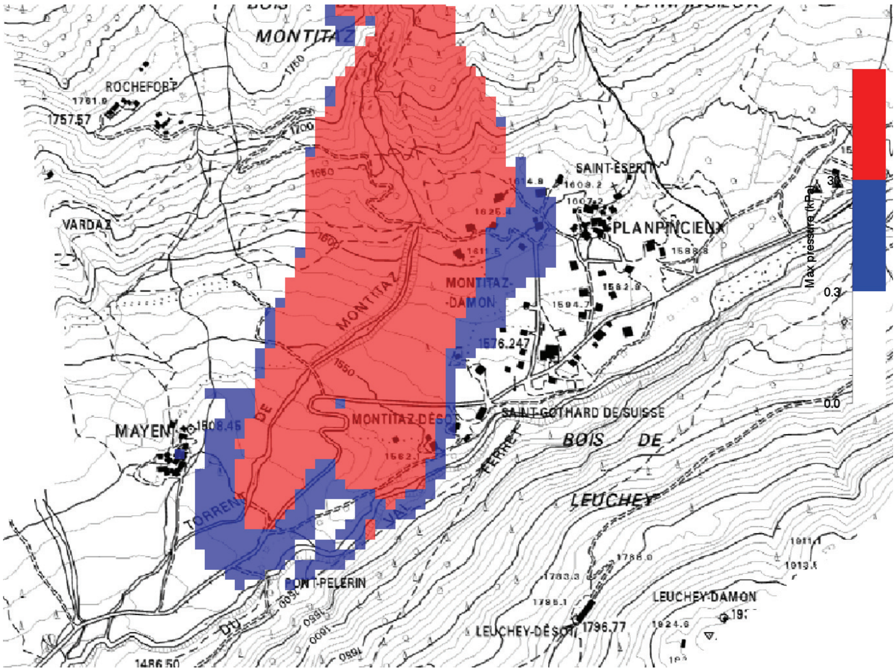

Fig. 14: Maximal pressure for scenario W6 with an ice volume of 200’000 m^3 in winter and avalanche danger level 2 or 3 (Moderate or Considerable) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

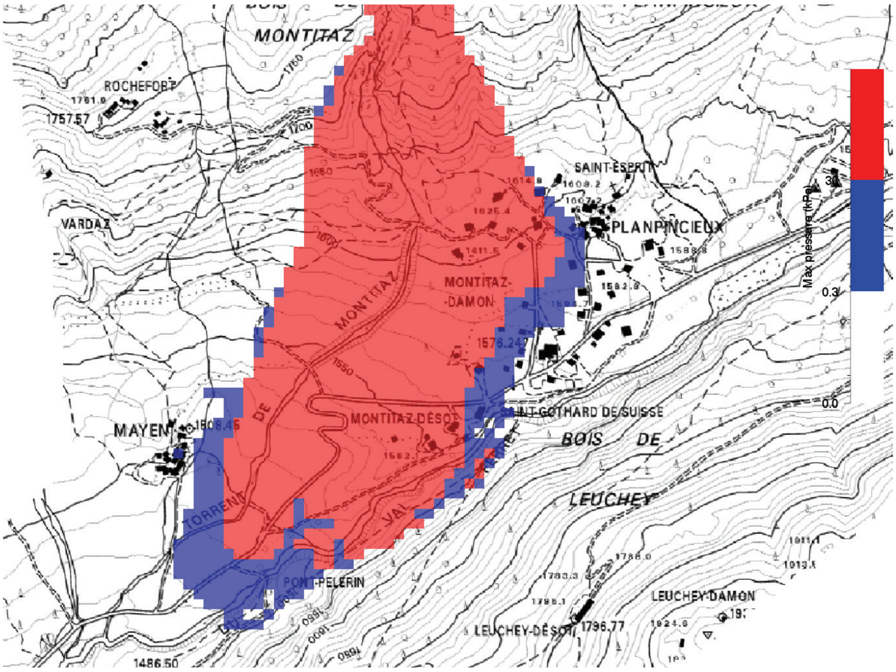

Fig. 15: Maximum pressure for scenario W7 with an ice volume of 200’000 m^3 in winter and avalanche danger level 4 or 5 (High or Very high)(Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

4.3.3 Ice avalanche with a volume of 1 million m^3 in winter

The results of the simulations are given in Appendix 7, Table 5 and Figures 16 and 17.

- **Simulations W8, W9 and W10:** An ice avalanche with a volume of 1 million m^3 in winter is a very extreme event regardless of the level of snowpack stability. An ice volume of 1 million m^3 will erode most of the snowpack along the track. The avalanche mass will be additionally increased by entrained debris and trees. The formation of a very powerful powder avalanche is likely. The extent of the endangered area by far exceeds the hazard zones of the hazard map of 2001. All the area from the exit of Entrèves up to the eastern end of Planpincieux will be endangered.

- The expected deposit height at the bottom of the valley is expected to be up to 30 m. That can dam the river “Doire du Val Ferret” and cause a lake with the danger of flooding if the dam breaks.

Tab. 5: Simulation results for ice avalanches from Planpincieux Glacier in winter with a release volume of 1 million m^3

Scenario	Danger level European Avalanche Danger scale	Release volume (m^3)	Simulation volume (m^3)	Entrainment h (m)	Entrainment K (-)	Total entrainment volume (m^3)	Friction value category	Runout ratio (%)	Interpretation of simulation results	Output file
W8	1	1.0 M	1.2 M	0.6	0.2	130’000	Large, 30y	38	Avalanche stops at an elevation of 1460 m and covers the bottom of Val Ferret on a length of >1.4 km. The maximum deposit height is ca. 20 m. We think that the entrained snow mass is underestimated.	P1_1Mio_L30_Winter_20m_noflux_H1.out.gz
W9	2 or 3	1.0 M	1.2 M	1.0	1.0	227‘000	Large, 100y	36	Avalanche stops at an elevation of 1435 m and covers the bottom of Val Ferret on a length of >1.5 km. The maximum deposit height is ca. 25 m.	P1_1Mio_L100_Winter_20m_noflux_H23.out.gz
W10	4 or 5	1.0 M	1.2 M	1.5	1.0	338’000	Large, 300y	35	Avalanche stops at an elevation of 1420 m and covers the bottom of Val Ferret on a length of >1.6 km. The maximum deposit height is ca. 30 m.	P1_1Mio_L300_Winter_20m_noflux_H45.out.gz

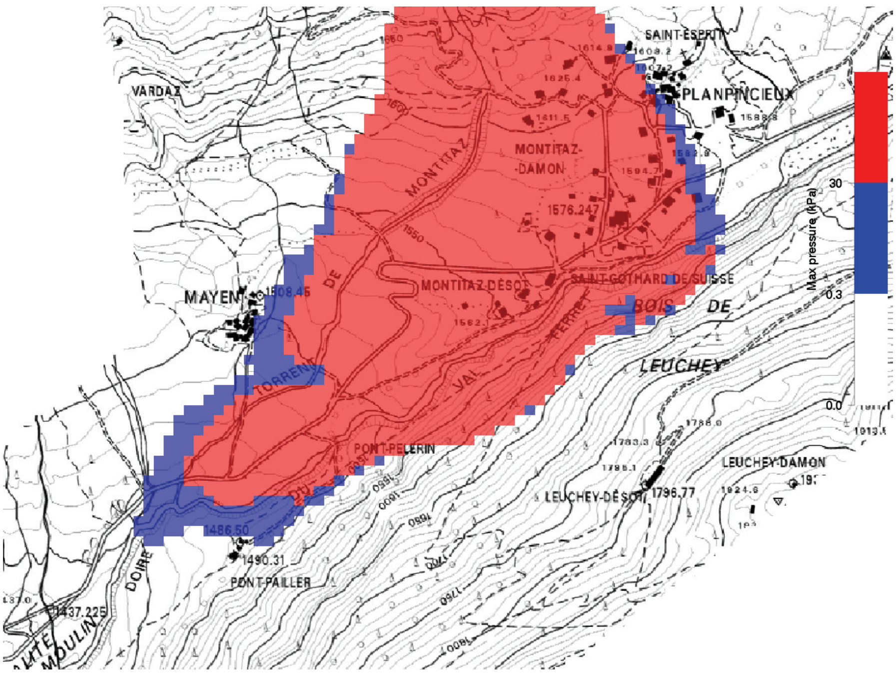

Fig. 16: Maximum pressure for scenario W8 with an ice volume of 1 million m^3 in winter and avalanche danger level 1 (Low) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

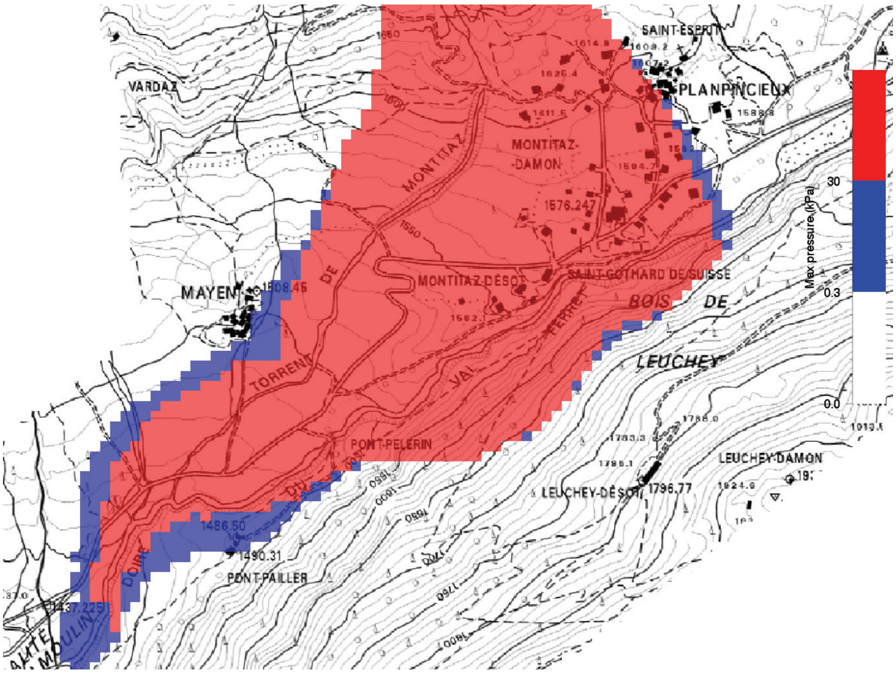

Fig. 17: Maximum pressure for scenario W10 with an ice volume of 1 million m^3 in winter and avalanche danger level 4 or 5 (High or Very high) (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

4.3.4 Powder snow avalanche calculations

For the summer scenarios and the winter scenario W3 we performed powder snow avalanche calculations with AVAL-1D. AVAL-1D is a one dimensional numerical avalanche dynamics program developed by the WSL Institute for Snow and Avalanche Research (SLF) in Davos (Christen et al. 2002). The program calculates runout distances, velocities and pressures due to dense flow and powder snow avalanches. We used the powder snow avalanche calculation module. We applied for the simulations a suspension rate of 5%. If, for example, an ice volume of 200’000 m^3 breaks off a volume of 10’000 m^3 (around 9000 t) forms the powder snow avalanche. The calculation results are summarized in Tab. 6. Pressure profiles of the simulations are given in Appendix 9. As AVAL-1D is a one dimensional calculation program, variation of the flow width along the track cannot be considered. With AVAL-1D the pressures are therefore overestimated and have to be reduced in the runout zone of a powder snow avalanche according to experience by a factor of 2 to 4.

Tab. 6: Powder snow avalanche calculations with AVAL-1D

Scenario		**S1**	**W3**	**S2**	**S3**
Release volume		20’000 m^3	20’000 m^3	200’000 m^3	1 million m^3
Entrainment		no	yes	no	no
Max. pressure	P_{max} at 1550 m	0.4 kN/m^2	1.8 kN/m^2	6.9 kN/m^2	33.0 kN/m^2
Corrected max. pressure	$P_{max,corr}$ at 1550 m	0.2 kN/m^2	0.9 kN/m^2	0.2 kN/m^2	16.5 kN/m^2
Height suspension cloud	H_{Susp} at 1550 m	100 m	100 m	110 m	110 m
Max. pressure	P_{max} 1500 m (road)	0.4 kN/m^2	1.3 kN/m^2	6.9 kN/m^2	24.9 kN/m^2
Corrected max. pressure	$P_{max,corr}$ 1500 m (road)	0.2 kN/m^2	0.5 kN/m^2	2.3 kN/m^2	8.3 kN/m^2
Max. pressure	P_{max} 1430 m	0.1 kN/m^2	0.4 kN/m^2	1.2 kN/m^2	2.9 kN/m^2
Corrected max. pressure	$P_{max,corr}$ 1430 m	-	0.1 kN/m^2	0.3 kN/m^2	0.7 kN/m^2
Height suspension cloud	H_{Susp} at 1430 m	120 m	170 m	170 m	200 m

The calculations show that for the extreme scenarios S2 and S3 the pressure of the powder cloud is large (>2.3 kN/m^2) at the location of the access road to Planpincieux. Towards La Palud the pressure decreases to less than 0.7 kN/m^2. The calculation for the scenario W3 (ice volume 20'000 m^3 and avalanche danger level 3 [Considerable]) gives a pressure of 0.5 kN/m^2 at the location of the access road to Planpincieux. The powder snow avalanche calculation for an extreme ice avalanche with 1 million m^3 combined with large entrainment does not provide sound results.

4.4 Verification of ice avalanche simulations

The simulation of ice avalanches with RAMMS involves rather large uncertainties. There are no dynamic models explicitly developed for the calculation of ice avalanches. To check the plausibility of the calculations, we double-checked the results with the one dimensional calculation model AVAL-1D as well as with the runout ratio (Alean 1985) of the different simulations.

AVAL-1D

We back-calculated the summer scenarios S1 (ice volume 20'000 m^3) and S2 (ice volume 200'000 m^3) with the dense flow avalanche calculation module of AVAL-1D (Tab. 6 and Fig. 18). The applied avalanche track is shown in Appendix 2. AVAL-1D was applied several times in the past to simulate ice avalanches (Dalban Canassy et al. 2011). The runout distance for scenario S1 calculated with AVAL-1D is a little shorter compared to the RAMMS simulation. However the simulation confirms that the access road will not be hit if an ice volume of 20'000 m^3 releases in summer. For scenario S2 AVAL-1D simulates a runout distance which is around 150 m shorter compared to the RAMMS simulation. However the AVAL-1D simulation confirms that the access road is in the reach of an ice avalanche with a volume of 200'000 m^3.

Tab. 6: Simulation of scenarios S1 and S2 with AVAL-1D

Scenario	Calculation volume	Unchannelled		Channelled		Elevation at end of runout	
		μ	ξ	μ	ξ	AVAL-1D	RAMMS
S1	41'000 m^3	0.25	1000	0.35	800	1772 m	1700 m
S2	307'000 m^3	0.25	1750	0.35	1000	1547 m	1515 m

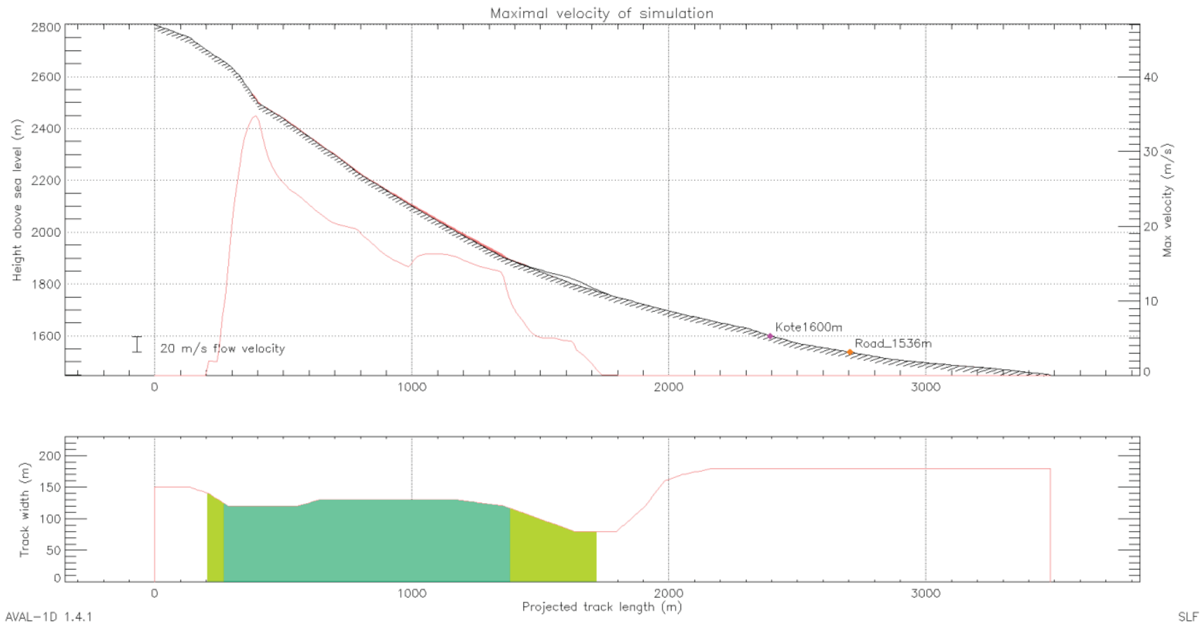

Fig. 18.1: Maximum avalanche velocity of the AVAL-1D simulation of the summer scenario S1 with a volume of 20'000 m^3.

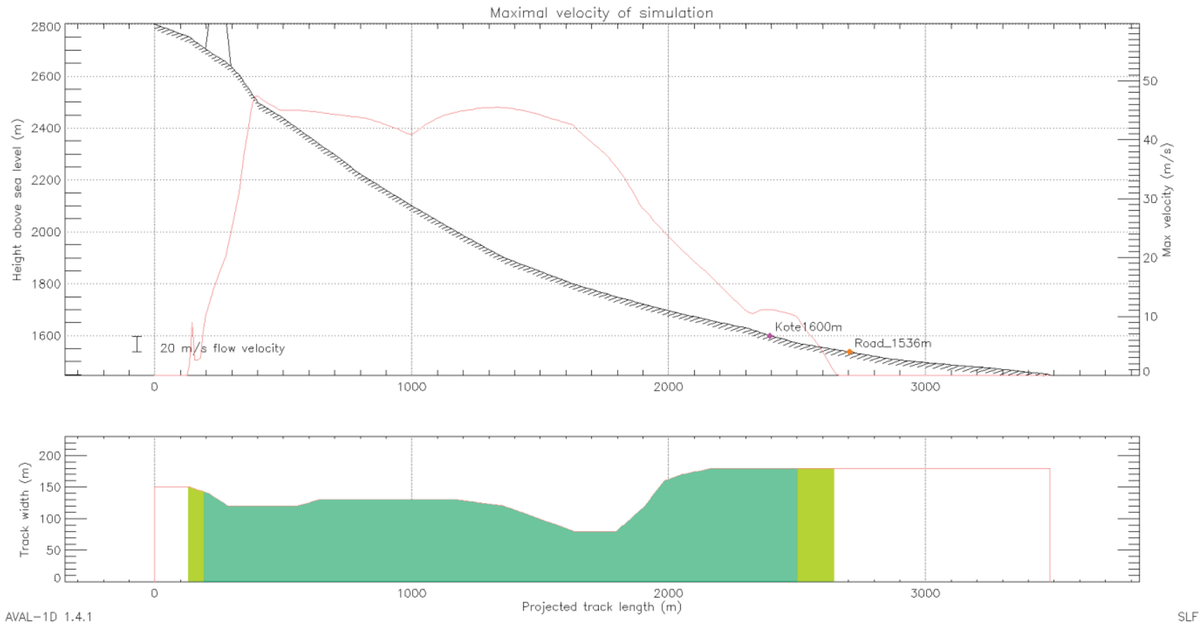

Fig. 18.2: Maximum avalanche velocity of the AVAL-1D simulation of the summer scenario S2 with a volume of 200'000 m^3.

Runout ratio

Alean (1985) demonstrated that the runout of an ice avalanches can be described with the runout ratio. It is the slope of a line which starts at the top of the zone of release and ends at the farthest point of the deposit. Alean evaluated the runout ratio of many ice avalanches and introduced several criteria to group the runout ratio in regard to topographical parameters and the volume of the ice avalanche (Fig. 19). The minimum runout ratio found for volumes larger than 1 million m^3 (criteria A1 in Fig. 19) is 0.31. Criteria D1 in Figure 19 is valid for avalanche volumes between 5'000 and 100'000 m^3 and track lengths of less than 1500 m. The track lengths of the investigated avalanches are longer than 1500 m and the elevation differences are smaller than 1200 m. The runout ratios of the avalanches calculated with RAMMS are shown in Figure 19. The runout ratios are situated in between the criterias A1 and D1 which is reasonable. The minimum runout ratio of the most extreme scenario W10 is with 0.35 larger than the proposed minimum ratio of 0.31 which is plausible.

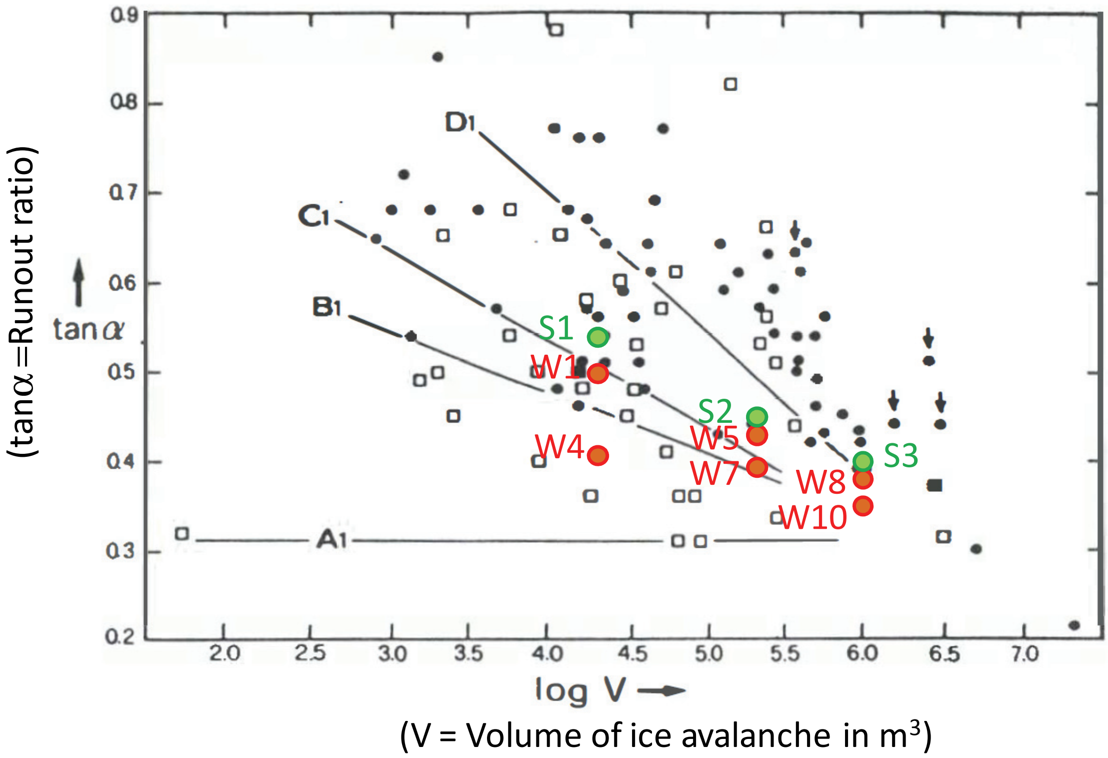

Fig. 19: Grouping of runout ratios (tan α) of ice avalanches with sets of terrain parameters according to Alean (1985). Additionally the runout ratio of the simulated scenarios in summer (S1 – S3) and winter (W1 – W3) are shown. A1, B1, C1 and D1 are sets of criteria proposed by Alean. Only symbols of avalanches which do not satisfy certain sets of criteria appear below the corresponding line. Squares show avalanches with more than 60% of the path over firn with no or few crevasses. Solid squares represent mixed ice/rock avalanches. Solid circles represent other ice avalanches. Arrows point to avalanches which descended over strongly terraced terrain.

4.5 Snow avalanches

We calculated a 100-year snow avalanche from the release area Glacier Planpincieux no. 1 and 2 (Figs. 20 and 21; Appendices 1 and 8). If the snowpack is rather unstable it is most likely that an ice avalanche from Planpincieux Glacier releases a snow avalanche in the release area no. 2. We assumed for the calculations a mean fracture depth of 1.3 m. The resulting avalanche volume is around 300'000 m^3. The maximum runout of the avalanche simulated with RAMMS corresponds relatively well with the existing hazard map (Ceriani 2001). The avalanche flow is along the main avalanche axis of the torrent Montitaz and the runout distance is around 100 m longer compared to the hazard map. However, along the secondary flow axis into the direction of Montitaz-Desot, the runout distance is around 50 m shorter. The RAMMS simulations show that the centre of Planpincieux is partly protected by the forested terrain ridge above the village. The snow masses from release zone no. 2 flow mostly along the Montitaz avalanche track and along the Planpincieux avalanche track situated either west or east of the village. The runout of the avalanche is a little smaller compared to the extreme ice avalanche scenarios.

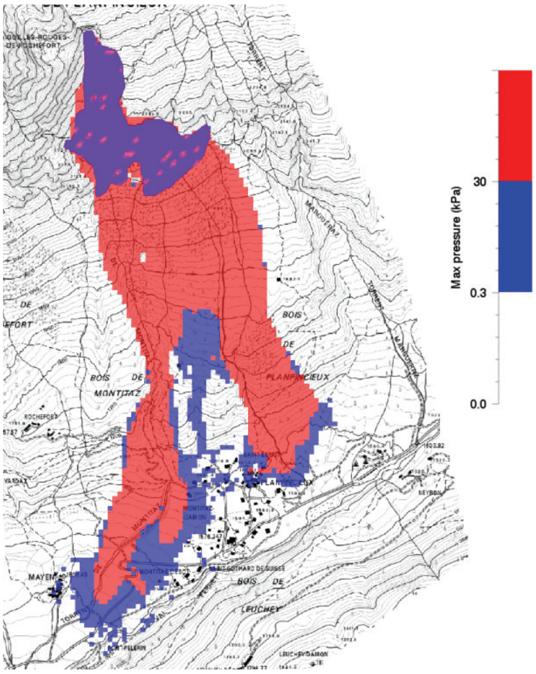

Fig. 20: Maximum pressure of the RAMMS simulation of a snow avalanche from the release zone no. 2 (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

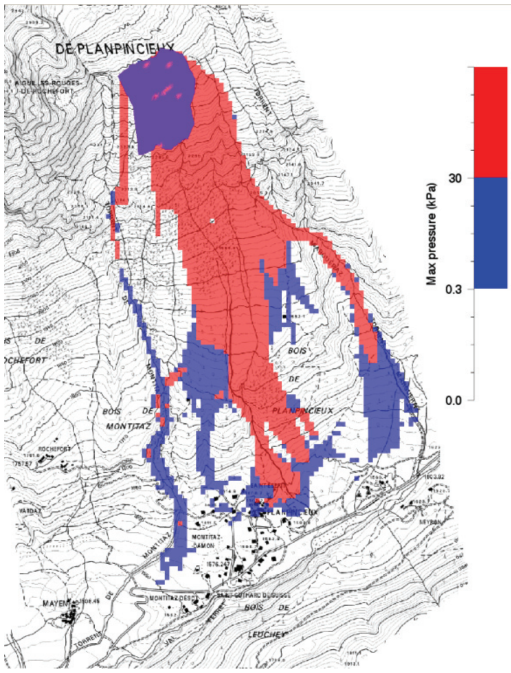

Fig. 21: Maximum pressure of the RAMMS simulation of a snow avalanche from the release zone no. 1 (Red = impact pressure > 30 kN/m^2 and Blue = impact pressure 30…0.3 kN/m^2).

4.6 Interpretation

- We think that the runout distances calculated with RAMMS are reasonable. It is unquestionable that an ice avalanche with a volume of 200’000 m^3 or larger endangers the access road to Planpincieux independent of the season. We assume that the accuracy of the RAMMS simulations might be in a range of +/- 100 m. Therefore the calculated runout distances have to be interpreted very carefully. It is important to state that the effect of powder snow avalanches which is very difficult to assess is not considered in the RAMMS simulations.
- In summer, when the avalanche track is free of snow, an ice avalanche with a volume of 20’000 m^3 does not endanger the access road to Planpincieux. If the volume is 200’000 m^3 or larger the access road and parts of Planpincieux are endangered.
- In winter an ice avalanche volume of 20’000 m^3 in combination with a fair to poor snowpack (corresponding to an avalanche danger level “Considerable”) is according to our evaluation the threshold that the access road to Planpincieux is endangered. For the more extreme scenarios the access road and parts of Planpincieux are in the reach of avalanches. The centre of Planpincieux is sheltered by a forested ridge (Bois de Planpincieux) so that dense flow avalanches endanger especially the peripheral areas west and east of the centre. However, if the avalanche volumes are big enough the centre of Planpincieux will be hit by the powder part.
- An icefall with a volume of 1 million m^3 is a very serious event which requires comprehensive safety measures in the Val Ferret. Such an avalanche can block the river “Doire du Val Ferret” with the consequence that an artificial lake can build up with the potential risk of a flash flood.
- The calculated time from the break-off of an ice avalanche until the avalanche reaches the access road to the Val Ferret is according to the simulations between 50 and 120 seconds.
- Compared to an icefall from the Whymper Glacier we think that the uncertainties in regard to the hazard assessment are somewhat smaller in the Montitaz avalanche

track below the Planpincieux Glacier because the flow direction is better defined. All avalanching snow flows along the Montitaz channel. On the other side, the avalanche track is shorter and has a smaller ground roughness (no crevassed glaciers, no terraces). Therefore already small avalanches along the Montitaz avalanche track will reach the access road more easily than along the different avalanche tracks below the Whymper Glacier.

5 Safety concept

5.1 Introduction

The goal of the safety concept is to provide the organisation, which is responsible for the safety in the Val Ferret with a procedure to define the necessary safety measures depending on the local avalanche hazard in combination with the hazard of an ice avalanche from the Planpincieux glacier. The proposed safety concept is based on the safety concept developed in the SLF report on the Whymper Glacier (SLF, 2009). The input values are the following ones:

A. Local avalanche danger:
The extent of the local avalanche danger depends on several factors, namely:

- the snowpack stability, which is determined by strength and stress in the individual snow layers.
- the triggering probability, which depends on the natural snowpack stability and can be increased by human activity (skiers, explosions etc.) or impacts of ice avalanches. The likelihood of an avalanche being triggered (and therefore the avalanche danger) is low if the snowpack stability is high and vice versa.
- the number and extent of dangerous slopes.
- the size and the type of the expected avalanches (e.g. dense or powder snow avalsanches); in other words, the fracture depth and the fracture area of the released snow masses (avalanche volume).

These factors have to be assessed in a specific situation on the basis of the actual and future weather conditions (snow height, new snow, wind, temperature, radiation), information about the snowpack (snow stratigraphy, wetness of the snowpack, property of the surface), regional avalanche bulletin, local avalanche observations (also avalanche deposits in the track) and other observations from experienced and knowledgeable people from the area. The result of the hazard assessment is a local danger level (see App. 4). It is not possible to "measure" the local danger level directly, but it has to be assessed by expert judgement. Because the starting zones below and on the Planpincieux Glacier are not well accessible in winter, especially in periods of imminent avalanche danger, information from other areas such as the Funivia del Monte Bianco (Pavillon, Rif. Torino) might be useful. The leaflet «Guide pratique: Le travail au sein du service des avalanches: organisation, evaluation du danger local d'avalanche et documentation» (Stoffel and Schweizer, 2007) describes the organisation of a local avalanche service, the procedure to determine the local avalanche hazard and the necessary documentation.
An important point is that the impact of an ice avalanche on the snowpack can generate a very large surcharge, which is much bigger than the classical additional load such as those considered in the avalanche bulletin (e.g. skier, explosion). To take this into account we propose to stay about 3 days longer at a hazard level 4 ("High") or 5 ("Very high") than necessary according to the natural snowpack stability. Especially the situation when a weak layer is covered by a heavy and thick snow slab has to be assessed carefully. With the impact of an ice avalanche it might be possible that a failure can occur deep in the snowpack and consequently a huge avalanche could be released. In such situations the hazard level has to be determined very carefully.

We recommend assessing the local avalanche danger in the Val Ferret and not working with the danger level of the regional avalanche bulletin issued for a larger region in the Aosta valley (e.g. zone D "alpine ridge" of the bulletin). The danger level of a regional avalanche bulletin does not cover the local features such as snow drift zones, former avalanche releases or avalanche deposits which can be important for deciding on local safety measures. If the regional avalanche bulletin is applied in the safety concept (Tab. 7) the most conservative safety measures have to be taken.

B. Ice avalanche volume
The possible ice avalanche volume in a certain time period can be assessed with a monitoring system (visual observations of cracks and crevasses, installation of an automatic camera, analysis of photos, displacement measurements). In the safety concept we have considered three different ice volumes:

- 20’000 m^3: These are very small ice avalanches from the front of the Planpincieux Glacier which are unforeseeable and which can occur at any time.
- 200’000 m^3: A larger ice segment of the glacier front breaks away.
- 1 million m^3: Such an ice volume corresponds to the total failure of the unstable mass of the Planpincieux Glacier. Such an event was not observed in the Val Ferret in the last decades.

5.2 Schedule

In the following Table 7 and Figure 22 we propose safety measures in relation to different combinations of ice volumes and local avalanche danger levels. Table 7 has to be used in combination with the safety plan of Figure 22 (see also App. 3). The recommendations cover the hazard of ice avalanches in summer as well as dense flow avalanches and powder snow avalanches triggered by ice avalanches. We defined in the safety plan the following 5 different zones:

- **Zone 1:** Zone 1 covers the part of the Montitaz avalanche track with the highest risk. Small avalanches stop in Zone 1. The access path to the hamlet "Rochefort" is situated in Zone 1. Zone 1 corresponds approximately to the red zone of the hazard map of Planpincieux (Ceriani, 2001).
- **Zone 2:** Zone 2 includes the yellow zone of the hazard map of Planpincieux (Ceriani, 2001). Zone 2 covers the two switchback curves and the following straight section of the access road to Planpincieux. The most exposed buildings in Montitaz-Damon are situated in that zone. The old access road to Planpincieux is protected by a terrain ridge and therefore not included in zone 2 (Fig. 23).
- **Zone 3:** Zone 3 covers the blue zone of the hazard map of Planpincieux (Ceriani, 2001) along the Montitaz avalanche track. The old road to Planpincieux and some more buildings of Montitaz-Damon and Montitaz-Desot are situated in zone 3.
- **Zone 4:** Zone 4 includes parts of the village of Planpincieux, which are situated in a blue hazard zone (Ceriani, 2001). Zone 4 involves the periphery of the main avalanche flow directions and covers the hazard due to the impacts of laterally out-breaking avalanche fingers and powder snow avalanche.
- **Zone 5:** Zone 5 covers the entire blue zone of the hazard map (Ceriani, 2001) and the adjacent area towards La Palud (Fig. 22).

Tab. 7: Safety concept for Planpincieux and the access road from La Palud to Planpincieux with recommendations for temporary measures during summer and winter in regard to ice avalanches from the Planpincieux Glacier.

	Local avalanche danger level Val Ferret:	Ice avalanche volume Planpincieux Glacier: 20'000 m³	200'000 m³	1 million m³
Sommer	None (track free of snow)	Exclusion of zone 1	Exclusion of zones 1 and 2. Curfew zone 3[c].	Exclusion[a] of zones 1, 2, 3, 4 and 5.
Winter	1 Low	Exclusion of zone 1	Exclusion of zones 1, 2 and 3. Curfew zone 4.	Exclusion[a] of zones 1, 2, 3, 4 and 5.
	2 Moderate	Exclusion of zone 1	Exclusion of zones 1, 2 and 3. Curfew zone 4.	Exclusion[a] of zones 1, 2, 3, 4 and 5.
	3 Considerable	Exclusion of zones 1 and 2[b]	Exclusion of zones 1, 2, 3 and 4. Curfew zone 5.	Exclusion[a] of zones 1, 2, 3, 4 and 5.
	4 High	Exclusion of zones 1, 2 and 3. Curfew zone 4	Exclusion[a] of zones 1, 2, 3, 4 and 5.	Exclusion[a] of zones 1, 2, 3, 4 and 5.
	5 Very high	Exclusion[a] of zones 1, 2, 3, 4 and 5.	Exclusion of zones 1, 2, 3, 4 and 5.	Exclusion[a] of zones 1, 2, 3, 4 and 5.

[a] Closure of the Val Ferret at the exit of La Palud.
[b] Exclusion of zone 2 only if the spontaneous release of medium-sized to large avalanches is possible (danger level considerable "3+").
[c] A controlled and limited access on the old road might be possible (see chapter 5.4).

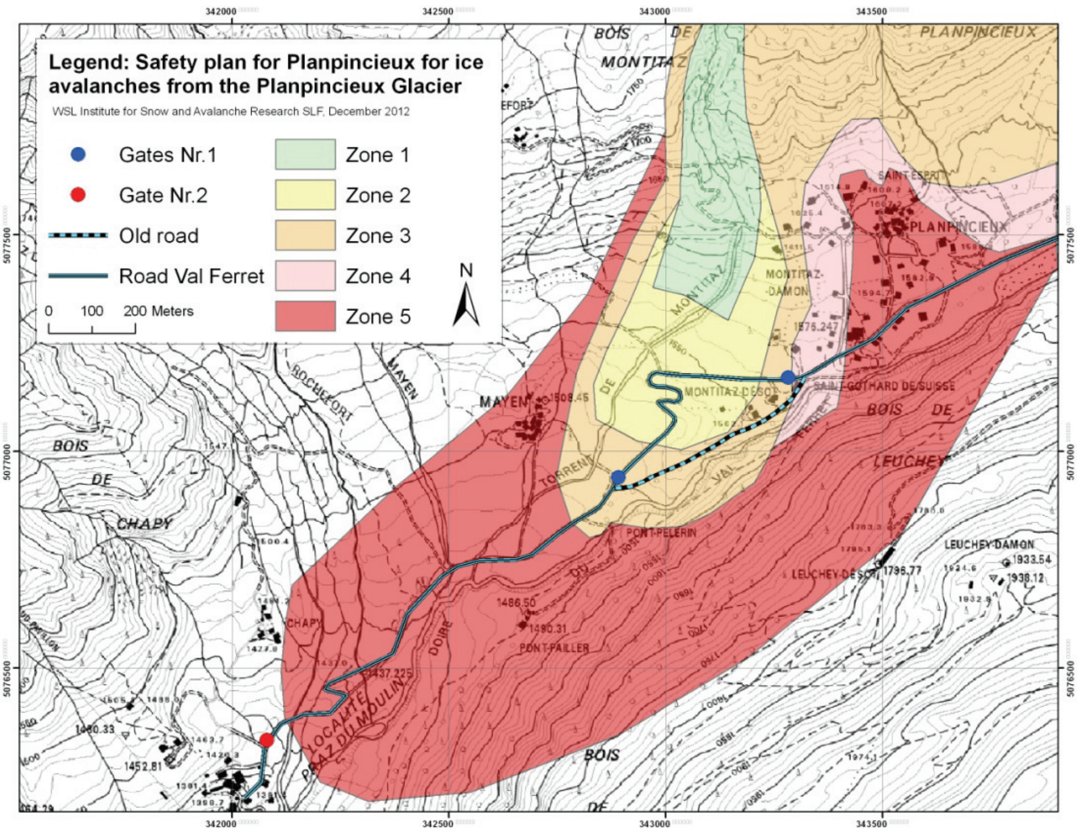

Fig. 22: Safety plan for Planpinceux for ice avalanches from the Planpinceux Glacier (Important remark: the area is also endangered by snow avalanches from other release areas. These avalanches are not considered in the safety plan!).

For the practical application of the safety plan the following points should be considered:

- **Exclusion** of a certain zone means that it is not allowed to stay in this zone (neither inside nor outside of buildings). The access to the zone has to be prevented and the zone has to be evacuated.
- If the zones 1 to 5 are evacuated we propose to close the access to the Val Ferret at La Palud (see Fig. 22).
- In certain scenarios when only a minor powder snow avalanche pressure has to be expected in the centre of Planpincieux, it is possible that the inhabitants can stay in their homes (we call this **"curfew"**).
- The safety concept was developed for the **valley bottom** of the Val Ferret. The safety concept cannot be applied for the hillside below the Planpincieux Glacier. Already a small ice avalanche of less than 20'000 m^3 can be dangerous on the hillside.
- The safety concept was elaborated for ice avalanches from the Planpincieux Glacier. It has to be considered that the safety concept was not developed to cover the hazard from snow avalanches without the influence of ice avalanches. For such situations other release areas and other avalanche tracks e.g. from the Mont de la Saxe which are not considered in the safety concept might be decisive for deciding on safety measures. Until now the Val Ferret was closed if the danger level was "High" or "Very high" (only snow avalanches).
- The safety concept was developed with the local avalanche danger level in the Val Ferret as the basic input parameter. However if the regional avalanche danger level is applied the most conservative safety measures proposed in Table 7 have to be taken (e.g. ice avalanche volume 20'000 m^3 and danger level "Considerable": exclusion of zone 1 and 2).

5.3 Application of the safety concept for ice avalanche volumes of 20'000 m^3 and danger level "considerable"

In the safety concept of Table 7 we propose to exclude the zone 1 and possibly the zone 2 for ice avalanche volumes of 20'000 m^3 and danger level "Considerable". The decision whether only the zone 1 or the zones 1 and 2 have to be excluded depends on the local avalanche danger and especially on the possible avalanche volume. At danger level 3 "considerable" the following two situations can be distinguished:

- **Danger level "3-": Release of large avalanches is rather unlikely**. Avalanches can be triggered with low additional loads mainly on steep slopes. Also remote triggering from well outside the starting zone is possible. This is a typical situation for "skier-triggered avalanches" when the snowpack contains a critical weak layer. Snow avalanches that are released by small ice avalanches (≤ 20'000 m^3), will probably stop at this danger level in zone 1. Taking into account that the probability for the release of a small ice avalanche is additionally rather small the risk of death is, in our view, acceptable in zone 2 if certain additional safety measures are taken (see chapter 5.5). We estimate that on 70% of the days with a danger level "Considerable" the level "3-" might prevail.

- **Danger level "3+": Release of medium-sized and large avalanches is possible**. Some medium-sized and occasionally large spontaneously releasing avalanches are possible. The snowpack stability is somewhat lower compared to the danger level "3-". The risk cannot be neglected that a small ice avalanche can release a large snow avalanche, which can reach zone 2. The dense part of snow avalanches with a fracture depth of 0.6 m and a volume of 50'000 m^3 will stop about 200 m above the valley road. However, the powder part of such an avalanche combined with the ice mass can develop an avalanche pressure of more than 0.5 kN/m^2 in zone 2. We estimate that on 30% of the days with a danger level "Considerable" the level "3+" might prevail.

To assess whether it is a level of “Considerable” “3-“ or an elevated level “3+” is not simple, requires much experience and a strong permanent engagement. There exists no direct method to determine such a level, but it has to be assessed by an expert judgement. The following points are important:

1. Observation of the avalanche activity
Daily observations and recordings of the snow and ice avalanche activity in the area of the Planpincieux Glacier are essential. The analysis of snow and weather data with observed avalanche activity in the past allows a better understanding of the problem. Information on the avalanche activity from nearby ski areas or from local experts should be considered. If e.g. there is a high activity of off-piste skiing around Punta Helbronner and no avalanches are released this is a sign that large avalanches are unlikely and that the danger level is “3-“.

2. State of the snow cover in the release area and release conditions
The release of medium-sized or large snow avalanches by an ice avalanche depends mainly on the following criteria:

Indications for “3+” (Spontaneous release of medium-sized and large avalanches is possible)	**Indications for “3–”** (Release of large avalanches is rather unlikely)
- new snow situations (new snow depth > 0.5 m) - weak layers up to 1.5-2 m deep in the snow cover which might be activated by the impact of an ice avalanche. - large snow heights > 1.5 m - natural avalanche activity in the area - partly wet snowpack (daytime warming) - observation of medium-sized or large avalanches in the area - instabilities on large areas (>100 m × 100 m, according to observations)	- new snow situations (new snow depth < 0.5 m) - shallow snow cover - storm periods with no or only few new snow - persistent weak layers not too deep in the snowpack (long period with danger level 3) - no natural avalanche activity in the area - poor to fair snowpack stability - starting zones below the Planpincieux Glacier are mainly discharged - instabilities on small areas (<100 m × 100 m, according to observations)

3. State of the snow cover in the avalanche track and runout
Medium-sized or large avalanches will only reach the valley bottom if the flow conditions along the avalanche track are favourable. The following criteria have to be considered:

Indications for “3+”	**Indications for “3–”**
- large snow heights - dry and light snow along the whole avalanche track (small friction and increase of avalanche mass) - small ground roughness because of former avalanche events (filled crevasses, smoothed out ground roughness) - partly wet snowpack (daytime warming) along the whole avalanche track (increase of avalanche mass)	- shallow snow cover - high ground roughness - open crevasses (loss of mass) - well bonded snow cover along the avalanche track (only small snow entrainment) - partly wet snowpack in the runout zone (ca. <2000 m; increased friction will prevent long runout distances)

5.4 Application of the safety concept for ice avalanche volumes of 200’000 m³ in summer

In the safety concept (Tab. 7) we propose to exclude for an ice avalanche in summer with a volume of 200’000 m³ the zones 1 and 2. Further we propose to foresee a curfew in zone 3. The dense part of the ice avalanche stops most likely in the zones 1 and 2. The current access road to Planpincieux is heavily endangered. The old access road is, however, mainly endangered by the powder part of such an avalanche (Fig. 23). The old access road to Planpincieux is somewhat sheltered by a terrain ridge. We think that a limited and controlled access by the old access road to Planpincieux might be possible (limitation of vehicles, exception for emergency vehicles and residents, supervision of hazard zones, one way traffic etc.). Nevertheless, we recommend closing the old road for the traffic (a proposal for the position of the gate no. 1 is given in Fig. 22).

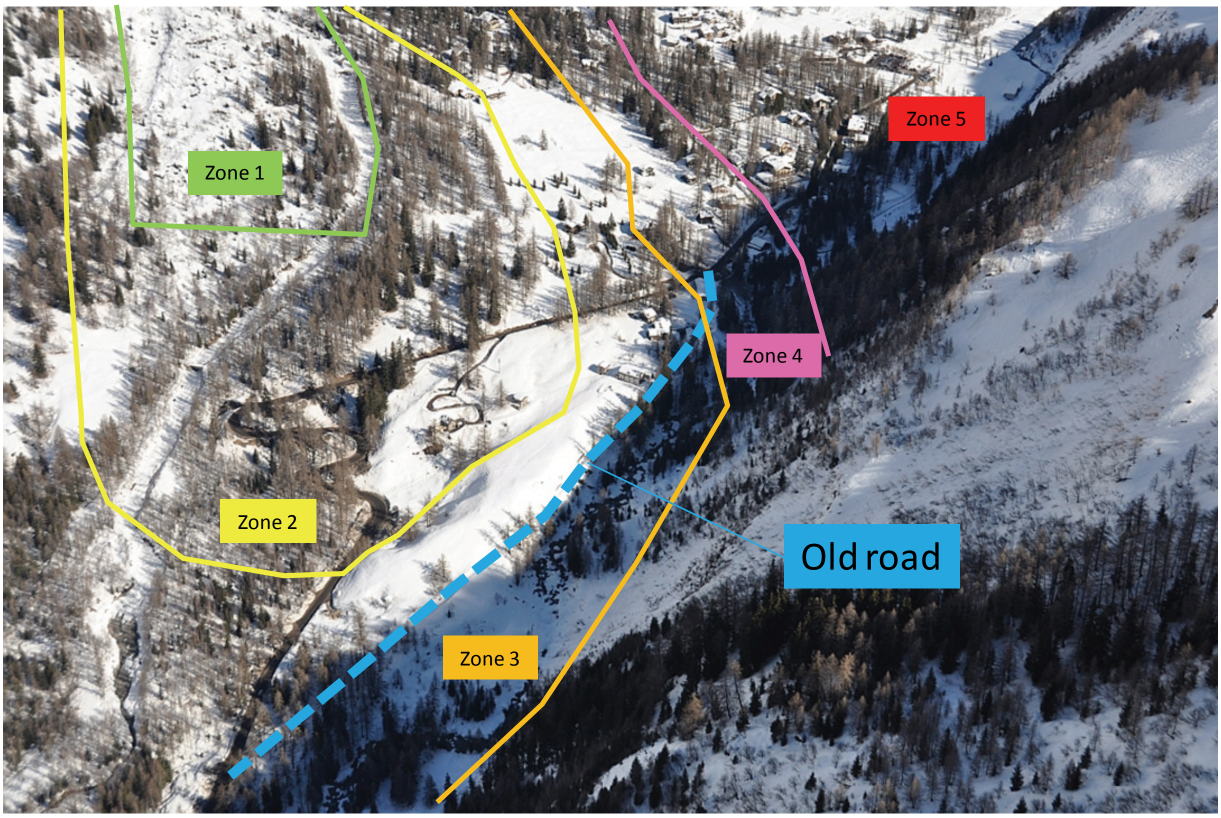

Fig. 23: Safety plan for Planpincieux with the location of the old road.

5.5 Discussion of additional safety measures

Warning signs

If the safety concept is properly applied, we think that the highest residual risk that remains is in the area of the switchback curves of the access road. There, the road is very close to the main avalanche axis and the traffic velocity is small. If the traffic is blocked in this sector, the risk of death will increase additionally. We propose to set up warning and stop signs along the zones 1 to 3. Furthermore, we recommend introducing a traffic management system (e.g. one way traffic) on that road section to decrease the risk for a traffic jam.

Alarm system

It is not possible for the supposed failure type of the Planpincieux Glacier to forecast a break-off in time with a monitoring system and survey of the sliding glacier (see Procès-verbal visite du 29 Février 2012 – Glacier de Planpincieux, Fondation Montagna Sicura 2012.). Therefore the only way would be to detect the flowing avalanche after break-off with an alarm system combined with an automatic closure of the access road by signals and with sirens. Such a system consists typically of three modules: a detecting system, a signaling system and a control system. The detecting system should detect a dangerous ice avalanche automatically. A combination of three different types of sensors would be necessary for a reliable detection of an ice avalanche which endangers the access road: a medium range Doppler radar to detect avalanches already uphill from the detection station, force measurements in steel cables tied across the avalanche track equipped with vertical detecting cables reaching into the dense flow cross section and geophones to measure seismic signals caused by avalanches. The reliable detection of a dangerous event is very demanding. The main disadvantage of such an alarm system is the short alert time and the long exposure time of vehicles. The endangered road section is long (length of zone 2 = 1000 m, length of zone 2 and 3 = 1500 m) and the velocity of the vehicles is small because of the steep and curved road (ca. 25 km/h). A car will need around 130 s to traverse zone 2 and around 200 s to traverse the zones 2 and 3. An ice avalanche from the Planpincieux Glacier reaches after around 60 s the access road (Appendix 5). If the avalanche is detected after a flow time of 10 s, the remaining closure and evacuation time is only around 50 s. We think that the pre-warning time is too short.

Structural mitigation measures
The access road could be protected with large earth dams. Because of the large flow heights and the high velocities the dam height would be larger than 20 m. The main disadvantage is that such a dam would be only partly effective against powder snow avalanches. Also with such a dam a relatively high residual risk will remain. Further the benefit-cost ratio of such a dam would be very small due to the possibly short period of use until the glacier reaches a new stable state. The visual impact of this solution would be tremendous.
The access road could be protected with snow sheds as well. However such a solution is very expensive because of the endangered road length of more than 1 km. The alignment of the road with the two switchback curves and the elevation difference of about 120 m would complicate the design of a snow shed additionally.

Road relocation
The alignment of the access road to the Val Ferret could be relocated to the location of the old road (Fig. 23). The alignment of the old road is a little less exposed to avalanches from the Planpincieux Glacier compared to the alignment of the existing access road. However the alignment of the old road is more endangered by snow avalanches which release on the NW-slopes of the Mont de la Saxe. Further we don't know if such a solution is technically feasible as the average slope of the road section is about 13%.

6 Conclusions

In November 2011 the separation of an ice mass in the lower part of the Planpincieux Glacier was identified. It was supposed that this ice mass moves faster than the remaining glacier. We investigated the consequences of the break-off of an ice avalanche with a volume of 20'000 m^3, 200'000 m^3 and 1 million m^3 in summer and winter. We prepared a safety concept with a corresponding safety plan.

An ice avalanche in summer with 200'000 m^3 endangers the access road to Planpincieux. A limited traffic subject to conditions seems to be possible on the old access road to Planpincieux. An ice avalanche in summer with 1 million m^3 requires the evacuation of Planpincieux and the closure of the access road at La Palud. An ice avalanche of 20'000 m^3 in summer will not endanger the access road to Planpincieux.

In winter, an ice avalanche with 20'000 m^3 in combination with an avalanche danger level "Considerable" is the threshold to close the access road to Planpincieux. For ice avalanches with 200'000 m^3 the access road has to be closed regardless of the local avalanche danger. The extent of the area to be evacuated depends on the local avalanche danger. An ice avalanche in winter with 1 million m^3 requires the evacuation of Planpincieux and the closure of the access road at La Palud.

The planning of effective mitigation measures is very difficult. An alarm system and structural mitigations measures seem not to be recommendable. However, we propose to set up warning and stop signs along the zones 1 to 3. Furthermore, we recommend introducing a traffic management system (e.g. one way traffic) on the endangered road section to decrease the risk for a traffic jam. In addition, we propose to install a monitoring system (visual observations of cracks and crevasses, installation of an automatic camera, analysis of photos, displacement measurements) to better recognize potential ice avalanche volumes at a certain time period. Finally, we point out that the assessment of the hazard due to ice avalanches or ice-snow avalanches from the Planpincieux Glacier includes large uncertainties. It must be accepted that there can be situations which are unpredictable and which are consequentially not covered in the proposed safety concept.

7 Documentation

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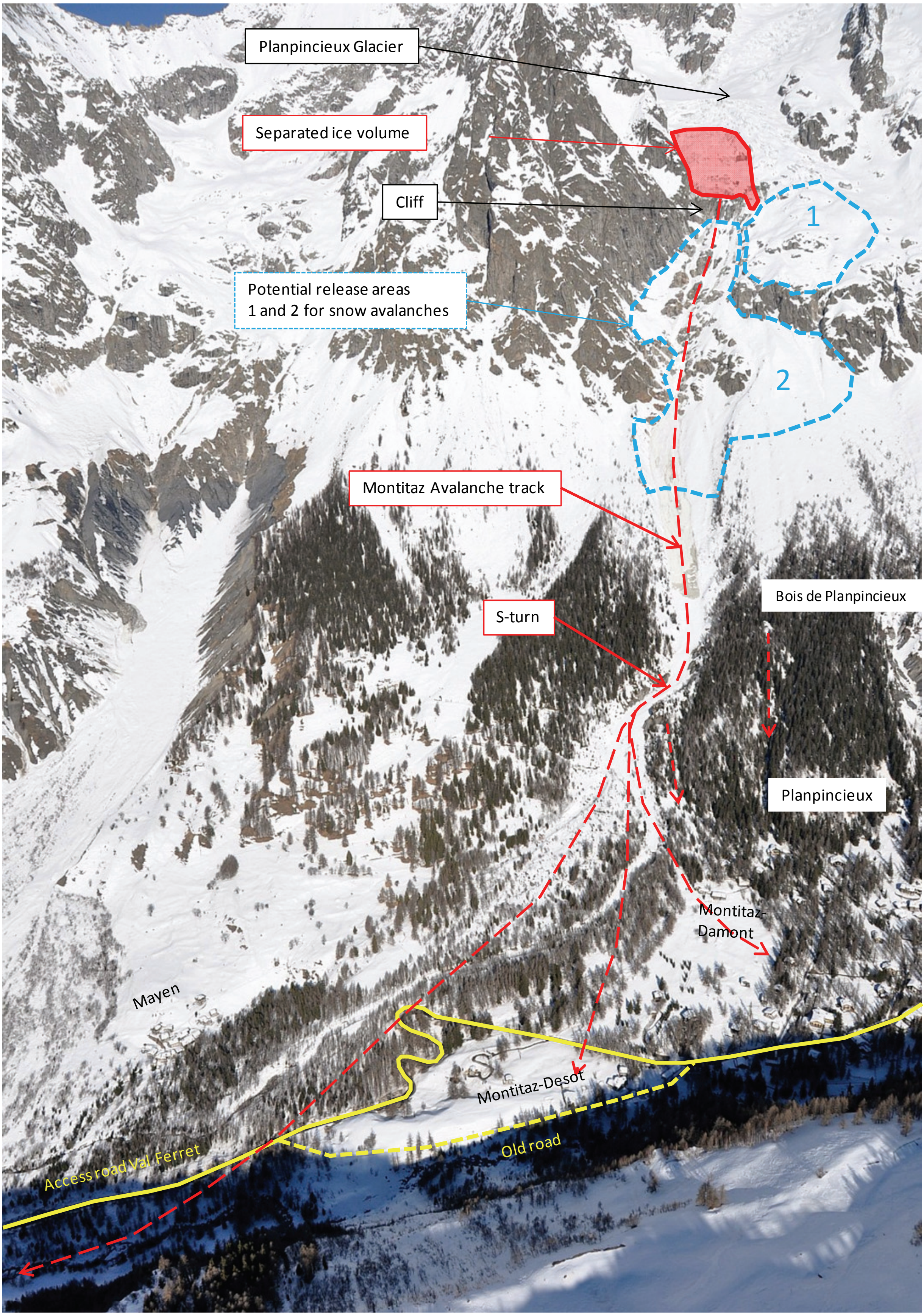
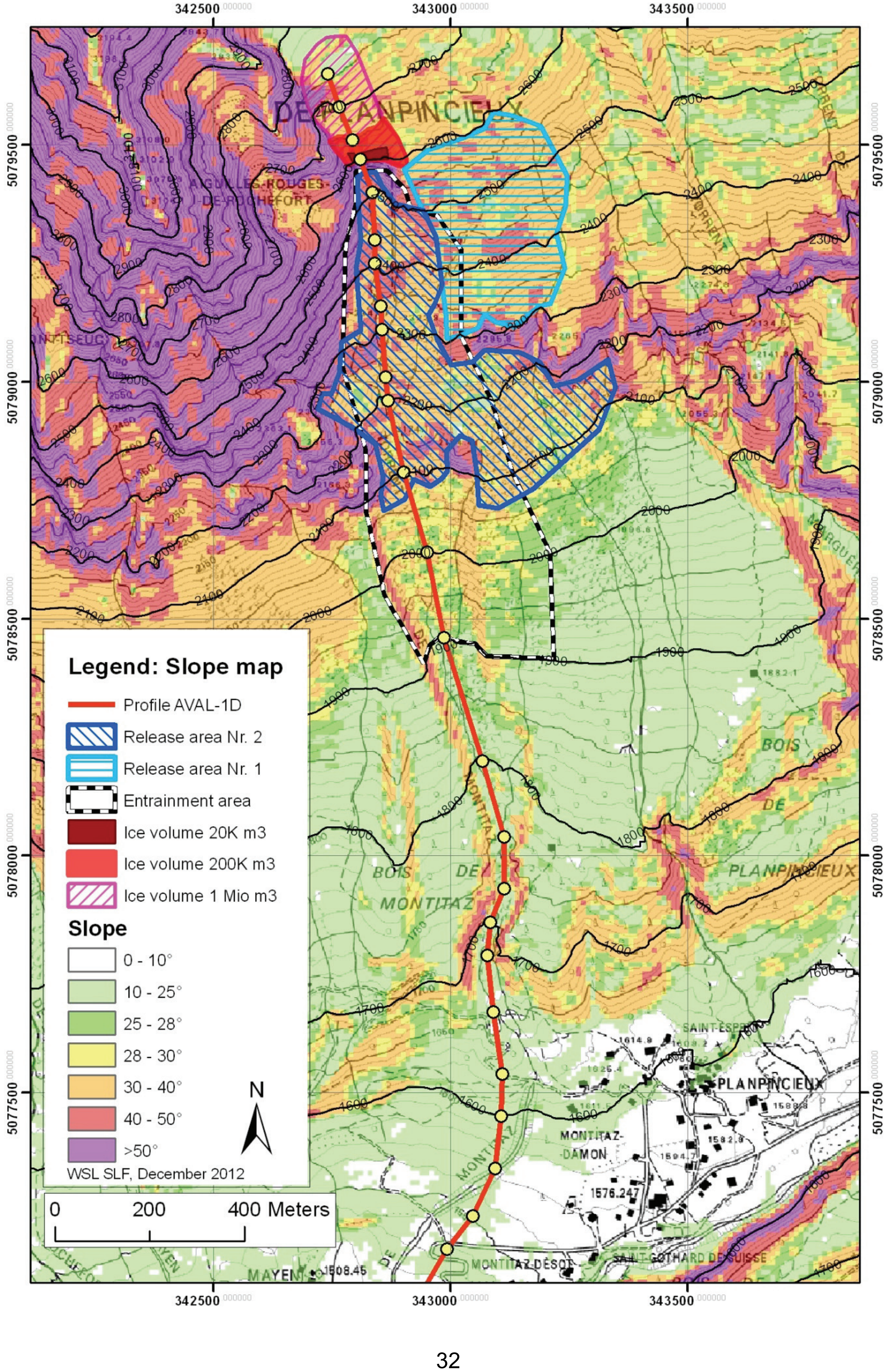
- SLF 2012b: Avalanche Bulletins and other products. Interpretation Guide. Edition 2012. WSL Institute for Snow and Avalanche Research SLF (publisher). 45 pages.
- Regione Autonoma Valle d'Aoste, 2012. Catasto Valanghe Regionale, Geonavigatore 2.0.
- Overview map Val Ferret, 1:10'000.
- Swiss Map 1:50'000.
- MNT, 2005. Digital Terrain Model, 10 m. 2005.

Davos, 17 January 2013/ Mar.

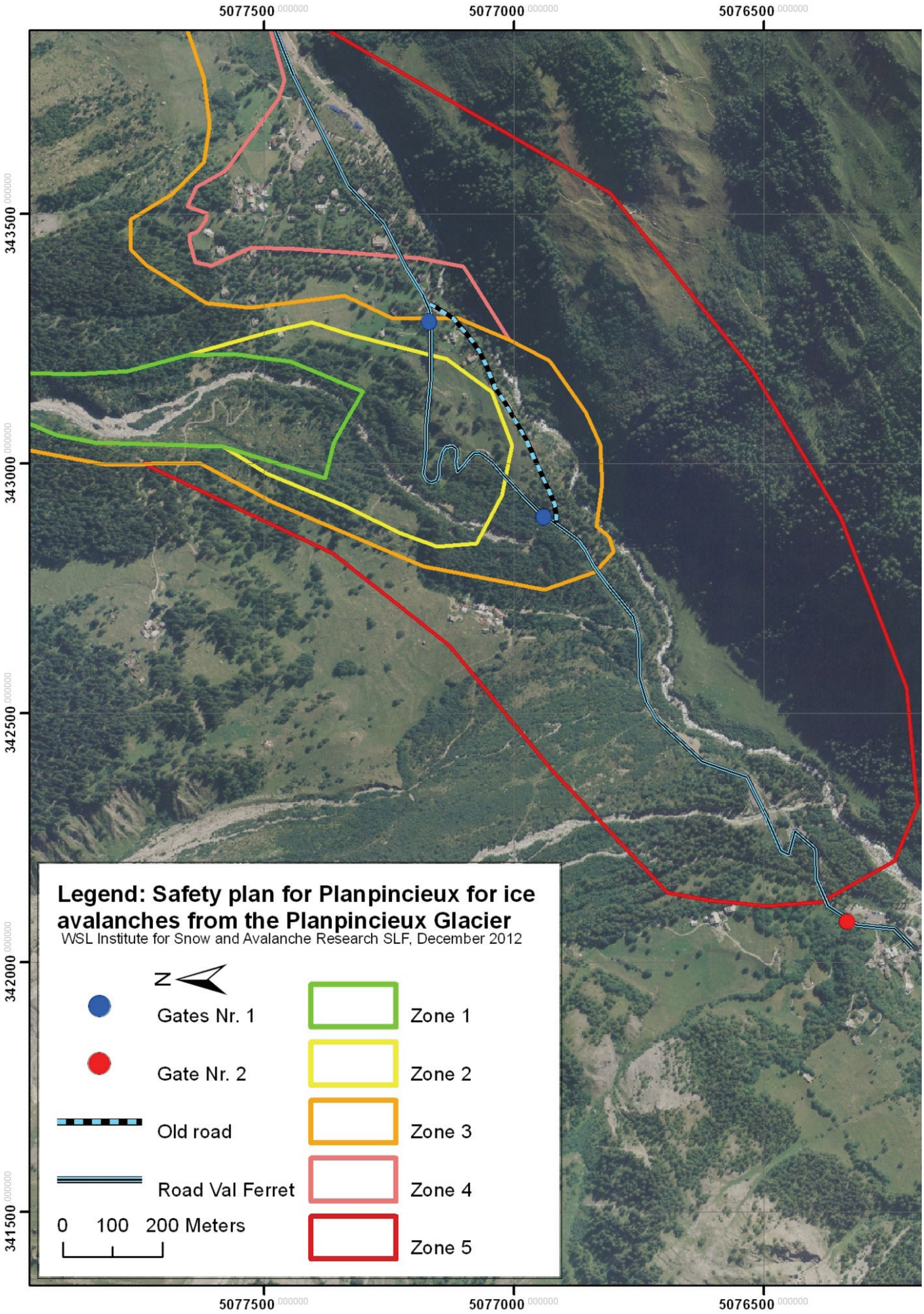
Appendix 1: Overview Planpincieux Glacier and Montitaz avalanche track



Appendix 2: Map with slope inclination, release areas, entrainment area and terrain profile for AVAL-1D calculations



Appendix 3: Safety plan for Planpincieux



Appendix 4: European Avalanche Danger Scale

European Danger Scale with Recommendations

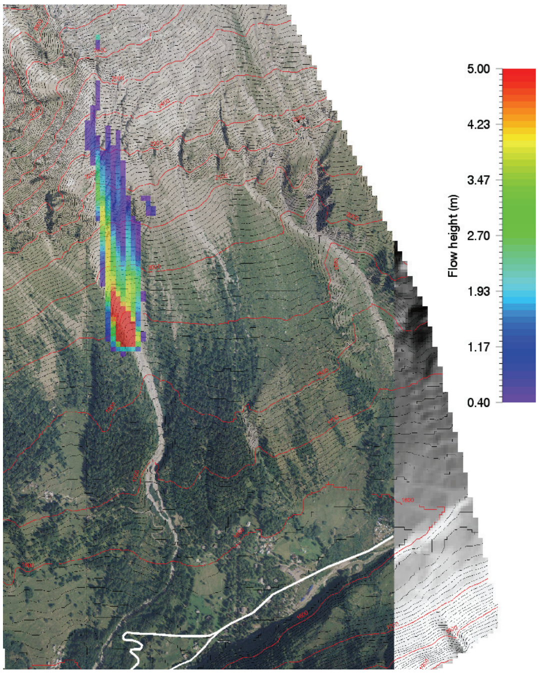
	Danger level	Snowpack stability	Avalanche triggering probability	Consequences for transportation routes and settlements / recommendations	Consequences for persons outside secured zones / recommendations
5	very high	The snowpack is poorly bonded and largely unstable in general.	Many large and multiple very large natural avalanches are expected, even in moderately steep terrain.	Acute danger. Comprehensive safety measures.	Highly unfavourable conditions. Avoid open terrain.
4	high	The snowpack is poorly bonded on most steep slopes*.	Triggering is likely even from low additional loads** on many steep slopes. In some cases, numerous medium-sized and often large-sized natural avalanches can be expected.	Many exposed sectors are endangered. Safety measures recommended in those places.	Unfavourable conditions. Extensive experience in the assessment of avalanche danger is required. Remain in moderately steep terrain / heed avalanche run out zones.
3	considerable	The snowpack is moderately to poorly bonded on many steep slopes*.	Triggering is possible, even from low additional loads** particularly on those steep slopes indicated in the bulletin. In some cases medium-sized, in isolated cases large-sized natural avalanches are possible.	Isolated exposed sectors are endangered. Some safety measures recommended in those places.	Partially unfavourable conditions. Experience in the assessment of avalanche danger is required. Steep slopes of indicated aspects and altitude zones should be avoided if possible.
2	moderate	The snowpack is only moderately well bonded on some steep slopes*, otherwise well bonded in general.	Triggering is possible primarily from high additional loads**, particularly on those steep slopes indicated in the bulletin. Large-sized natural avalanches are unlikely.	Low danger of natural avalanches.	Mostly favourable conditions. Careful route selection, especially on steep slopes of indicated aspects and altitude zones.
1	low	The snowpack is well bonded and stable in general.	Triggering is generally possible only from high additional loads** in isolated areas of very steep, extreme terrain. Only sluffs and small-sized natural avalanches are possible.	No danger	Generally safe conditions

Explanations: ** Additional load:
- high (e.g. group of skiers without spacing, snowmobile/groomer, avalanche blasting)
- low (e.g. single skier, snowboarder, snowshoe hiker)

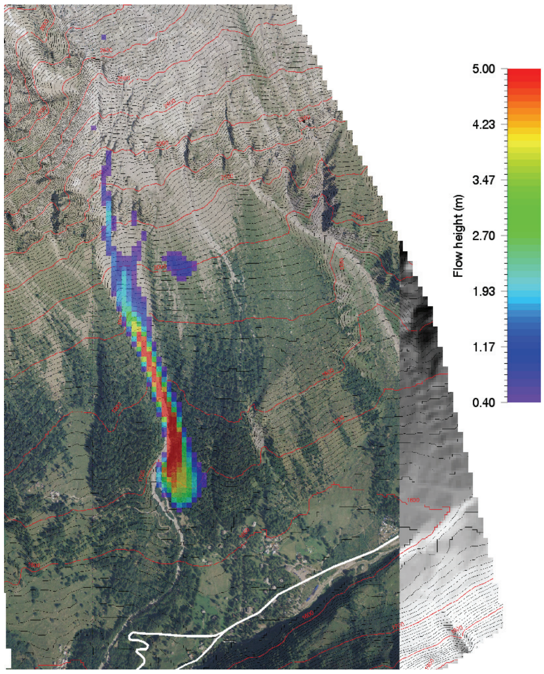
* generally explained in greater detail in Avalanche Bulletin (e.g. altitude zone, aspect, type of terrain)
→moderately steep terrain: slopes flatter than about 30 degrees
→steep slopes: slopes with an angle of more than about 30 degrees
→steep extreme terrain:: those which are particularly unfavourable as regards slope angle (usually steeper than about 40°), terrain profile, proximity to ridge, roughness of underlying ground

- natural: without human assistance
- aspect: the compass direction in which a downward slope faces
- exposed: especially exposed to danger

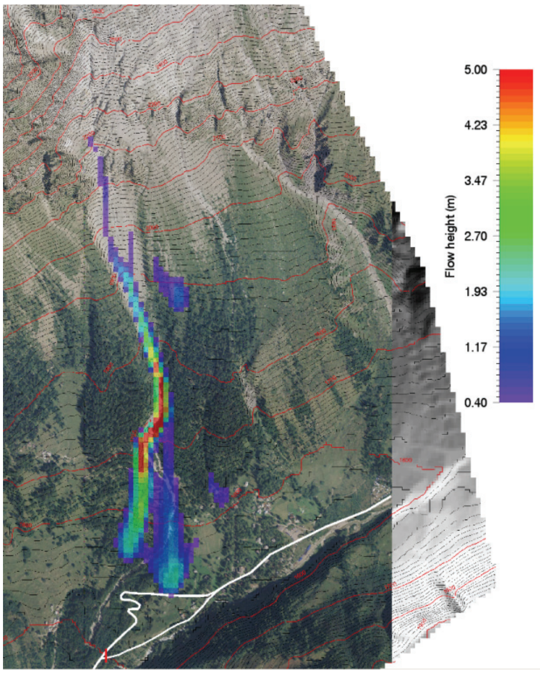
Appendix 5: Time steps of the RAMMS simulation for scenario W5



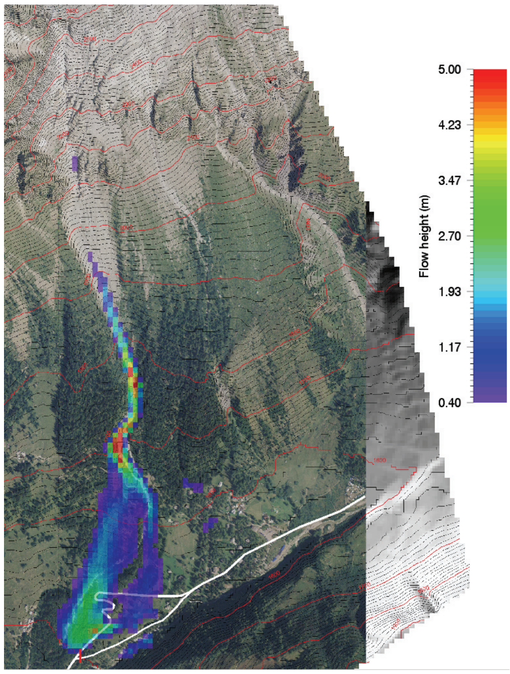
Flow time 30 s.



Flow time 45 s.



Flow time 60 s.



Flow time 80 s.

Maximal flowheight of the simulation: “P1_200K_L30_Winter_1_noflux2_HD23_20m.av2”

Appendix 6: RAMMS simulations ice avalanches summer scenarios

Scenario summer S1 — Ice volume 20’000 m^3

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename:
D:\RAMMS\Projekte12\Ferret_2012\Plamp1_20K_S10_Summer_Noflux_1.out.gz

Simulation stopped due to TIME END CONDITION!
It is possible that the runout distance would increase if calculated with increased "End time" parameter!
Real calculation time (min.): 1.33333
Simulation resolution (m): 10.0000

SIMULATION RESULTS
Number of cells: 78420
Number of nodes: 79199
Calculated Release Volume (m3): 40094.211
Overall MAX velocity (m/s): 146.382
Overall MAX flowheight (m): 18.6816
Overall MAX pressure (kPa): 6428.28

****

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Tue Oct 30 19:05:08 2012
Input filename:
D:\RAMMS\Projekte12\Ferret_2012\Plamp1_20K_S10_Summer_Noflux_1.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)

Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_20k_m3_rep.shp
Release heights:
Release nr 0: 20.30m
Estimated release volume: 40094 m3

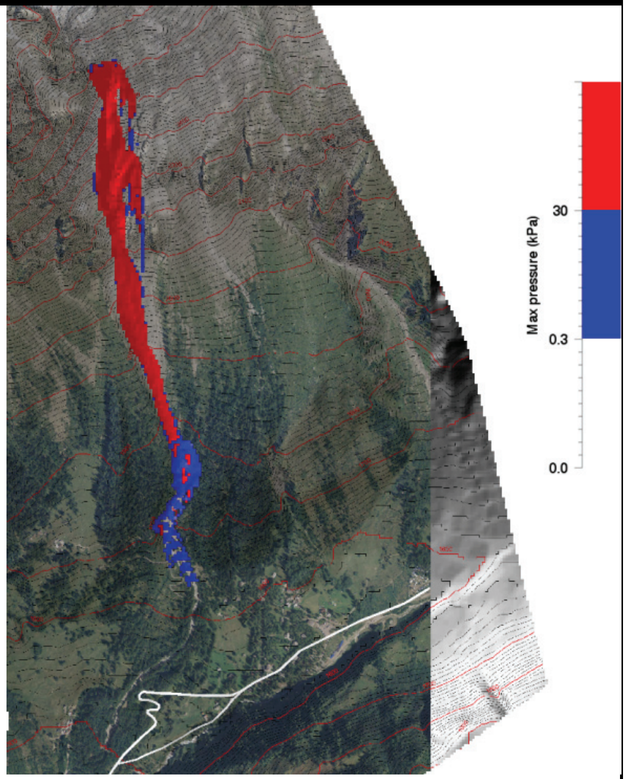
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\Summer_20K__S10_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\Summer_20K__S10_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.295 - 0.275 - 0.260
Xi: 1500 - 1750 - 2000
Channelled parameters:
Mu: 0.340 - 0.325 - 0.310
Xi: 1200 - 1350 - 1500
Gully parameters:
Mu: 0.430 - 0.410 - 0.400
Xi: 1000 - 1100 - 1200
Flat parameters:
Mu: 0.270 - 0.255 - 0.240
Xi: 2000 - 2250 - 2500
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

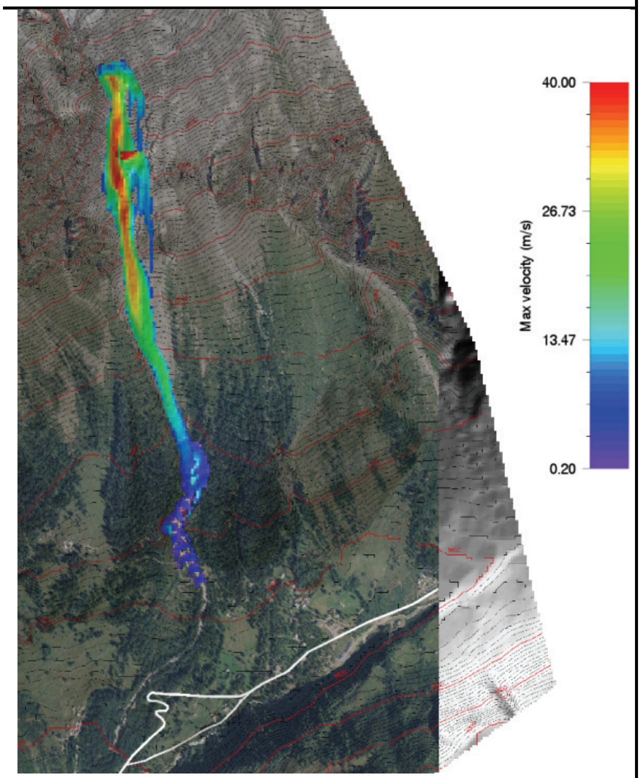
RETURN PERIOD (y): 10
VOLUME category: Small

EROSION:
No EROSION specified.

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario summer S2 — Ice volume 200'000 m^3

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename:
D:\RAMMS\Projekte12\Ferret_2012\Plamp1_200K_M30_Summer_Noflux_1.out .gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 140.000s
Real calculation time (min.): 1.70000
Simulation resolution (m): 10.0000

SIMULATION RESULTS
Number of cells: 78420
Number of nodes: 79199

Calculated Release Volume (m3): 304000.31
Overall MAX velocity (m/s): 149.999
Overall MAX flowheight (m): 47.6078
Overall MAX pressure (kPa): 6749.90

****
RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Tue Oct 30 16:44:11 2012
Input filename:
D:\RAMMS\Projekte12\Ferret_2012\Plamp1_200K_M30_Summer_Noflux_1.av2
Project: Ferret_2011
Info: .

DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux200K_1.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Icevol_200Km3_2_rep.shp
Release heights:
Release nr 0: 36.00m
Estimated release volume: 304000 m3

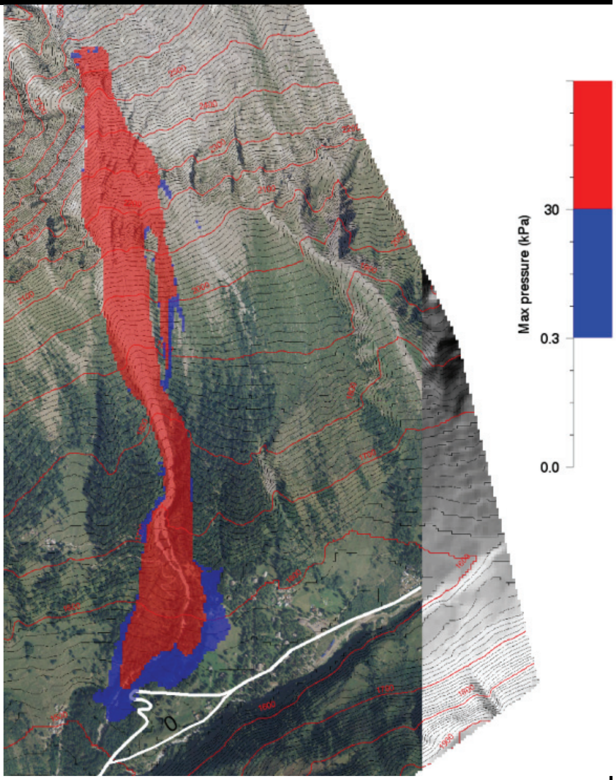
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\sommer_200k_M30_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\sommer_200k_M30_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.250 - 0.230 - 0.215
Xi: 1750 - 2100 - 2500
Channelled parameters:
Mu: 0.300 - 0.285 - 0.270
Xi: 1350 - 1530 - 1750
Gully parameters:
Mu: 0.380 - 0.350 - 0.340
Xi: 1100 - 1200 - 1350
Flat parameters:
Mu: 0.230 - 0.210 - 0.190
Xi: 2500 - 2900 - 3250
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

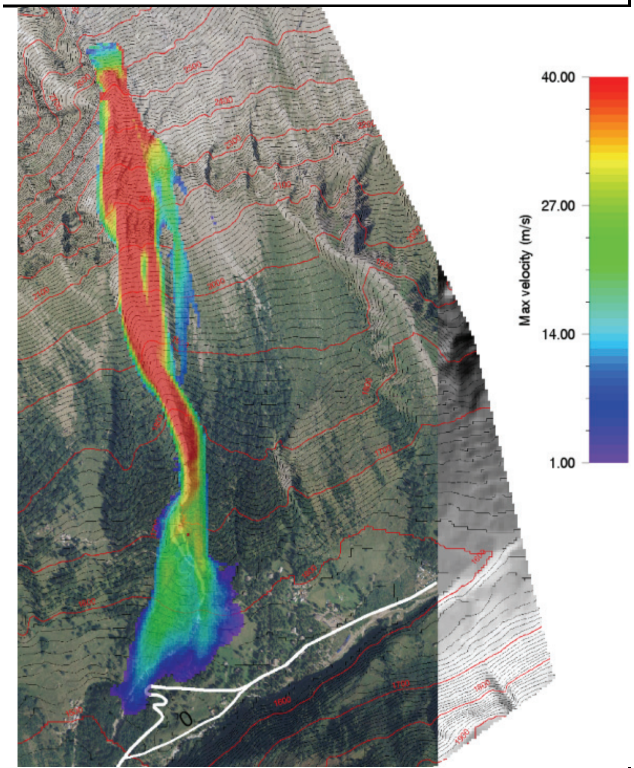
RETURN PERIOD (y): 30
VOLUME category: Medium

EROSION:
No EROSION specified.

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario summer S3 — Ice volume 1 million m^3

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Tue Oct 30 10:45:07 2012
Input filename:
D:\RAMMS\Projekte12\Ferret_2011\Plamp1_1Mio_M30_Summer_2_10m_noflux.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2011\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)

Nr of nodes: 158316
Nr of cells: 157500
Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2011\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2011\noflux1mio_m3.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2011\Ice_1MioK_1_rep.shp
Release heights:
Release nr 0: 38.00m
Estimated release volume: 1242006 m3

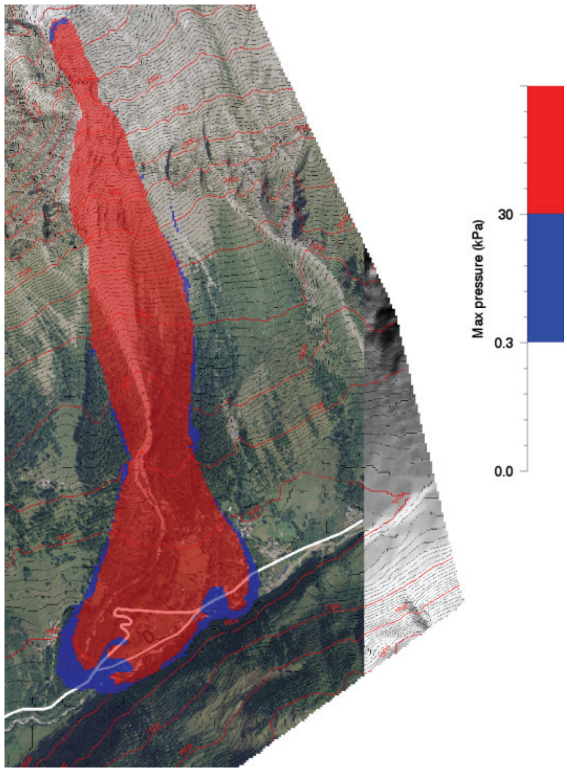
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2011\sommer_200k_M30_mu.asc
D:\RAMMS\Projekte12\Ferret_2011\sommer_200k_M30_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.250 - 0.230 - 0.215
Xi: 1750 - 2100 - 2500
Channelled parameters:
Mu: 0.300 - 0.285 - 0.270
Xi: 1350 - 1530 - 1750
Gully parameters:
Mu: 0.380 - 0.350 - 0.340
Xi: 1100 - 1200 - 1350
Flat parameters:
Mu: 0.230 - 0.210 - 0.190
Xi: 2500 - 2900 - 3250
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

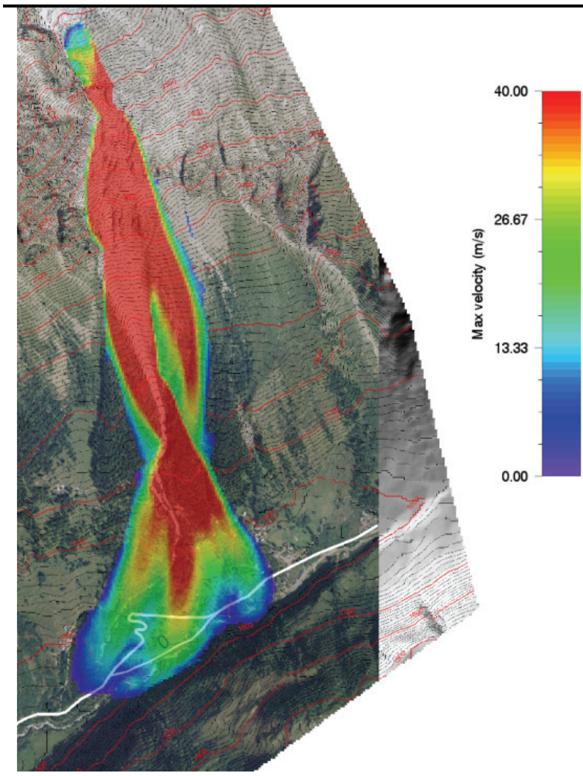
RETURN PERIOD (y): 30
VOLUME category: Medium

EROSION:
No EROSION specified.

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Jorasses_12_3.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Appendix 7: RAMMS Simulations ice avalanches winter scenarios

Scenario winter W1 — Ice volume 20’000 m^3 / Hazard degree 1

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_20K_M10_Winter_Noflux_1_Entr1_HD1.out.gz

Simulation stopped due to TIME END CONDITION!
It is possible that the runout distance would increase if calculated with increased "End time" parameter!
Real calculation time (min.): 1.73333
Simulation resolution (m): 10.0000

SIMULATION RESULTS
Number of cells: 78420
Number of nodes: 79199
Calculated Release Volume (m3): 40094.211
Overall MAX velocity (m/s): 146.969
Overall MAX flowheight (m): 18.6854
Overall MAX pressure (kPa): 6479.99
****
RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE
Date: Wed Nov 14 13:31:57 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_20K_M10_Winter_Noflux_1_Entr1_HD1.av2

Project: Ferret_2011
Info: DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_20k_m3_rep.shp
Release heights:
Release nr 0: 20.30m
Estimated release volume: 40094 m3
Eroded volume: 30607.6
Flow volume: 70701.8

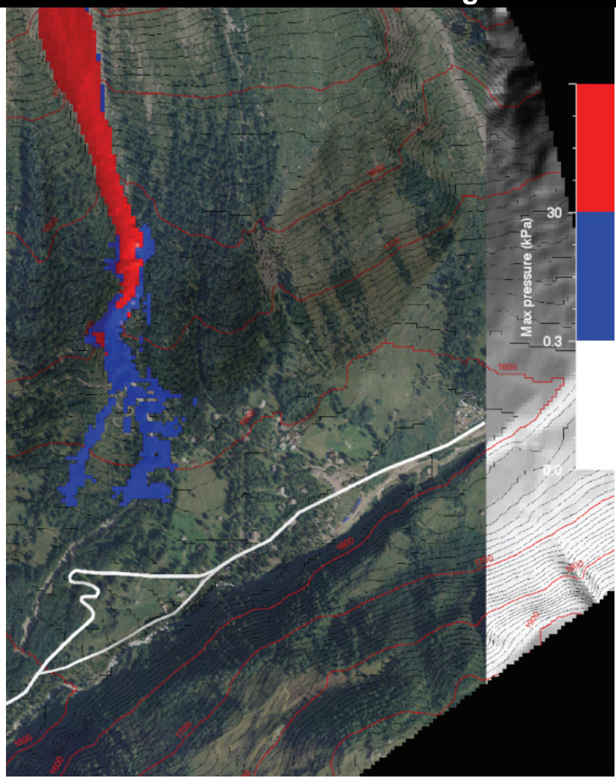
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\M10_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\M10_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.260 - 0.240 - 0.225
Xi: 1750 - 2100 - 2500
Channelled parameters:
Mu: 0.310 - 0.295 - 0.280
Xi: 1350 - 1530 - 1750
Gully parameters:
Mu: 0.390 - 0.360 - 0.350
Xi: 1100 - 1200 - 1350
Flat parameters:
Mu: 0.240 - 0.220 - 0.200
Xi: 2500 - 2900 - 3250
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

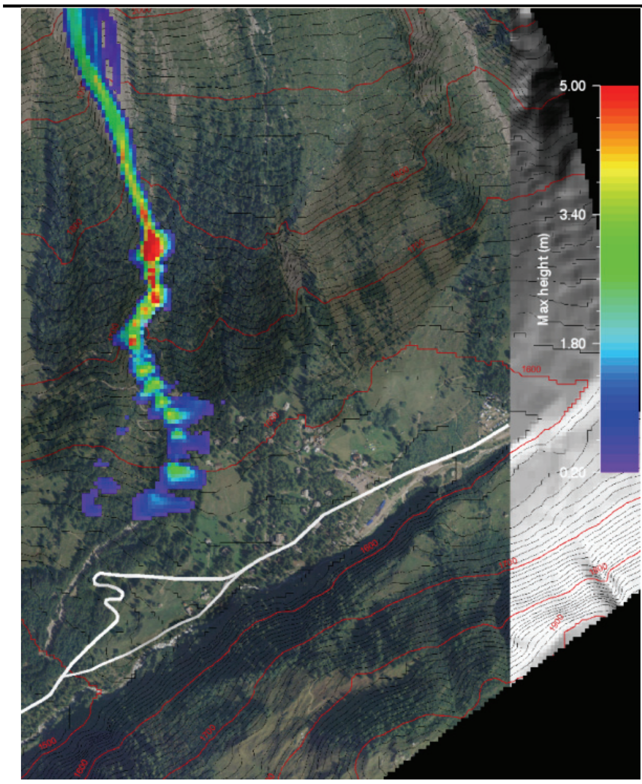
RETURN PERIOD (y): 10
VOLUME category: Medium

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 0.400000m Rho: 200kg/m3 K: 0.200000
Erosion law: 0 (0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W2

Ice volume 20'000 m³ / Hazard degree 2

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_20K_M10_Winter_Noflux_1_Entr1_HD2.out.gz

Simulation stopped due to TIME END CONDITION!
It is possible that the runout distance would increase if calculated with increased "End time" parameter!
Real calculation time (min.): 1.56667
Simulation resolution (m): 10.0000

SIMULATION RESULTS
Number of cells: 78420
Number of nodes: 79199
Calculated Release Volume (m3): 40094.211
Overall MAX velocity (m/s): 146.969
Overall MAX flowheight (m): 18.6854
Overall MAX pressure (kPa): 6479.99
****

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Fri Nov 09 16:33:22 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_20K_M10_Winter_Noflux_1_Entr1_HD2.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500
Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_20k_m3_rep.shp
Release heights:
Release nr 0: 20.30m
Estimated release volume: 40094 m3
Eroded volume (m3): 35786.7
Flow volume (m3) 75880.9

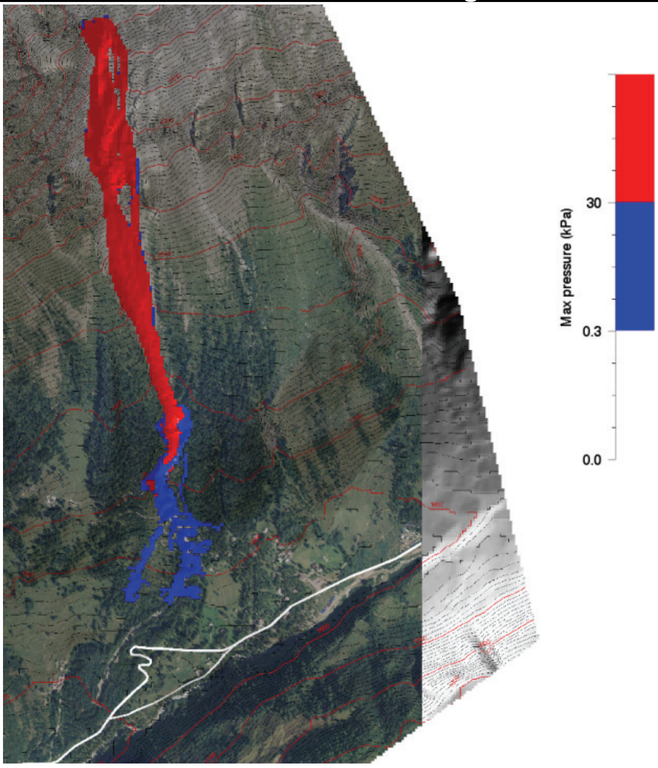
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\M10_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\M10_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.260 - 0.240 - 0.225
Xi: 1750 - 2100 - 2500
Channelled parameters:
Mu: 0.310 - 0.295 - 0.280
Xi: 1350 - 1530 - 1750
Gully parameters:
Mu: 0.390 - 0.360 - 0.350
Xi: 1100 - 1200 - 1350
Flat parameters:
Mu: 0.240 - 0.220 - 0.200
Xi: 2500 - 2900 - 3250
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

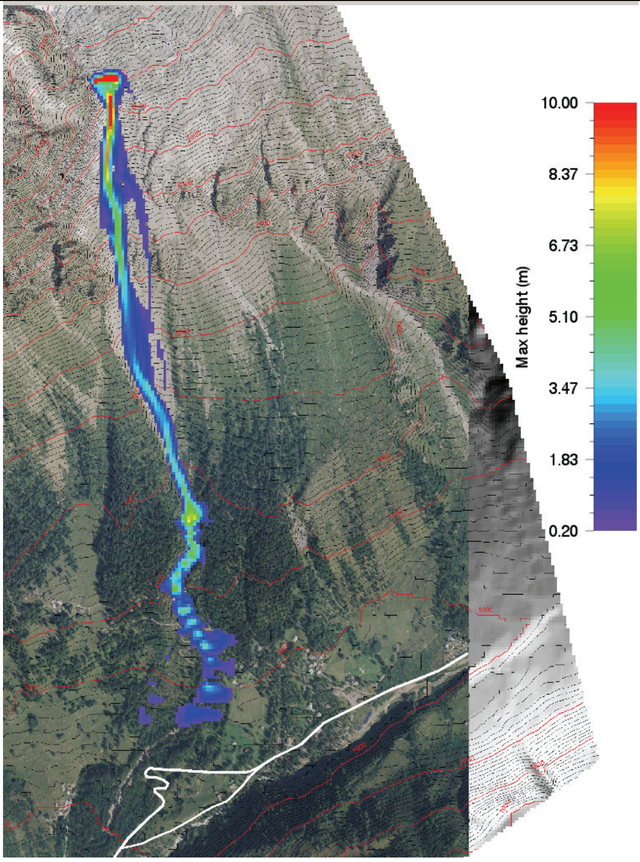
RETURN PERIOD (y): 10
VOLUME category: Medium

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 0.500000m
Rho: 200kg/m3 K: 0.200000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W3 — Ice volume 20'000 m^3 / Hazard degree 3

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\
P1_20K_L10_Winter_Noflux_1_Entr1_HD3.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 290.000s
Real calculation time (min.): 1.61667
Simulation resolution (m): 10.0000

SIMULATION RESULTS
Number of cells: 78420
Number of nodes: 79199
Calculated Release Volume (m3): 40094.211

Overall MAX velocity (m/s): 148.265
Overall MAX flowheight (m): 18.6901
Overall MAX pressure (kPa): 6594.76

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Tue Nov 13 17:16:19 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\
P1_20K_L10_Winter_Noflux_1_Entr1_HD3.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel

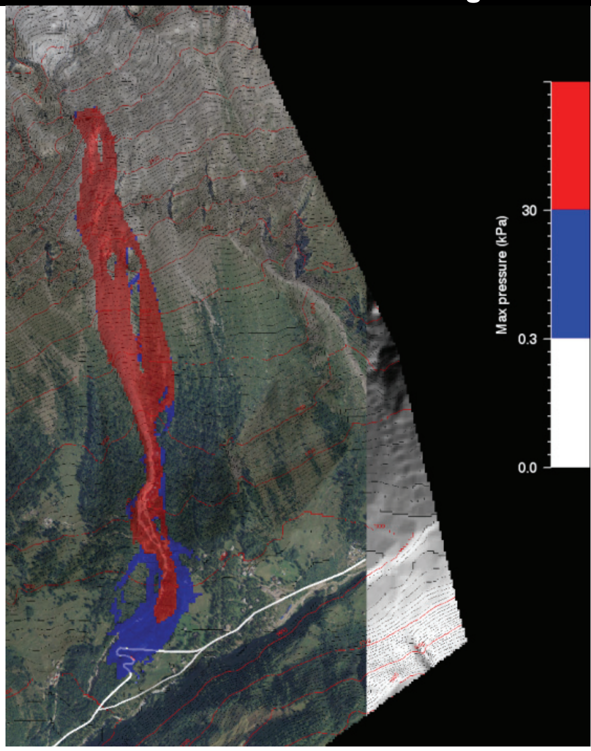
RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_20k_m3_rep.shp
Release heights:
Release nr 0: 20.30m
Estimated release volume: 40094 m3
Eroded volume: 81820.9
Flow volume: 121915.1
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L10_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L10_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.220 - 0.200 - 0.180
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.270 - 0.250 - 0.235
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.345 - 0.325 - 0.300
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.200 - 0.180 - 0.165
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

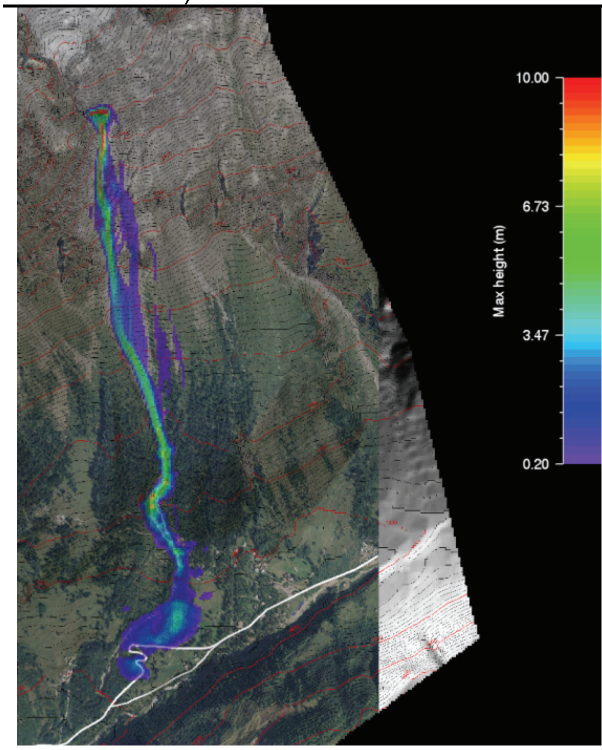
RETURN PERIOD (y): 10
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 0.600000m Rho: 200kg/m3 K: 0.500000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W4 — Ice volume 20’000 m³ / Hazard degree 4/5

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_20K_L30_Winter_Noflux_1_Entr1_HD45.out.gz

Simulation stopped due to LOW FLUX!

Simulation stopped after 180.000s
Real calculation time (min.): 1.58333
Simulation resolution (m): 10.0000

SIMULATION RESULTS
Number of cells: 78420
Number of nodes: 79199
Calculated Release Volume (m3): 40094.211

Overall MAX velocity (m/s): 149.982
Overall MAX flowheight (m): 18.6912
Overall MAX pressure (kPa): 6748.40

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Fri Nov 09 17:25:43 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_20K_L30_Winter_Noflux_1_Entr1_HD45.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)

Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_20k_m3_rep.shp
Release heights:
Release nr 0: 20.30m
Estimated release volume: 40094 m3
Eroded volume (m3): 177847.8
Flow volume (m3) 217942.0

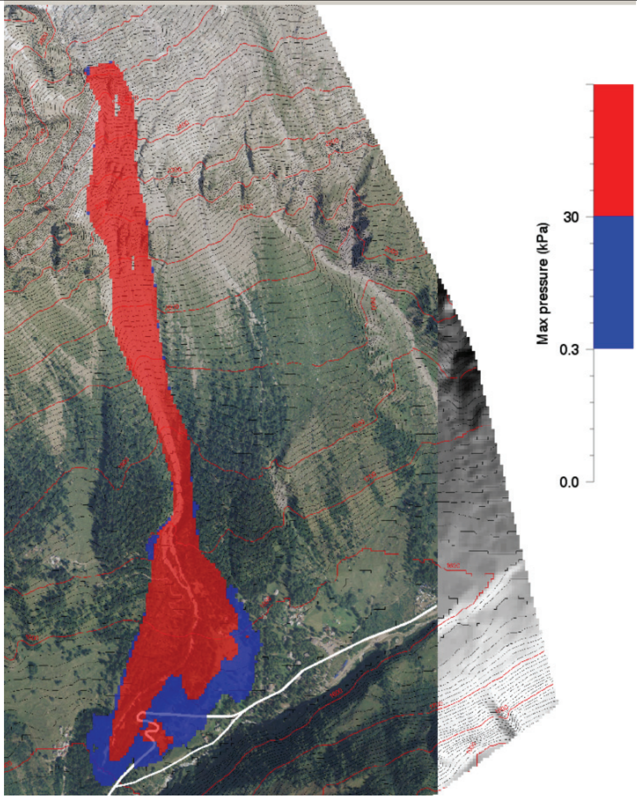
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L30_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L30_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.210 - 0.190 - 0.170
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.260 - 0.240 - 0.225
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.330 - 0.310 - 0.290
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.190 - 0.170 - 0.155
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

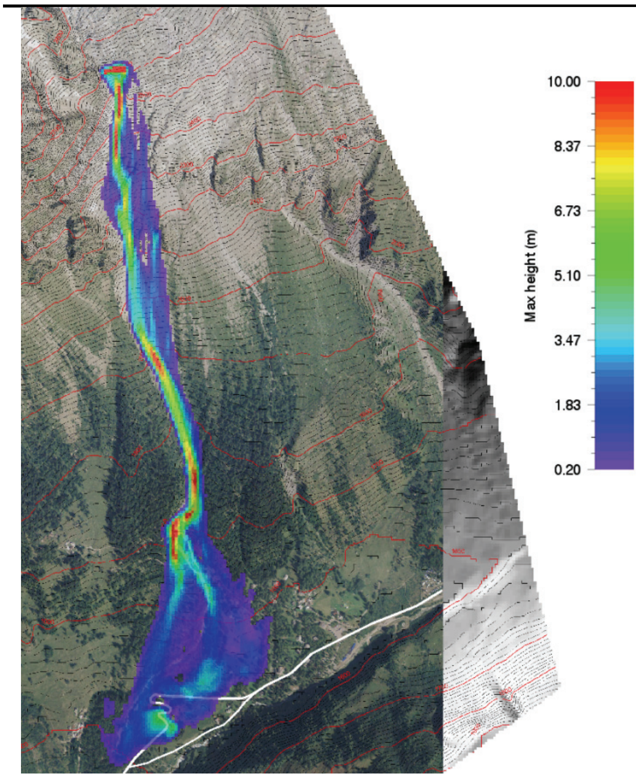
RETURN PERIOD (y): 30
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 1.50000m Rho: 200kg/m3 K: 1.00000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W5 — Ice volume 200'000 m^3 / Hazard degree 1

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_200K_L30_Winter_1_noflux2_HD1_20m.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 160.000s
Real calculation time (min.): 0.166667
Simulation resolution (m): 20.0000

SIMULATION RESULTS

Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 315914.64
Overall MAX velocity (m/s): 70.2111
Overall MAX flowheight (m): 35.2096
Overall MAX pressure (kPa): 1478.88

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Fri Nov 09 18:16:54 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_200K_L30_Winter_1_noflux2_HD1_20m.av2

Project: Ferret_2011
Info: .

DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)

Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\noflux_2.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Icevol_200Km3_2_rep.shp
Release heights:
Release nr 0: 36.00m
Estimated release volume: 304000 m3

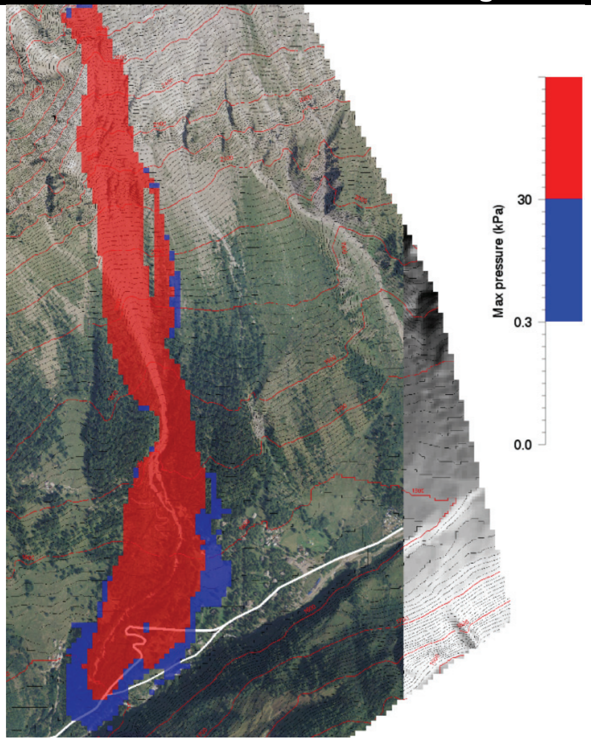
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L30_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L30_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.210 - 0.190 - 0.170
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.260 - 0.240 - 0.225
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.330 - 0.310 - 0.290
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.190 - 0.170 - 0.155
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

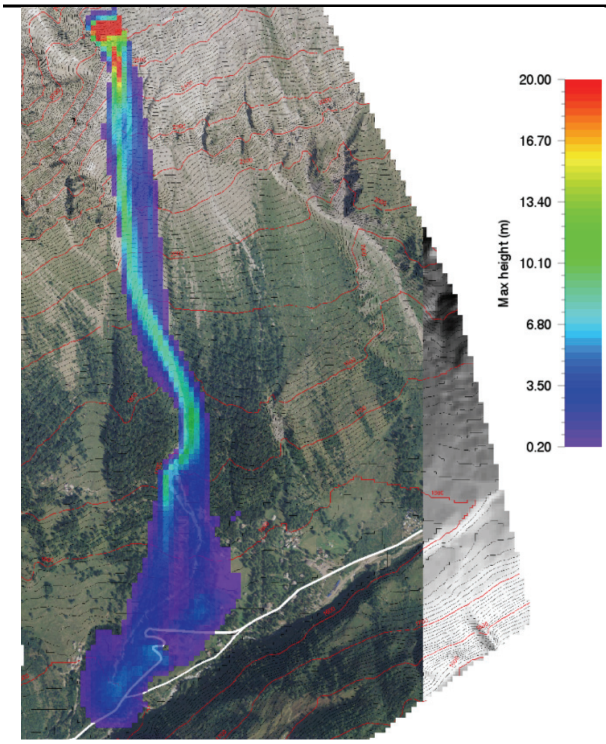
RETURN PERIOD (y): 30
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 0.500000m Rho: 200kg/m3 K: 0.200000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W6 — Ice volume 200’000 m^3 / Hazard degree 2/3

RAMMS: AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012
P1_200K_L30_Winter_1_noflux2_HD23_20m.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 170.000s
Real calculation time (min.): 0.200000
Simulation resolution (m): 20.0000

SIMULATION RESULTS
Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 315914.64

Overall MAX velocity (m/s): 149.386
Overall MAX flowheight (m): 35.2096
Overall MAX pressure (kPa): 6694.85

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Mon Nov 12 09:01:25 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012
P1_200K_L30_Winter_1_noflux2_HD23_20m.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\noflux_2.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Icevol_200Km3_2_rep.shp
Release heights:
Release nr 0: 36.00m
Estimated release volume: 304’000 m3
Eroded volume (m3): 128’019.4
Total flow volume (m3): 443’934.1

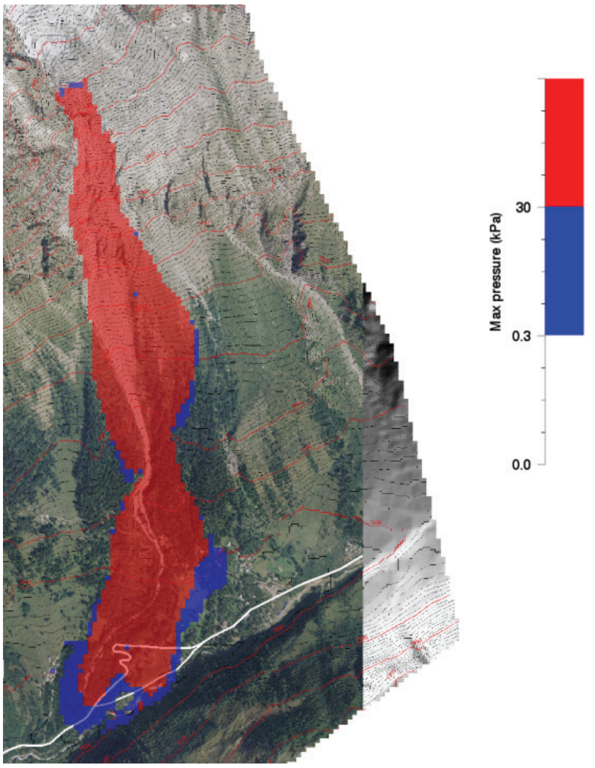
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L30_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L30_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.210 - 0.190 - 0.170
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.260 - 0.240 - 0.225
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.330 - 0.310 - 0.290
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.190 - 0.170 - 0.155
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

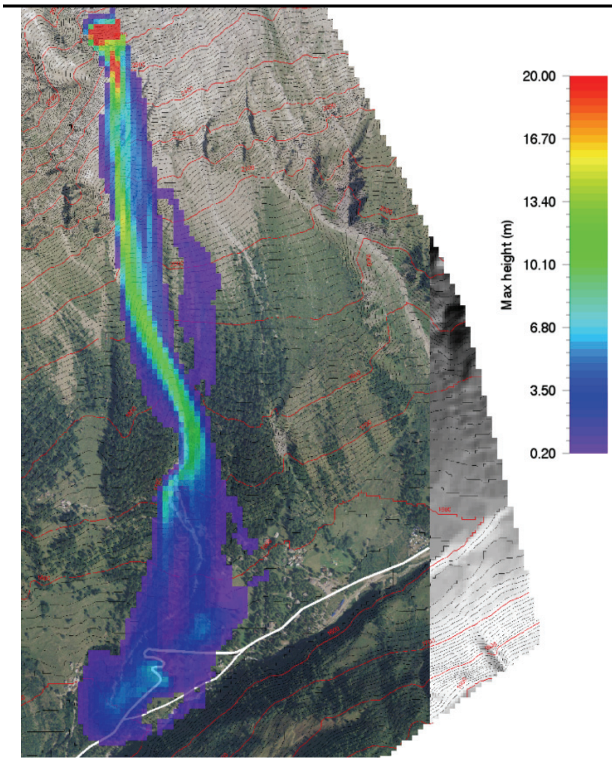
RETURN PERIOD (y): 30
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 0.600000m Rho: 200kg/m3 K: 1.00000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W7

Ice volume 200'000 m^3 / Hazard degree 4/5

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_200K_L100_Winter_1_noflux2_HD45_20m.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 170.000s
Real calculation time (min.): 0.200000
Simulation resolution (m): 20.0000

SIMULATION RESULTS
Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 315914.64
Overall MAX velocity (m/s): 130.683
Overall MAX flowheight (m): 35.2103
Overall MAX pressure (kPa): 5123.38

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE
Date: Tue Nov 13 16:45:39 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_200K_L100_Winter_1_noflux2_HD45_20m.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)

Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\noflux_2.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Icevol_200Km3_2_rep.shp
Release heights:
Release nr 0: 36.00m
Estimated release volume: 304000 m3

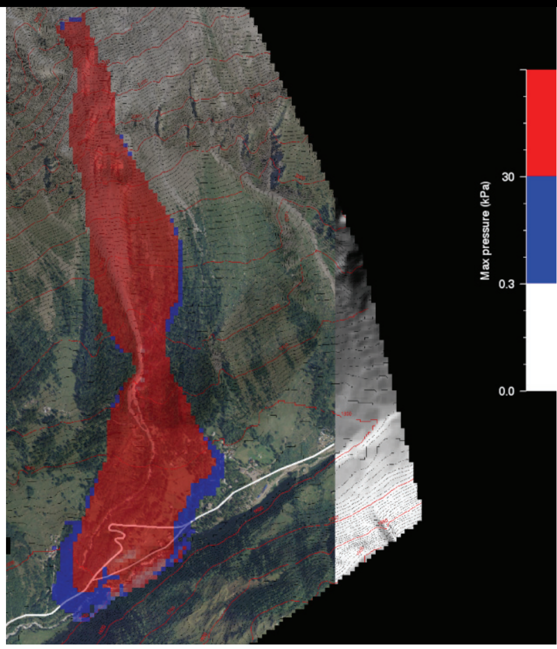
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L100_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L100_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.200 - 0.180 - 0.165
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.250 - 0.230 - 0.220
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.315 - 0.300 - 0.280
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.180 - 0.160 - 0.150
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

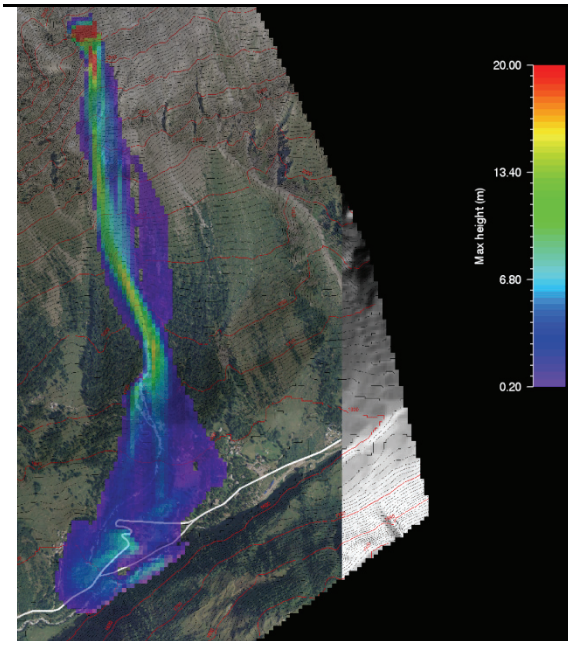
RETURN PERIOD (y): 100
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file: D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel
H: 1.50000m Rho: 200kg/m3 K: 1.00000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W8 — Ice volume 1 million m^3 / Hazard degree 1

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_1Mio_L30_Winter_20m_noflux_H1.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 120.000s
Real calculation time (min.): 0.183333
Simulation resolution (m): 20.0000

SIMULATION RESULTS
Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 1180455.9
Overall MAX velocity (m/s): 74.4191
Overall MAX flowheight (m): 70.0305
Overall MAX pressure (kPa): 1661.46

RAMMS: AVALANCHE 1.4.20 INPUT LOGFILE

Date: Mon Nov 12 11:01:39 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_1Mio_L30_Winter_20m_noflux_H1.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500
Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\noflux1mio_m3.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_1MioK_1_rep.shp
Release heights:
Release nr 0: 38.00m
Estimated release volume: 1242006 m3
Eroded volume (m3): 129567.2
Flow volume (m3): 1310023.1

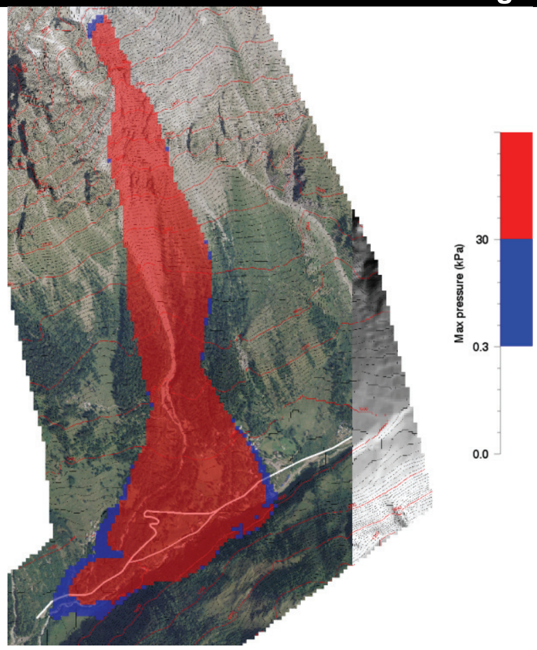
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L30_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L30_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.210 - 0.190 - 0.170
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.260 - 0.240 - 0.225
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.330 - 0.310 - 0.290
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.190 - 0.170 - 0.155
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

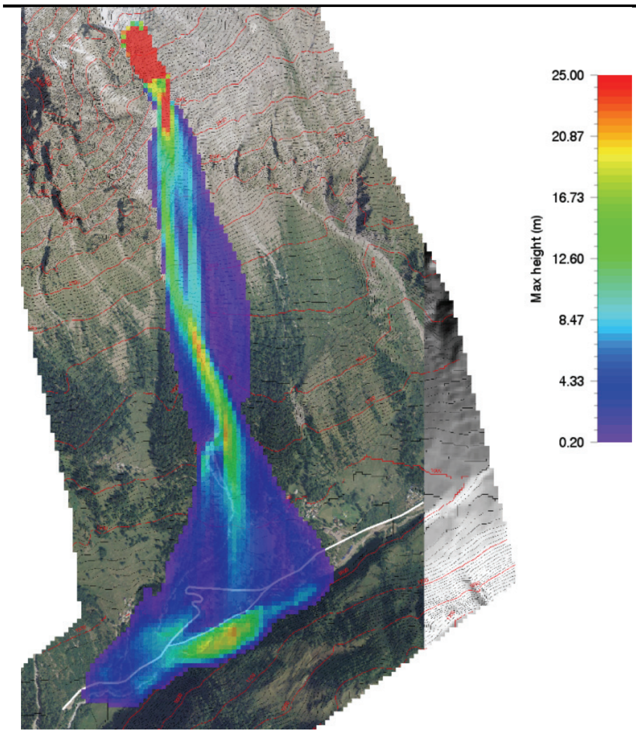
RETURN PERIOD (y): 30
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 0.600000m Rho: 200kg/m3 K: 0.200000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W9 — Ice volume 1 million m^3 / Hazard degree 2/3

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename:
D:\RAMMS\Projekte12\Ferret_2012\P1_1Mio_L100_Winter_20m_noflux_H23.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 115.000s
Real calculation time (min.): 0.216667
Simulation resolution (m): 20.0000

SIMULATION RESULTS
Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 1180455.9
Overall MAX velocity (m/s): 86.2598
Overall MAX flowheight (m): 69.7273
Overall MAX pressure (kPa): 2232.22

RAMMS: AVALANCHE 1.4.20 INPUT LOGFILE
Date: Mon Nov 12 11:38:01 2012
Input filename:
D:\RAMMS\Projekte12\Ferret_2012\P1_1Mio_L100_Winter_20m_noflux_H23.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom
GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\noflux1mio_m3.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_1MioK_1_rep.shp
Release heights:
Release nr 0: 38.00m
Estimated release volume: 1242006 m3
Eroded volume (m3): 226984.0
Total flow volume (m3): 1407439.9

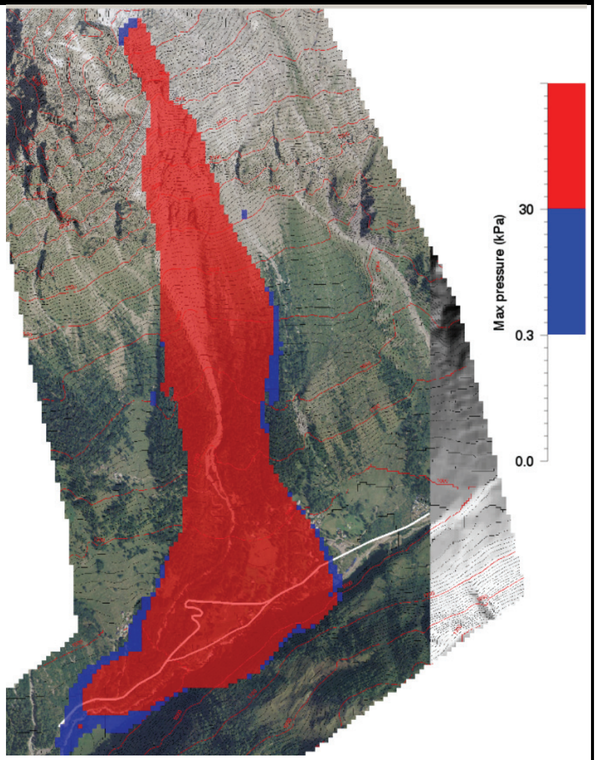
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L100_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L100_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.200 - 0.180 - 0.165
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.250 - 0.230 - 0.220
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.315 - 0.300 - 0.280
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.180 - 0.160 - 0.150
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

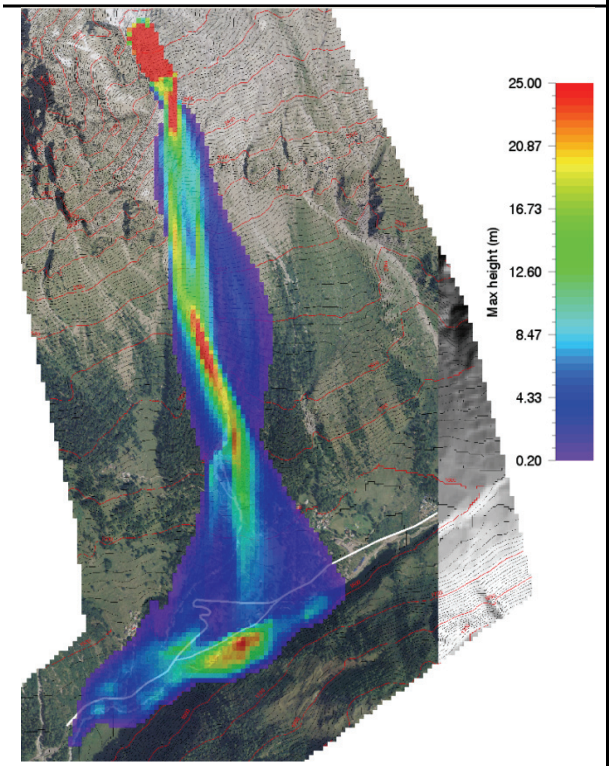
RETURN PERIOD (y): 100
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 1.00000m Rho: 200kg/m3 K: 1.00000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Scenario winter W10

Ice volume 1 million m^3 / Hazard degree 4/5

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012\P1_1Mio_L300_Winter_20m_noflux_H45.out.gz

Simulation stopped due to LOW FLUX!
Simulation stopped after 115.000s
Real calculation time (min.): 0.216667
Simulation resolution (m): 20.0000

SIMULATION RESULTS
Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 1180455.9
Overall MAX velocity (m/s): 127.937
Overall MAX flowheight (m): 69.7295
Overall MAX pressure (kPa): 4910.38

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE
Date: Mon Nov 12 11:23:48 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\P1_1Mio_L300_Winter_20m_noflux_H45.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 5.00
Stopping criteria (momentum threshold) (%): 5
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\noflux1mio_m3.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Ice_1MioK_1_rep.shp
Release heights:
Release nr 0: 38.00m
Estimated release volume: 1'242'006 m3
Eroded volume (m3): 337'292.8
Total flow volume (m3): 1'517'748.7

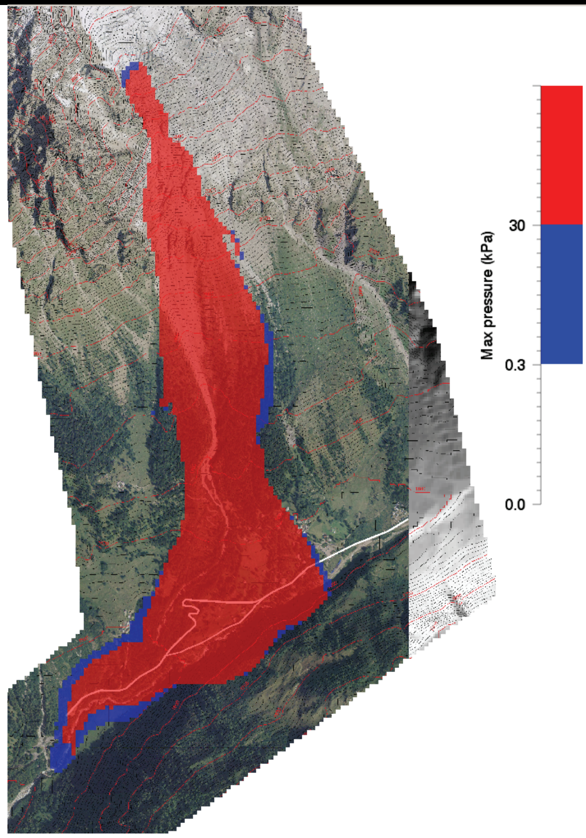
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\L300_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\L300_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.190 - 0.170 - 0.155
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.240 - 0.220 - 0.210
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.300 - 0.285 - 0.270
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.170 - 0.150 - 0.140
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

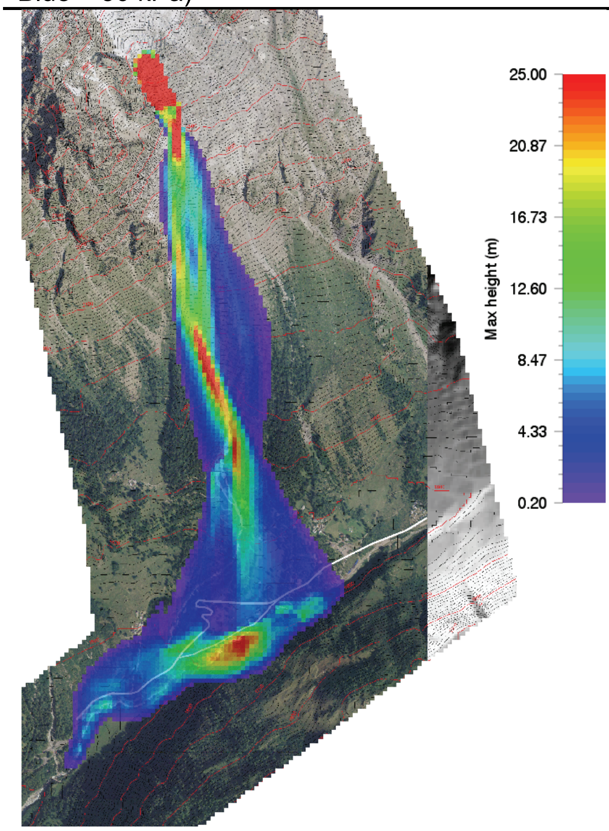
RETURN PERIOD (y): 300
VOLUME category: Large

EROSION:
Additional EROSION polygon files:
1st additional EROSION file:
D:\RAMMS\Projekte12\Ferret_2012\Entrainment_1.rel H: 1.50000m Rho: 200kg/m3 K: 1.00000
Erosion law: 0
(0: Velocity - 1: Momentum - 2: Velocity square)

MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



Appendix 8: RAMMS Simulations snow avalanches

100-year snow avalanche from the release area Glacier Planpincieux Nr. 2

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

**Output filename: D:\RAMMS\Projekte12\Ferret_2012\
Snow_Plamp2_Forest_20m_d128cm_L100_1.out.gz**

**Simulation stopped due to TIME END CONDITION!
It is possible that the runout distance would increase if calculated with increased "End time" parameter!
Real calculation time (min.): 0.366667
Simulation resolution (m): 20.0000**

SIMULATION RESULTS

**Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 295892.84
Overall MAX velocity (m/s): 149.419
Overall MAX flowheight (m): 10.5198
Overall MAX pressure (kPa): 6697.83**

**RAMMS: AVALANCHE 1.4.20 INPUT LOGFILE
Date: Tue Nov 13 18:39:04 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012\
Snow_Plamp2_Forest_20m_d128cm_L100_1.av2**

Project: Ferret_2011

**DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500**

**Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0**

**CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom**

**GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 10.00
Stopping criteria (momentum threshold) (%): 1
Constant density (kg/m3): 300
Lambda (): 1.0**

**NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel**

**RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Snow_Plamp_2_rep.shp
Release heights:
Release nr 0: 1.29m
Estimated release volume: 305496 m3**

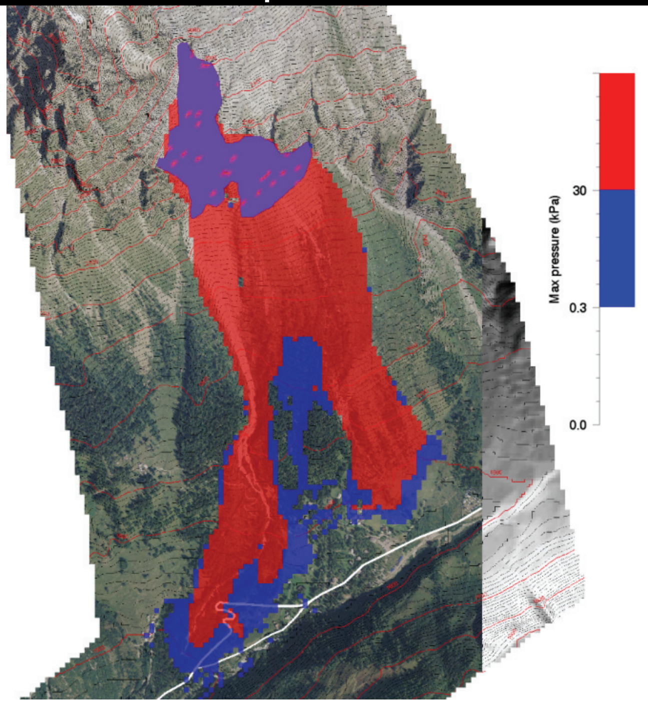
**FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\Forest_L100_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\Forest_L100_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]**

**Open slope parameters:
Mu: 0.200 - 0.180 - 0.165
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.250 - 0.230 - 0.220
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.315 - 0.300 - 0.280
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.180 - 0.160 - 0.150
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400**

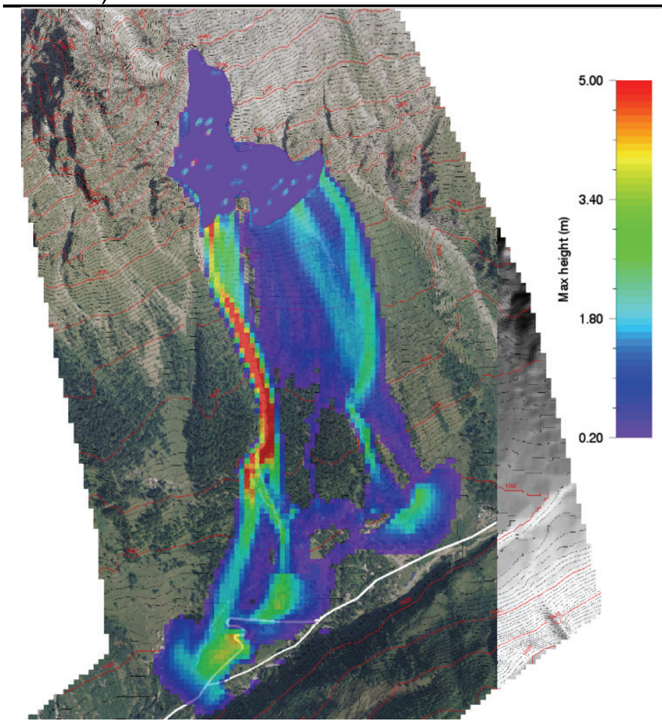
**RETURN PERIOD (y): 100
VOLUME category: Large**

**EROSION:
No EROSION specified.**

**MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif**



Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



100-year snow avalanche from the release area Glacier Planpincieux Nr. 1

RAMMS::AVALANCHE RAMMS OUTPUT LOGFILE

Output filename: D:\RAMMS\Projekte12\Ferret_2012
Snow_Plamp1_Forest_20m_d134cm_L100_1.out.gz

Simulation stopped due to TIME END CONDITION!
It is possible that the runout distance would increase if calculated with increased "End time" parameter!
Real calculation time (min.): 0.333333
Simulation resolution (m): 20.0000

SIMULATION RESULTS
Number of cells: 19418
Number of nodes: 19807
Calculated Release Volume (m3): 133005.50
Overall MAX velocity (m/s): 149.907
Overall MAX flowheight (m): 6.53639
Overall MAX pressure (kPa): 6741.67

RAMMS::AVALANCHE 1.4.20 INPUT LOGFILE

Date: Tue Nov 13 18:32:52 2012
Input filename: D:\RAMMS\Projekte12\Ferret_2012
Snow_Plamp1_Forest_20m_d134cm_L100_1.av2

Project: Ferret_2011
Info: .
DEM file: D:\RAMMS\Projekte12\Ferret_2012\Ferret_2011.xyz
DEM resolution (m): 10.00
(imported from: D:\RAMMS\DEM\mnt_jorasses2.asc)
Nr of nodes: 158316
Nr of cells: 157500

Project region extent:
E - W: 344900.00 / 341750.00
S - N: 5075800.0 / 5080800.0

CALCULATION DOMAIN:
D:\RAMMS\Projekte12\Ferret_2012\Ferret_1.dom

GENERAL SIMULATION PARAMETERS:
Simulation time (s): 400
Dump interval (s): 10.00
Stopping criteria (momentum threshold) (%): 1
Constant density (kg/m3): 300
Lambda (): 1.0

NUMERICS:
Numerical scheme: SecondOrder
H cutoff: 0.000100
Curvature effects are OFF!
D:\RAMMS\Projekte12\Ferret_2012\Noflux_20K_1.rel

RELEASE:
D:\RAMMS\Projekte12\Ferret_2012\Snow_Plamp_1_rep.shp
Release heights:
Release nr 0: 1.34m
Estimated release volume: 186110 m3

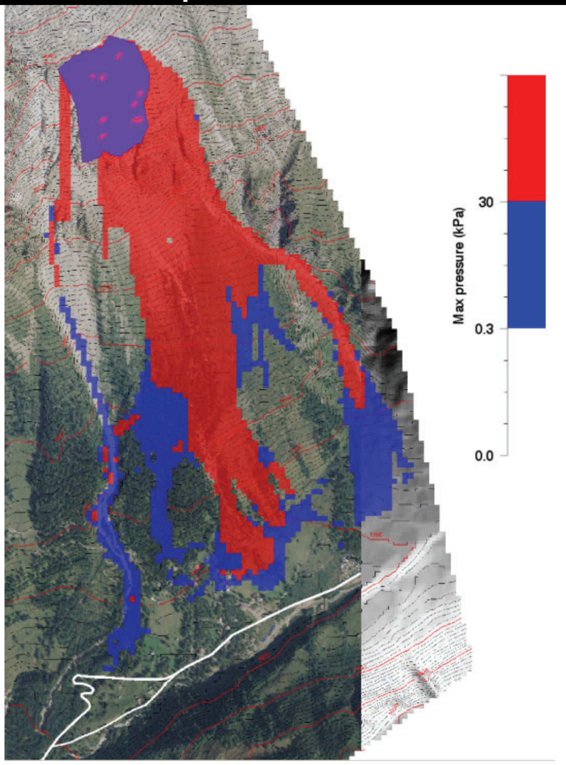
FRICTION MUXI:
D:\RAMMS\Projekte12\Ferret_2012\Forest_L100_mu.asc
D:\RAMMS\Projekte12\Ferret_2012\Forest_L100_xi.asc
Altitude limit 1: 1500m a.s.l
Altitude limit 2: 1000m a.s.l
Format of following parameters: [< 1000] - [1000 - 1500] - [> 1500]

Open slope parameters:
Mu: 0.200 - 0.180 - 0.165
Xi: 2000 - 2500 - 3000
Channelled parameters:
Mu: 0.250 - 0.230 - 0.220
Xi: 1500 - 1750 - 2000
Gully parameters:
Mu: 0.315 - 0.300 - 0.280
Xi: 1200 - 1350 - 1500
Flat parameters:
Mu: 0.180 - 0.160 - 0.150
Xi: 3000 - 3500 - 4000
Forest parameters:
Mu (delta): 0.020 - 0.020 - 0.020
Xi: 400 - 400 - 400

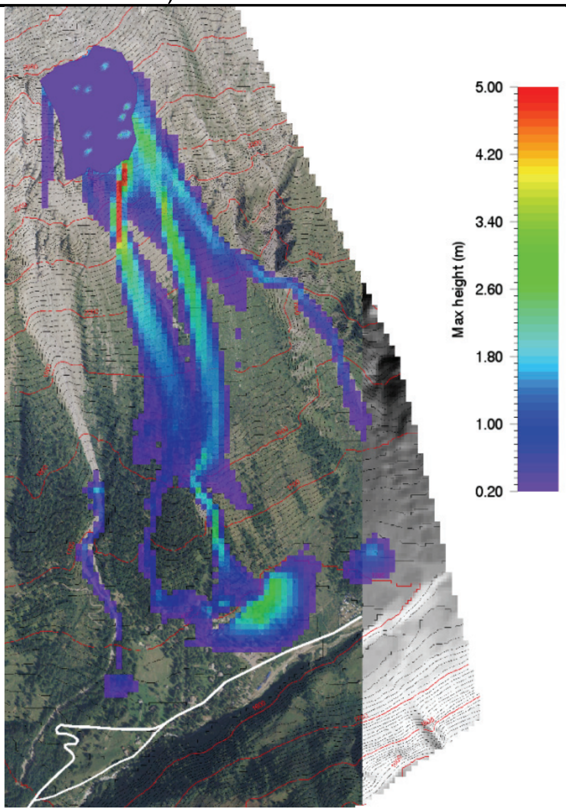
RETURN PERIOD (y): 100
VOLUME category: Large

EROSION:
No EROSION specified.

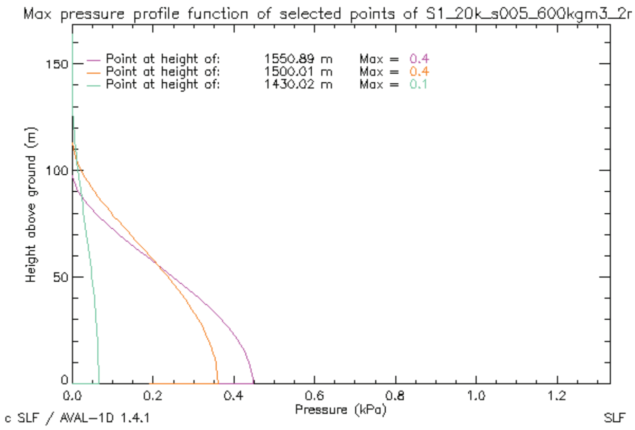
MAP / ORTHOPHOTO INFO:
Map file: D:\RAMMS\Maps\Map_Ferret_Road.tif



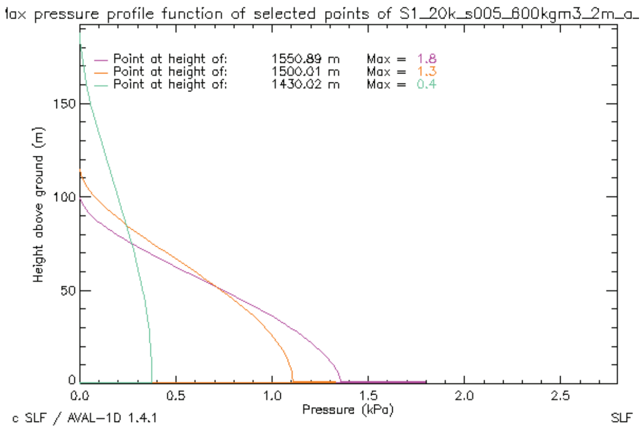
Max. pressure of the simulation (Red > 30 kPa, Blue ≤ 30 kPa)



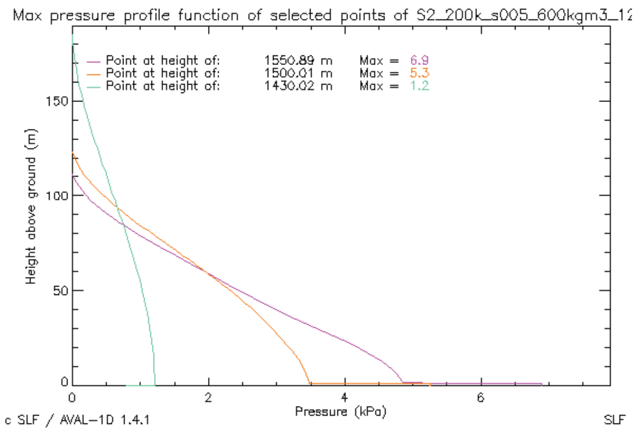
Appendix 9: Powder snow avalanche calculations with AVAL-1d – pressure profiles



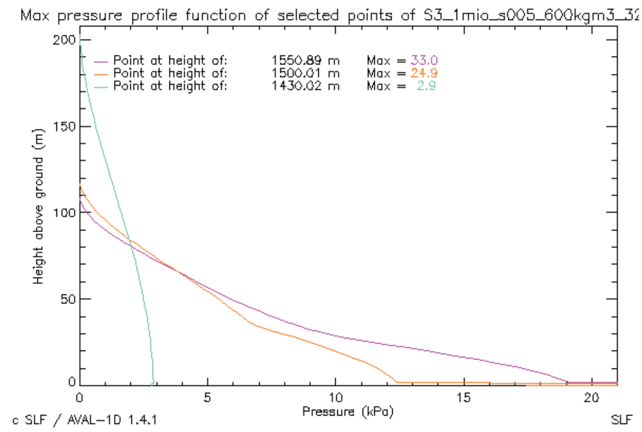
Pressure profile of the powder part of scenario S1 (ice avalanche volume 20’000 m^3) at the elevations of 1550 m, 1500 m and 1430 m.



Pressure profile of the powder part of scenario W3 (ice avalanche volume 20’000 m^3 and hazard level “considerable”) at the elevations of 1550 m, 1500 m and 1430 m.



Pressure profile of the powder part of scenario S2 (ice avalanche volume 200’000 m^3) at the elevations of 1550 m, 1500 m and 1430 m.



Pressure profile of the powder part of scenario S3 (ice avalanche volume 1 million m^3) at the elevations of 1550 m, 1500 m and 1430 m.