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Results of the 2D avalanche model SAMOS for Flateyri, Súðavík and Innri-Kirkjubólshlíð

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Contents

Background

The 2D avalanche model SAMOS, developed by the Advanced Simulation Technologies (AVL) of Graz, Austria, has been run for several starting zones in the mountains above the villages of Súðavík and Flateyri, northwestern Iceland. In addition, the model has been run for starting zones in Innri-Kirkjubólshlíð near the village of Ísafjörður. The runs are intended to shed light on the following aspects of the avalanche hazard situation in the villages:

1. The shortening of avalanche run-out due to lateral spreading.
2. The difference in run-out between avalanches from the main gullies due to the different sizes of the starting zones and different degree of lateral spreading.
3. The direction of the main avalanche tongues from the gullies.
4. The shape of the main avalanche tongues from the gullies.

The results of the runs will be used in the delineation of the hazard zones for the two villages and Innri-Kirkjubólshlíð. Similar results have previously been used for the same purpose for the villages Eskifjörður, Neskaupstaður, Seyðisfjörður, Siglufjörður, Ísafjörður and Hnífsdalur, Bolungarvík, Bíldudalur and Patreksfjörður, Ólafsvík and Ólafsfjörður (Jóhannesson *et al.*, 2001a,b, 2002a,b,c, 2003; Sigurðsson, 2004).

The SAMOS model was developed for the Austrian Avalanche and Torrent Research Institute in Innsbruck by AVL and has recently been taken into operational use in some district offices of the Austrian Foresttechnical Service in Avalanche and Torrent Control. The model is based on assumptions regarding avalanche dynamics similar to other depth integrated 2D avalanche models that are used in Switzerland and France. Friction in the dense flow part of the model is assumed to be composed of a Coulomb friction term proportional to a coefficient $\mu = \tan(\delta)$ with $\delta = 16.0^\circ (\mu = 0.287)$ and a turbulent friction term which may be represented by a coefficient $\xi = 446$ m^2/s (Sampl and Zwinger, 1999). Rather than adding the two friction components as is done in the Swiss and French 2D models, the SAMOS model uses the maximum of the two friction terms and ignores the smaller term. This leads to slightly higher modelled velocities than for the Swiss and French 2D models for avalanches with similar run-out. The velocities are, also, somewhat higher than corresponding velocities in the same path from the Swiss AVAL-1D model or the PCM model (Sauermoser, personal communication). The model runs are, furthermore, based on an assumed value $\rho = 200$ kg/m^3 for the density of flowing snow. The density is used to convert a given mass of snow in the starting zone to a corresponding volume or depth perpendicular to the terrain of the snow that is released at the start of the simulation.

A description of the applicability of the SAMOS model for Icelandic conditions can be found in the above mentioned reports about SAMOS model runs for other Icelandic villages.

Results for Flateyri

A total of 5 different avalanche starting zones were defined in the Eyrarfjall mountain above the inhabited area of Flateyri.

The starting zone classification system below is the same as the one previously used in the other villages where SAMOS similations have been carried out. Only class I was used for the Flateyri runs.

Class	Relative snowdepth	Comment
I+	2	Deep and narrow gullies near the top of the mountain
I	1	Large deep bowls or gullies near the top of the mountain
II	2/3	Shallow bowls or relatively flat areas near the top of the mountain
III	1/2	Small and shallow bowls at comparatively low elevations
IV	1/4	Other parts of the mountain with a small snow accumulation potential

Three runs with the SAMOS model were made in Flateyri. The first run was started with a uniform snow depth of 1.25 m in the starting areas and the other runs were started with a snow depth of 2.5 m in the starting areas.

The following table gives the total mass and volume of snow for each of the runs.

Input	run1	run2	run3
Snow depth in class I areas (m)	1.25	2.5	2.5
Total mass (10^3t)	95.5	61.4	129.5
Total volume (10^3m^3, ρ = 200 kg/m^3)	477.5	307.0	647.5

The mass and volume are total values for all the avalanches that were released simultaneously in the different starting zones. The snow was released simultaneously from the multiple starting zones in each run in order to simplify the model computations and in order to make them more economical in terms of computer time and time needed to set up the runs. This aspect of the simulations should not be taken to indicate that simultaneous release of this kind is likely to occur in Nature.

The following table summarises the area and the relative snow depth for each of the starting zones in Flateyri. The last column of the table lists the runs where snow was released from the zone.

Starting zone id	name	Map area (10^3m^2)	Area (10^3m^2)	Relative snow depth	Runs
1	Innra-Bæjargil	56.9	73.4	1	1,2
2	Between Innra-Bæjargil and Skollahvilft	22.0	29.4	1/2	—
3	Skollahvilft	174.0	222.4	1	1,3
4	Miðhryggsgil	38.2	48.3	1	1,2
5	Litlahryggsgil	27.4	34.5	1	1,3
Total		318.5	408.0	—	—

As in the simulations described in separate reports for the other villages where SAMOS simulations have been carried out, snow entrained in the lower part of the path is not considered in the computations. Therefore, the volume of the avalanches from each starting zone is smaller than for real, large avalanches that might be released from the corresponding part of the mountain.

The results of the 3 runs are displayed as coloured contour plots of the depth and velocity of the flowing avalanche at 10 second intervals (files `fl_run1-3.ppt` on the attached CD). The CD also contains similar files for other Icelandic villages where SAMOS computations have been carried out. Plots of the maximum dynamic pressure (given by $p = \rho u^2$) along the paths were also made (also on the CD). Some of the results are shown on Figs. 2-7 (the flow depths are in m and the maximum pressure in kPa on the figures).

Starting zone		Volume (10^3m^3)		Run-out index	
id	name	run1	run2/3	run1	run2/3
1	Innra-Bæjargil	91.8	183.5	15.5[a]	16.3
2	Between Innra-Bæjargil and Skollahvilft	—	—	—	—
3	Skollahvilft	278.0	556.0	17.5[a]	18.8
4	Miðhryggsgil	60.4	120.8	15.0[a]	16.1
5	Litlahryggsgil	43.1	86.3	15.0[a]	16.0
Total		473.3	946.6	—	—

[a]Run-out index approximated due to interaction with flow from neighbouring starting zone.

The release volume (ρ = 200 kg/m^3) and run-out index (Jónasson and others, 1999) for the avalanches from the different starting zones for each of the 3 Flateyri simulations is summarised in the table above. The columns labeled "run1" summarise the results of runs 1 and the columns labeled "run2/3" summarise the results of runs 2 and 3. The columns labeled "run1" correspond to a snow depth of 1.25 m in class I starting zones and columns labeled "run2/3" correspond to a snow depth of 2.5 m in class I starting zones.

It should be noted that the volumes given in the table are not completely consistent with the volumes given in the previous table that summarises the mass and volume of snow in each run. This discrepancy, which is in all cases is around 1%, is caused by discretisation errors in the computational grid because the delineation of the starting zones does not run along grid boundaries.

Previous simulations for other villages in Iceland (Jóhannesson and others, 2001a,b, 2002 a,b,c, 2003; Sigurðsson, 2004) showed that large bowl shaped class I starting zones, for example in Neskaupstaður, release avalanches that reach a run-out index in the approximate range 15.5–16.5 for a snow depth of 1.25 m and run-out index in the range 17–18 for a snow depth of 2.5 m. The much smaller class I starting zones in Bolungarvík produced shorter avalanches that reached run-out index 13.5–14 and 15–15.5 for snow depths of 1.25 and 2.5 m, respectively. The class II and III starting zones in Neskaupstaður produced avalanches with a run-out similar as the class I zones in Bolungarvík in some cases, whereas other starting zones, for example in Urðarbotn, released avalanches with an intermediate run-out index of about 15 for runs with a class I snow depth of 1.25 m.

Innra-Bæjargil and Skollahvilft are probably the most dangerous avalanche tracks above settled areas in Iceland.

The modelled avalanches from Innra-Bæjargil (labeled 1) reach run-out index about 15.5 and 16.3, respectively, for the small and large SAMOS runs. The simulated avalanche from Innra-Bæjargil in the smaller run interacts partly with the avalanche from Skollahvilft (labeled 3). As a consequence the run-out is approximated for that run.

The run-out of the simulated avalanches from Skollahvilft is about 17.5 and 18.8 for the small and large SAMOS runs, respectively. This run-out is very long compared to other villages in Iceland where the simulation has been carried out.

SAMOS runs were not made for the starting zone between Innra-Bæjargil and Skollahvilft (labeled 2).

The avalanches from starting zones 4 and 5 reach run-out index about 15 and 16 for the small and large SAMOS runs, respectively.

The simulations in Innra-Bæjargil and Skollahvilft reach well into the settlement. In 1998, deflecting dams were built to deflect avalanches from the settlement (see location map for Flateyri). The dams are not taken into account in the SAMOS runs. The simulations from starting areas 4 and 5 reach beyond the shoreline.

Results for Súðavík

A total of 9 different avalanche starting zones were defined in the mountains above the inhabited area of Súðavík.

The same starting zone classification system was used as described above in the section about the Flateyri simulations.

Three runs with the SAMOS model were made in Súðavík. The first run were started with a uniform snow depth of 1.25 m in class I starting areas and the other runs were started with a snow depth of 2.5 m in class I starting areas. The snow depth in all the runs was determined from the relative snow depth class for the respective areas as given in the snow depth classification table in the previous section.

The following table gives the total mass and volume of snow for each of the runs.

Input	run1	run2	run3
Snow depth in class I areas (m)	1.25	2.5	2.5
Total mass (10^3t)	84.4	78.5	109.5
Total volume (10^3m^3, ρ = 200 kg/m^3)	422.0	392.5	547.5

The mass and volume are total values for all the avalanches that were released simultaneously in the different starting zones as described above in the section about Flateyri.

The following table summarises the area and the relative snow depth for each of the starting zones in Súðavík. The last column of the table lists the runs where snow was released from the zone.

Starting zone id	name	Map area ($10^3 m^2$)	Area ($10^3 m^2$)	Relative snow depth	runs
1	Kofri	17.7	21.0	1/2	1,2
2	Kofri	6.7	8.2	1/2	1,3
3	Traðargil	31.5	38.6	1	2
4	Sauratindar	22.8	28.4	1	1,2
5	Sauratindar	36.8	45.2	1/2	1,3
6	Traðargil	25.3	28.8	1/2	1,2
7	Traðargil	62.5	74.8	1	1,3
8	Súðavíkurhlíð	47.9	64.7	1	1,2
9	Súðavíkurhlíð	86.3	117.0	1	1,3
Total		337.4	426.7	—	—

As described in the previous section about Flateyri, snow entrained in the lower part of the path is not considered in the computations. Therefore, the volume of the avalanches from each starting zone is smaller than for real, large avalanches that might be released from the corresponding part of the mountain.

The results of the 3 runs are displayed as coloured contour plots of the depth and velocity of the flowing avalanche at 10 second intervals (files `su_run1-3.ppt` on the attached CD). The CD also contains similar files for other Icelandic villages where SAMOS computations have been carried out. Plots of the maximum dynamic pressure (given by $p = \rho u^2$) along the paths were also made (also on the CD). Some of the results are shown on Figs. 9-14 (the flow depths are in m and the maximum pressure in kPa on the figures).

Starting zone id	name	Volume ($10^3 m^3$) run1	Volume ($10^3 m^3$) run2/3	Run-out index run1	Run-out index run2/3
1	Kofri	13.1	26.3	14.0	14.6
2	Kofri	5.1	10.3	13.8	14.4
3	Traðargil	—	96.5	—	≈16
4	Sauratindar	35.5	71.0	14.3	15.4
5	Sauratindar	28.3	56.5	12.0	13.4
6	Traðargil	18.0	36.0	—	15.1
7	Traðargil	93.5	187.0	—	16.4
8	Súðavíkurhlíð	80.9	161.8	14.7	15.9
9	Súðavíkurhlíð	146.3	292.5	16.2	>17[a]
Total		420.7	937.8	—	—

[a]The avalanche terminates beyond the computational grid

The release volume (ρ = 200 kg/m^3) and run-out index (Jónasson and others, 1999) for the avalanches from the different starting zones in the mountains for each of the 3 Súðavík simulations is summarised in the table above. The “run1” column corresponds to a class I snow depth of 1.25 m and the “run2/3” column corresponds to a snow depth of 2.5 m in class I starting zones.

As noted in the section about Flateyri, the volumes given in the table are not completely consistent with the volumes given in the previous table that summarises the mass and volume of snow in each run due to small discretisation errors in the computational grid.

The simulated run-out at Traðargil and Súðavíkurhlíð is comparable to the modelled run-out from large bowl shaped class I starting areas in some of the other communities where SAMOS simulations have been carried out.

The avalanches from Traðargil (labeled 3, 6 and 7) reach run-out index in the approximate range 15.1–16.4) for the large SAMOS run. A run-out index is not given for the smaller run from the starting zones in Traðargil due to interaction between the avalanches.

The modelled avalanches from starting zone 8 in Súðavíkurhlíð reach run-out 14.7 and 15.9 for the small and large SAMOS runs, respectively. The run-out index from the smaller run from starting zone 9 in Súðavíkurhlíð is 16.2 but the avalanche from the larger run from that zone runs beyond the computational grid and therefore a run-out index cannot be determined for them in the same way as for the others subareas.

The modelled avalanches from the other starting zones (1, 2, 4 and 5) is comparatively short. The run-out in Kofri mountain is 13.8 and 14.6 for the small and large SAMOS runs, respectively, and the run-out in Sauratindar mountain is 14.3 and 15.4 from starting zone 4 and 12.0 and 13.4 from starting zone 5 for the small and large SAMOS runs, respectively.

The avalanches from Innra-Bæjargil and Súðavíkurhlíð reach well into the old settlement (northern part) and beyond the shoreline. None of the avalanches threaten the new settlement (southern part).

Results for Innri-Kirkjubólshlíð

A total of 12 different avalanche starting zones were defined in Innri-Kirkjubólshlíð near the village of Ísafjörður.

The same starting zone classification system was used as described in the above sections.

Three runs with the SAMOS model were made in Innri-Kirkjubólshlíð. The first and third runs were started with a uniform snow depth of 1.25 m in class I starting areas and the second run was started with a snow depth of 2.5 m in class I starting areas. The snow depth in all the runs was determined from the relative snow depth class for the respective areas as given in the snow depth classification table in the previous section.

The following table gives the total mass and volume of snow for each of the runs.

Input	run1	run2	run3
Snow depth in class I areas (m)	1.25	2.5	1.25
Total mass (10^3t)	199.8	399.5	114.6
Total volume (10^3m^3, ρ = 200 kg/m^3)	999.0	1997.5	573.0

The mass and volume are total values for all the avalanches that were released simultaneously in the different starting zones as described in the above sections.

The following table summarises the area and the relative snow depth for each of the starting zones in Innri-Kirkjubólshlíð. The last column of the table lists the runs where snow was released from the zone.

Starting zone id	name	Map area (10^3m^2)	Area (10^3m^2)	Relative snow depth	runs
1	Naustahvilft	60.3	82.4	1	1,2,3
2	Naustahvilft	38.3	61.3	1	1,2
3	Naustahvilft	27.8	34.4	2/3	1,2
4	Naustahvilft	19.4	25.6	1	1,2
5	Innri-Kirkjubólshlíð	55.8	83.4	1	1,2,3
6	Innri-Kirkjubólshlíð	44.7	65.9	1	1,2
7	Innri-Kirkjubólshlíð	82.9	117.6	1	1,2,3
8	Innri-Kirkjubólshlíð	28.8	40.4	1	1,2
9	Innri-Kirkjubólshlíð	52.2	74.2	1	1,2,3
10	Innri-Kirkjubólshlíð	50.9	68.4	1	1,2
11	Kirkjubólshvilft	72.4	98.5	1	1,2,3
12	Kirkjubólshvilft	39.6	56.1	1	1,2
Total		573.1	808.2	—	—

As described in the previous sections, snow entrained in the lower part of the path is not considered in the computations. Therefore, the volume of the avalanches from each starting zone is smaller than for real, large avalanches that might be released from the corresponding part of the mountain.

The results of the 3 runs are displayed as coloured contour plots of the depth and velocity of the flowing avalanche at 10 second intervals (files `ik_run1-3.ppt` on the attached CD). The CD also contains similar files for other Icelandic villages where SAMOS computations have been carried out. Plots of the maximum dynamic pressure (given by $p = \rho u^2$) along the paths were also made (also on the CD). Some of the results are shown on Figs. 16-21 (the flow depths are in m and the maximum pressure in kPa on the figures).

Starting zone		Volume ($10^3 m^3$)		Run-out index	
id	name	run1/3	run2	run1/3	run2
1	Naustahvilft	103.0	206.0	15.6	—
2	Naustahvilft	76.6	153.3	—	—
3	Naustahvilft	28.6	57.1	—	—
4	Naustahvilft	32.0	64.0	—	—
5	Innri-Kirkjubólshlíð	104.3	208.5	15.9	17.5
6	Innri-Kirkjubólshlíð	82.4	164.8	16.0	17.5
7	Innri-Kirkjubólshlíð	147.0	294.0	16.0	17.5
8	Innri-Kirkjubólshlíð	50.5	101.0	13.7[a]	15.5[a]
9	Innri-Kirkjubólshlíð	92.8	185.5	16.1	17.7
10	Innri-Kirkjubólshlíð	85.5	171.0	14.9[a]	16.4[a]
11	Kirkjubólshvilft	123.1	246.3	14.8	—
12	Kirkjubólshvilft	70.1	140.3	—	—
Total		995.8	1991.6	—	—

The release volume (ρ = 200 kg/m^3) and run-out index (Jónasson and others, 1999) for the avalanches from the different starting zones in the mountains for each of the 3 Innri-Kirkjubólshlíð simulations is summarised in the table above. The "run1/3" column corresponds to a class I snow depth of 1.25 m and the "run2" column corresponds to a snow depth of 2.5 m in class I starting zones.

As noted in the previous sections, the volumes given in the table are not completely consistent with the volumes given in the previous table that summarises the mass and volume of snow in each run due to small discretisation errors in the computational grid.

Most of the starting zones in Naustahvilft, Innri-kirkjubólshlíð and Kirkjubólshvilft have been defined as class I. Starting zone 3 has been defined as class II.

The run-out index is not given for most of the starting zones in Naustahvilft (labeled 1–4) because interaction between the avalanches from this area makes it impossible to determine the run-out. The run-out from starting zone 1 is 15.6 for the smaller run.

For most of the starting zones in Innri-Kirkjubólshlíð (labeled 5–10) the run-out index is about 16.0 and 17.5, respectively, for the small and large SAMOS runs. Due to interaction between avalanches, the run-out is approximated for starting zones 8 and 10 but it seems to be shorter than for avalanches from the other starting zones. Some of the starting zones cover several gullies and the interaction between avalanches from neighbouring gullies may increase the run-out slightly.

The simulated avalanches from the starting zones in Kirkjubólshvilft (labeled 11 and 12) interact with each other. Therefore, nothing but the run-out index for the smaller run in starting zone 11 is given, which is 14.8.

The avalanches from Naustahvilft and the outer part of Innri-Kirkjubólshlíð reach well beyond the shoreline.

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Figures

Figure 1. Location map for Flateyri.

Figure 2. Simulated final snow depth for run 1 in Flateyri.

Figure 3. Simulated final snow depth for run 2 in Flateyri.

Figure 4. Simulated final snow depth for run 3 in Flateyri.

Figure 5. Simulated maximum dynamical pressure for run 1 in Flateyri.

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Figure 8. Location map for Súðavík.

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Figure 12. Simulated maximum dynamical pressure for run 1 in Súðavík.

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Figure 19. Simulated maximum dynamical pressure for run 1 in Innri-Kirkjubólshlíð.

Figure 20. Simulated maximum dynamical pressure for run 2 in Innri-Kirkjubólshlíð.

Figure 21. Simulated maximum dynamical pressure for run 3 in Innri-Kirkjubólshlíð.