VEÐURSTOFA
ÍSLANDS

Report
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Hazard zoning for Bíldudalur, Vesturbyggð

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Contents

1 Introduction

This report is an assessment of avalanche hazard for the village Bíldudalur which is within the community of Vesturbyggð. It was carried out by the Icelandic Meteorological Office (IMO). The assessment is done according to a regulation on hazard zoning due to avalanches and landslides, classifications and utilization of hazard zones, and preparation of provisional hazard zoning issued by the Ministry for the Environment in July 2000.

Similar reports have been published for Neskaupstaður, Siglufjörður, Seyðisfjörður, Eskifjörður, Ísafjörður/Hnífsdalur (Thorsteinn Arnalds *et al.* 2001a,b,c, 2002a,b,c), Bolungarvík and Patreksfjörður (Kristján Ágústsson *et al.* 2002, 2003).

1.1 Work process

The main participants in this work were Kristján Ágústsson, Tómas Jóhannesson, Hörður Þór Sigurðsson, Þorsteinn Arnalds, Esther H. Jensen (IMO), Siegfried Sauermoser (Austrian Forest-technical Service), Thomas Glade and Rainer Bell (University of Bonn).

Other employees of IMO have also contributed to the work. Þóranna Pálsdóttir has investigated the climatic conditions of the region. Leah Tracy has drawn maps in the report and the local snow observer, Jón Rúnar Gunnarsson, assisted in the field work

Halldór G. Pétursson (Icelandic Institute of Natural History) has compiled debris flow chronicles (Halldór G. Pétursson 2000).

Sólrún Geirsdóttir (Natural Research Center of the NW Peninsula of Iceland) has collected information on the development of the settlement as well as the history of individual houses (Sólrún Geirsdóttir 2000).

The work on this project started in the summer of 2000. A field investigation was carried out in the autumn of 2000 when Siegfried Sauermoser and Kristján Ágústsson mapped the potential avalanche paths. Esther H. Jensen, Thomas Glade and Rainer Bell investigated debris flow and rockfall conditions.

The following items were the subject of the field investigations regarding avalanche conditions:

a) *Topographic conditions, i.e.* the topography of the starting zone, track and runout area.

b) *Climatic conditions* would be dealt with mostly on a regional basis, but locally the effect of the regional climate on snow accumulation in starting areas would be discussed.

c) *Assessment*. The group would give its general opinion of the avalanche hazard in a particular path. This would be done by quantifying the size of the starting areas and their relative frequency with respect to other paths.

These descriptions form the basis of the final report presented here.

In the debris flow and rockfall investigation (Glade and Esther H. Jensen 2003), similarly, potential starting areas and runout zones were mapped and the recurrence time estimated.

A hazard zoning committee for Vesturbyggð was formally established 23.04.2003. The first meeting of the committee with the IMO staff was held on 14.04.2003.

To strengthen the basis of the hazard zoning, two-dimensional model calculations were carried out by Advanced Simulation Technologies (AVL) of Graz, Austria (Leah Tracy and Tómas Jóhannesson, 2003).

Based on the background data described above the hazard zones were delineated. The delineation was done by Kristján, Tómas, Hörður Þór and Esther.

1.2 Organisation of the report

The first part of the report is an overview of the general topographic and climatic conditions in the area and a review of the settlement history and former work on hazard related investigations. The investigated area is shown on Map 1.

The next 5 sections contain more detailed description of avalanche areas in Bíldudalur in which following items are addressed:

Topographic conditions: Physical characteristics of the starting zone, track and runout area.

Local climatic conditions: Characteristics of the starting areas with respect to snow accumulation.

Chronicle: A short review of the avalanche history.

Assessment: Discussion of the avalanche conditions and qualitative hazard analysis.

Model estimates: Model results are the basis of the hazard zoning.

Conclusion: Hazard evaluation and proposed hazard zoning.

Finally, there is a summary of the results of the project.

There are five appendices in the report. In appendix A technical concepts and notations are explained. Those are parameters like runout indices (r) and runout angle (α). Further, definitions of α- and β-points and a description of the α/β-model. A short description of recorded avalanches is given in appendix B and maps are in appendix C. Appendix D contains climatic data and appendix E contains the longitudinal sections of the profiles and the results of runout modeling.

1.3 Methodologies and regulations

The hazard zoning presented in this report is based on Icelandic hazard zoning regulations that were issued in July 2000 after having been under development for several years. A summary of these regulations is included below.

Table 1. *Icelandic hazard zone definitions*

Zone	**Lower level of local risk**	**Upper level of local risk**	**Construction allowed**
C	$3 \cdot 10^{-4}$/yr	–	No new buildings, except for summer houses*, and buildings where people are seldom present.
B	$1 \cdot 10^{-4}$/yr	$3 \cdot 10^{-4}$/yr	Industrial buildings may be built without reinforcements. Domestic houses have to be specially reinforced. Existing hospitals, schools *etc*. can be enlarged and then have to be specially reinforced.
A	$0.3 \cdot 10^{-4}$/yr	$1 \cdot 10^{-4}$/yr	Houses where large gatherings are expected, such as schools, hospitals *etc*., have to be specially reinforced.

*If the risk is less than $5 \cdot 10^{-4}$ per year.

Hazard zoning in Iceland has since 1995 been based on individual risk which is the yearly probability that a person living at a given place will be killed by an avalanche. The definition of hazard zones is based on the *local risk* defined as the annual probability of being killed given that a person is staying all the time in a house which is not specially reinforced. The *actual risk* can be found by taking into account the probability of the person being present in a house when an avalanche hits and the increased safety obtained by reinforcing houses. Increased safety by evacuations and other non-permanent safety measures is not taken into account in the hazard zoning. The authorities in Iceland have adopted the value $0.2 \cdot 10^{-4}$ per year as an accepted actual risk for avalanche hazard zoning (The Ministry for the Environment, 1997). This value corresponds to different values of the local risk for different types of constructions depending on the fraction of time people may be expected to spend in the buildings (typical values are assumed to be 75% in domestic houses, and 40% in commercial buildings). The regulations on hazard zoning (The Ministry for the Environment, 2000) defines three types of hazard zones, see Table 1.

These guidelines for zoning are tailored to attain the acceptable risk level of $0.2 \cdot 10^{-4}$ per year in residences when presence probability and increased safety provided by special reinforcements have been taken into account. The risk in industrial buildings is probably somewhat higher.

The methodology used here to estimate avalanche risk was developed at the University of Iceland and the Icelandic Meteorological Office in the period 1995–1998. The methods, called RiskEst, are described by Kristján Jónasson *et al*. (1999).

The methodology for hazard zoning with regard to debris flows and rockfall is described by Tómas Jóhannesson and Kristján Ágústsson (2002) and summarised in the following section.

This discussion is concluded by quoting §10 of the Icelandic regulations on how to proceed where formal risk calculation is impossible: “In areas, where it is not possible to estimate the risk formally due to insufficient information, a hazard map shall nevertheless be prepared according to

§12 [§12 describes the risk zones of a hazard map]. In the preparation of the map an attempt shall be made to estimate risk.”

1.4 General guidelines regarding debris flows, rockfall, slushflows and torrents

Hazard zones in Iceland shall according to the hazard zoning regulation of July 2000 (Ministry for the Environment, 2000) take into account hazard due to debris flows and other landslides, rockfall and torrents in addition to snow avalanches and slushflows. Guidelines for hazard zoning with regard to such processes have been formulated by IMO (Tómas Jóhannesson and Kristján Ágústsson, 2002). The guidelines attempt to formulate a zoning procedure where the delineation of hazard zones reflects the risk that people are exposed to due to the respective events.

The principle problem encountered in this type of hazard zoning is how to treat the risk in areas where neither the landslide chronicle nor geological investigations directly indicate an impeding danger to the settlement. Another problem is the widely different probability of death for people that encounter the different types of events. It is, for example, clear that typical torrents in Iceland pose a much smaller risk to the lives of people than snow avalanches. Thus, the probability or return period corresponding to a set value of acceptable risk is widely different for the different events.

According to the guidelines, the landslide chronicle and geological investigations are first used to identify potential areas of high risk where the danger of catastrophic landslide events may be directly inferred from such investigations. The delineation of hazard zones with regard to the results of these investigations cannot be formulated beforehand and must be subjectively determined by the experts performing the zoning.

It is assumed that hazard zones with regard to *rockfall* will typically be of type A (the lowest risk zones), except in special circumstances where the danger of rockfall is judged very high. It is recommended that the hazard line with regard to rockfall is drawn where the return period of rockfall is on the order of 50–100 years. This return period should reflect an area of the size of a building or a typical lot on which a building stands. This location may be estimated by a statistical or a dynamical rockfall model. The model should be calibrated to reproduce the runout distance corresponding to observed loose rocks below source areas of rockfall that have fallen during the last decades or century.

The guidelines propose following classification for slush flow and debris flow paths.

1. **A well confined path of a river or a brook** such that a landslide may be expected to be largely limited to the course of the river. A less powerful part of it may overflow the banks and spread into nearby areas. The area of the watershed of paths in this class is on the order of 10–30 hectares up to and over 100 hectares and extreme floods may range from a few m^3/s up to tens of m^3/s.

2. **A partly confined path of a river or a brook** where landslides do not follow a predeter-

mined direction and may take different directions when they enter the endangered area. The area of the watershed and the size of extreme floods is similar as in class 1.

3. **A gully or the path of a small brook** which may be dry for a part or most of the year. The watersheds of these paths are smaller than in the first two classes, *i.e.* on the order of a hectare or a few hectares, and extreme floods are on the order of a m^3/s or less.

The guidelines propose that type C hazard zones will in general be delineated for the central parts of paths of class 1, type B hazard zones will be defined for the wide paths of type 2 and type A hazard zones in areas affected by paths of type 3. A delineation of watersheds and an estimation of extreme floods in the main rivers and brooks of the mountainside is recommended as a part of the preparation of a hazard zoning for paths of this kind.

In some areas there is a danger of *debris flows* outside of the courses of rivers or brooks that are classified above. Unless there are special indications of high danger, such debris flows are considered to be much less dangerous than snow avalanches. The guidelines propose that the hazard line with regard to debris flows in such areas corresponds to a return period of several hundred years, *i.e.* a much shorter return period than for snow avalanches but longer than for rockfall.

According to the guidelines, river floods should only be considered in steep paths where there is a danger of debris flows or slushflows. General river flooding problems are not to be considered as a part of the snow- and landslide hazard zoning according to the Icelandic hazard zoning regulation of July 2000.

In Bíldudalur debris flows have caused material damage and they are considered to pose a threat to human lives. Rockfall is frequent and large boulders have recently fallen down the slope and caused damage.

1.5 Uncertainty

The estimation of avalanche risk is difficult in many areas. This is especially the case when dealing with a slope that from the topographical point of view has the characteristics of an avalanche path, but where no avalanches have been recorded. Accurate records of avalanches have only been kept for a few years or decades in many areas and the settlement may be quite recent. In such a situation, it is almost impossible to rule out the possibility that an avalanche hitting the settlement might be released from the slope. An attempt must then be made to strike a compromise that balances the lack of recorded avalanches and the possibility of avalanche release.

Another problem that must be addressed is the estimation of avalanche hazard in non-typical or low avalanche tracks. The available data about Icelandic avalanches was mostly collected from hills between 500 and 800 m high with large starting areas. The runout potential of avalanches from smaller slopes, both with a lower fall height and smaller starting areas, is not as well investigated.

While delimiting the hazard zones, an attempt has been made to classify the uncertainty in each area by dividing the uncertainty into three classes according to the level of uncertainty in the

Figure 1. *Overview of the area around Bíldudalur. Meteorological stations are marked with red circles. © The National Land Survey of Iceland.*

area. An uncertainty of $\frac{1}{2}$ means that the estimation could be wrong by half a hazard zone, *i.e.* the hazard lines may misalign by approximately $\frac{1}{2}$ of a hazard zone. Since the risk varies by a factor of 3 between the risk lines of the hazard map, the risk may be over- or underestimated by factor of $\sqrt{3}$. Similarly, classes 1 and 2 certainty mean that the zoning could be wrong by 1 and 2 zones in either direction, respectively, meaning that the risk could be over- or underestimated by factor of 3 or 3^2 respectively. Considering the “nominal” nature of avalanche risk estimates, it is not possible to attach a given significance level in a statistical sense to these uncertainty indicators. They are intended to mean that the work group considers it “unlikely” that the risk is over- or underestimated by the indicated uncertainty, but the meaning of “unlikely” is not further quantified.

The three chosen classes of uncertainty and their characteristics are:

$\frac{1}{2}$ Records of avalanches are available and the avalanche path is large and typical.

1 Some records of avalanches are available and the avalanche path is small or atypical.

2 No records of avalanches are available, but the topography indicates avalanche hazard.

The uncertainty of hazard zoning in areas where protective measures have been built will probably be in class 1 or 2.

Figure 2. *Bíldudalur and the name of the main landmarks. (Photo: © Mats Wibe Lund).*

2 General

The tertiary geological formation of Iceland consists, in general, of a relatively flat, layered basaltic lava pile. Individual lava layers are separated by sedimentary layers which are made of fossil soils, lake deposits, eroded material and scoria. The thickness of both types of layers varies from a few meters to some tens of meters. Generally the lava beds are thicker than the sedimentary layers.

The characteristic erosional form in these areas is a stepped profile of the upper part of the mountainside. The cliffs and cliffbands are made of individual thick lavas or a sequence of thinner lava layers separated only by scoria. The shelfs between the cliffs, usually gently sloping and covered with debris and in some cases vegetation, are the sedimentary layers. Below a talus is formed by rockfall from the cliffs. In the talus the size of stones and blocks increases downwards. Some lava layers are more competent than others and form cliffbands along the mountainside within the talus zone. The longitudinal section of an undisturbed slope below the cliffs is typically parabolic in shape.

Generally the slopes are cut by several gullies. They can be separated into two main types. First, small elongated depressions in the cliffs below the edges of the mountains with small and unclearly defined debris cones below. Second, large bowls in the cliffs which open in narrow gullies or canyons in the lowest part of the cliffs or the talus zone. Large debris cones have accumulated at the foothill below gullies of this type. The location and direction of the large gullies is mainly tectonically dependent and, to some extent, also their size.

Above the edges of the mountains there are in many cases large plateaus which are remnants of an old peneplain. These plateaus serve as catchment areas of snow which accumulates in the gullies below during snowdrift and snowstorms.

The NW part of Iceland as well as the E part are of tertiary age.

2.1 Topographic description

Bíldudalur is a valley on the NW peninsula of Iceland, Vestfirðir, and it opens into the inner part of the large fjord Arnarfjörður (Fig. 1). Its trend is NE-SW and at its NE end there is a bay, Bíldudalsvogur. The village of Bíldudalur is located below the mountain Bíldudalsfjall along the NW shoreline of Bíldudalsvogur bay (Fig. 2). Bíldudalsfjall is typical for the description made in the previous section. The mountainside is trending NE-SW as the main line of the valley. From the edge of about 450 m a.s.l. and down to 300 m a.s.l. there are cliffs with inclination of 45–55° on the average. Below, there are screes with individual cliffbelts and the inclination is 30–40°. Two large gullies cut the mountainside above the settlement. The inner one is Gilsbakkagil and the outer one is Búðargil. Both gullies have a E-W trend but the bottom curves slightly to the S (convex to N). Outwards (NE) of Búðargil the trend of the mountainside turns to more N-erly direction and outside of the village it gradually reaches NW direction. The cliffs are cut by smaller gullies, both on the even slope along the main trend of the mountainside as well as on the sides of the large gullies. The part of the slope between the large gullies is called Milligil in this report. The gullies in that area are relatively shallow. Below the large gullies there are large debris cones starting at 100–120 m a.s.l. and reach beyond the shore. Below the Milligil there are debris cones of considerable size, though small compared to the debris cones below the large gullies. The top of those cones is at slightly lower level than than the top of the cones below the large gullies. Above the edge of Bíldudalsfjall there is a plateau of 500 m width to the next valley which is parallel to the Bíldudalur valley. The village of Bíldudalur is located on the debris cones from the large gullies and debris from the Milligili gullies.

2.2 History of the settlement

Bíldudalur is a traditional trade center from old times. The tradesman Pétur Thorsteinsson took the trade in Bíldudalur over in 1880. At that time there was only one residential house and some warehouses in the area. The population grew rapidly during the next two decades and in 1901 317 persons were registered in Bíldudalur. The population grew to maximum of about 350 inhabitants at the end of the fourth decade of the twentieth century. Today, the number of inhabitants is around 240.

2.3 Chronicle

On Map 2 recorded avalanches, slushflows, flashfloods, debris flows and rockfall are shown and Appendix B contains a list of the events including a brief description of each. A more detailed description is given in the landslide and avalanche chronicle of Bíldudalur (IMO, 2003).

There have not been casualties in these events in Bíldudalur but they have caused a great material damage.

Snow avalanches and slushflows

In January 1902 an avalanche fell from Búðargil. It hit a domestic house and moved it on its foundation and caused considerable damage to the interior.

A slushflow was released from Búðargil in February 1939. It reached the shore and a man that was caught by it and carried out to the sea was rescued.

In Mars 1969 an avalanche fell from the Milligil area adjacent to Gilsbakkagil. It hit a house and caused considerable damage.

In January 1981 an avalanche was released in Búðargil and it damaged the constructions for electrical supply such that the electrical distribution was temporarily out of order.

In January 1983 a slushflow fell from Búðargil. It stopped just above the settlement and broke a sheepshed and killed 33 sheep. It broke powerlines and a workshop and damaged an avalanche defence wall.

In February 1989 an avalanche fell from Búðargil and damaged powerlines.

In may 1990 a slushflow was released from Búðargil. Powerlines, transformers and roads were damaged.

In January 1997 a slushflow was released from Búðargil and two slushflows were released from Gilsbakkagil. The first flow from Gilsbakkagil caused a damage in a garage.

In March 1998 two slushflows were released from Gilsbakkagil. The first one was larger and caused some damage.

In February 1999 several small avalanches fell from Bíldudalsfjall. Among others, avalanches were released from Búðargil, Milligil and Gilsbakkagil.

Debris flows, rockfall and flashfloods

There are sources which indicate that a debris flow in 1797 hit a sheepshed at the farm Hóll which is just inside of the present village of Bíldudalur. It killed all the sheep at the farm.

In June 1920 a flashflood came from the gully Búðargil and damaged some goods and boats at the shore.

In December 1931 three debris flows were released in the Milligil area. Two flows reached the shore and caused material damage. The third one stopped above the settlement.

Between 1930 and 1940 a debris flow fell from the innermost Milligil. It stopped below the road Dalbraut but caused no damage.

In 1937 and 1942 debris flows hit the house Jaðar (Lönguhlíð 43).

In 1950 a flashflood fell from Búðargil. The same year a debris flow was released from Merkigil (in Milligil).

In January 1959 a debris flow fell from Gilsbakkagil. It hit the house Sælundur and went over fields and damaged the road. The same day a debris flow fell from Búðargil and reached the shore. It caused consideral material damage.

In August 1968 a debris flow fell from Klofagil (Milligil). It damaged fields and fences. The same day another debris flow fell from Merkigil (Milligil).

In 1971 a rock hit the house at Langahlíð 20 and smashed a bed. Nobody was injured.

In November 1976 two debris flows were released from Klofagil (Milligil).

In October 1985 two debris flows were released from Milligil.

2.4 Previous investigations and hazard assessments

In 1983 Hafliði Helgi Jónsson and Helgi Björnsson (1983) investigated the situation after the slushflows in January that year.

In 1990 a geological investigation to estimate the debris flow danger was carried out by the Stuðull consulting engineers (1990). Defence structures are proposed in the report that was written about the investigations. VST consulting engineers made a preliminary investigation of slushflow defence structures in Patreksfjörður in 1997 (1998). In their report suggestions are made for defence structures for slushflows in Bíldudalur. Tómas Jóhannesson *et al.* (1996) investigated the need for avalanche defence structures in Iceland and in their report suggestions and cost estimate for such structures in Bíldudalur are included.

In 1997 the Icelandic Meteorological Office made plans for emergency evacuations of several communities in Iceland. The plans included a division of the communities into evacuation zones and description of the conditions when the individual zones should be evacuated. Such a plan was made for Bíldudalur (IMO, 1997). According to the plan the settlement which is located on the debris cone of Búðargil and the area adjacent to it are evacuation zones that need to be evacuated under extreme conditions. When a final hazard map has been issued officially the evacuation plan will be revised to reflect the hazard zoning.

2.5 Climatic conditions

The climate of Vesturbyggð is influenced by the rough topography of the region, with high mountains and narrow fjords and a location adjacent to the Denmark Strait. There are a number of weather stations in the southern part of Vestfirðir. Summaries of station data can be found in Appendix D. The mountain stations Hálfdán and Kleifaheiði are automatic weather stations (AWS) owned and operated by the Icelandic Public Roads Administration. The stations Bíldudalur and Patreksfjörður are automatic stations, Kvígindisdalur is a synoptic station and Mjólkárvirkjun is a precipitation station operated by Veðurstofa Íslands (see Fig. 1). Kvígindisdalur is the only station that measures snow depth and snow cover is observed there and at Mjólkárvirkjun too.

The annual mean temperature in the region for the period 1997–2002 is 3,8–4,9°C in the lowland which is significantly higher than for the standard period 1961–1990. At the station Kleifaheiði, 400 m above sea level, the annual mean temperature is 1,0°C and at Hálfdán, 525 m a.s.l., the annual mean temperature is 0,4°C. This indicates a temperature decrease with altitude of about 0,6–0,8°C for every 100 m. At all stations, temperatures below zero may be measured in all months of the year and the lowest measured temperature is down to -20°C.

Precipitation is highly variable from location-to-location and from year-to-year. High winds and sub-zero temperatures are associated with the largest systematic errors in precipitations measurements. In general, the precipitation tends to be underestimated in such conditions. It seems that automatic precipitation gauges measure smaller precipitation amounts than the gauges used at manned stations. The average total precipitation at Kvígindisdalur is 1380 mm per year and the yearly sum varies much from year-to-year. The highest measured daily, *i.e.* 24 hour (09–09), accumulated precipitation is 131,6 mm in March 2000, and a 24 hour precipitation larger than 100 mm has been measured on three other occasions, in September 1942 and 1949 and in October 1987. In the wintertime (November-April), rain amounts to about 30% of the precipitation and sleet and snow about 70% in Kvígindisdalur. At Mjólkárvirkjun, rain is about 50% and sleet and snow about 50% during winter. During the years 1961–1990 the average annual precipitation at Mjólkárvirkjun was 850 mm and during the period 1997–2002 it was 950 mm. At the Bíldudalur station which has been operated since 1999 the average precipitation for the periods 1999-2002 was 953 mm/year. This indicates that the precipitation at Bíldudalur is similar to the precipitation at Mjólkárvirkjun and considerable lower than at the Kvígindisdalur station (about 450 mm/year). But in these consideration one must bear in mind that the series from Bíldudalur are short.

Wind direction and wind speed is estimated subjectively by the observers at Kvígindisdalur and only 16 wind directions are used. The wind directions at each station are strongly influenced by the topography of the adjacent area and wind directions in the fjords are predominantly “inwards or outwards”. In wintertime when temperature is below 1°C, precipitation in Kvígindisdalur occurs mainly when the wind is blowing from southwest to west but the most common wind directions there are from north and northeast. In Bíldudalur, the wind directions from northeast and southwest are the most common and the wind speed is strongest from those directions. The same pattern is prevailing both winter and the whole year and reflects the local topography .

Snow cover is lighter in Vesturbyggð than in the northern part of Vestfirðir and the snow depth is smaller. The climate is milder and thaw periods during winter are more frequent. The monthly average snow depth in Kvígindisdalur is calculated for days when the ground is totally covered with snow and is 12 cm in January for the period 1961–1990 and 10–12 cm in February–April. The maximum measured snow depth is 88 cm in February and March 1957. In the region around Bíldudalur, the maximum snow depth with a 50 year return period is 100–160 cm and 150–200 cm for a return period of 200 years.

The danger of snow avalanches in Vestfirðir arises most frequently during strong winds from the north associated with intensive low pressure systems coming from south or east. These low pressure systems bring relative warm air masses from the south with intensive precipitation to the area and lead to heavy snow accumulation in the starting areas of many avalanche paths. In the same paths, heavy snow accumulation can also occur in prevailing northeasterly winds with snow fall. The weather preceding many avalanches in the northern part of Vestfirðir is according to this description. The danger of snow avalanches in the southern part of Vestfirðir arises most likely during similar conditions, although the strength of northerly winds and the intensity of snow fall is not as large there as in the northern part of the peninsula. The avalanches in January 1995 fell during a widespread avalanche cycle of this type that affected the whole Vestfirðir peninsula and most of northern and northeastern Iceland.

Before the slush flows at Patreksfjörður and Bíldudalur on 22nd January 1983, there had been heavy snowfall in Vestfirðir. The snow depth at Kvígindisdalur was in the range 40–60 cm from the beginning of January until shortly before the avalanches fell. An occluded frontal zone came from the south on the 21st and moved to the north over Vestfirðir in the early morning of the 22nd followed by heavy rain. The temperature reached 8°C in the lowland. In Kvígindisdalur, the measured precipitation from 18hr on the 21st to 18hr on the 22nd was 124 mm and it is estimated that 110 mm of this precipitation fell during 21 hours before a slush flow fell from Geirseyrargil in Patreksfjörður at 15:40hr. According to this description and an investigation of the weather preceding slush flows at Bíldudalur, the largest slush flows in both these villages have been preceded by heavy precipitation. The slush flow in Bíldudalur 1997 and 1998, on the other hand, show that smaller slush flows can occur without intensive precipitation.

2.6 Debris flows and rockfall hazard

As described before, the current Icelandic regulation on hazard zoning requires the same criteria to be used for debris flows/rockfall hazard zoning as for avalanche hazard zoning, *i.e.* individual risk. Furthermore, the combined risk should be presented on one map. Therefore, debris flow hazard zoning should be done in synchronisation with avalanche hazard zoning.

A debris flow chronicle for Bíldudalur has been compiled by Halldór G. Pétursson (2000). A geomorphological map of the area has been prepared and the potential runout of debris flows and rockfall in the area has been estimated (Glade and Esther H. Jensen, 2003). The debris flow chronicle is included in the avalanche chronicle (IMO, 2003).

Debris flows and rockfall have caused severe damage to the present settlement of Bíldudalur. Low catching and deflection dams have been constructed to prevent that but they are much to low to be considered a sufficient protection.

3 Inside(SW) of Gilsbakkagil

3.1 Topographic description

Starting area

In this area there are several small but rather deep gullies facing SE. Due to their depth, which is up to 20 m, and the rough cliff ridges between the gullies, it is not considered likely that the slope as a whole is a starting area for a large avalanche. Individual starting areas are from about 450 m a.s.l. down to 350 m a.s.l. with area up to 0.9 ha. The average width is 60 to 80 m and the inclination is 36–45°. The surface is typical for the stepped profile described above.

Track

The tracks are from about 350 m .a.s.l. and down to about 25 m a.s.l. where the inclination becomes lower than 10°. In the upper part the inclination is 36° and the track is parabolic in shape. The tracks are formed by the small gullies in the cliffs and the screes below and they are slightly confined. The track corresponding to the outmost starting area crosses the debris cone of Gilsbakkagil. The lower part is covered with vegetation.

Runout area

The runout area is more or less the flat fields in the inner part and in the outer part it covers the inner part of the debris cone of Gilsbakkagil. It is used for agriculture, settlement and communication. The inclination is between 5 and 10 °. No geological indications of avalanches could be found on the surface in the area.

3.2 Local climatic conditions

The flat plateau above the edge can be considered as a catchment area for snowdrift. Snow can accumulate by drift in wind directions around NW from the flat. Drift along the slope can also cause accumulation in the starting areas.

3.3 Chronicle

Unclear sources indicate that a debris flow fell on a sheepshed of the farm Hóll in 1797.

3.4 Assessment

Due to the limited size of potential starting areas and the wide runout zone no hazard is estimated in the area of the present settlement.

3.5 Model estimates

The results of the model calculations are shown on Map 3 and longitudinal sections of profiles `bild01`, `bild02` and `bild03` on Drawings 1–3.

The β-point for profiles `bild01` and `bild02` are located at runout indx $r = 10.5$. Profile `bild03` crosses the debris cone of Gilsbakkagil and the β-point is considerably lower than for the other profiles or at runout index $r = 11.8$. The SAMOS simulations indicate that an avalanche released from starting area 1 on Map 3 has runout where the profile `bild03` is drawn. According to the SAMOS simulations the avalanches reach runout indices $r = 13.5$ and $r = 15$ for Run 1 and Run 4 respectively.

3.6 Conclusion

The starting areas to the inside (SW) of starting area no. 1 on Map 3 have runout inside of the debris cone of Gilsbakkagil. The β-point is 100–200 m above the road and the runout zone is flat. It is therefore concluded that the risk is within acceptable limits for this part of the investigated area.

Similarly, avalanches released from starting area 1 on Map 3 are not considered hazardous although the β-point is located just above the houses. The situation is similar as in the Milligil area and this conclusion is mainly based on the small size of the starting area and limited conditions for snow accumulation. The hazard in the area is due to avalanches, slushflows and debris flows which can be released in Gilsbakkagil and is described in the next section.

Figure 3. *View along BÌldudalsfjall to NE. The first large gully is Gilsbakkagil and then the Milligil. B˙ðargil and its debris cone is above the harbor (Photo: © Mats Wibe Lund).*

4 Gilsbakkagil

4.1 Topographic description

Starting area

Gilsbakkagil gully has a shape of a big rounded wedge, which is 400 m wide and 250 m deep, and reaches altitude of 450 m a.s.l. The inclination is 35–45°. Both sides of the gully are slightly concave and consist of stepped cliffs which interrupt the profile considerably. Three cliffbelts are significantly higher than the others. They are at a level of 300 m, 390 m and 430 m a.s.l. respectively. Between the cliffbelts some loose material has accumulated. Also, the sides are cut by deep and narrow subgullies. The outmost parts of the gully on both sides are smoother than the inner parts. Two areas are delineated which are considered to have higher potentiality for releasing avalanches than other areas in the gully (areas no. 2 and 3 on Map 3). They are located between approximately 390 m a.s.l and 250 m a.s.l. on each side of the large upper part of the gully.

Track

The track extends from the lower part of the bowl, at about 250 m a.s.l. and down to the lower part of the big debris cone at about 20 m a.s.l. In the upper part it is a steep, narrow canyon interrupted by cliffbelts. At 120 m a.s.l. the gully opens out to the convex debris cone below. The cone has an inclination of 17–20° in the upper part. In the middle of the debris cone *i.e.* where the brook of the gully is presently located, the surface is flat and even a small depression can be observed. Between 25 and 35 m a.s.l. a deflecting dam has been constructed to the inside of the brook to lead water and debris along the course of the brook. The debris cone spreads out to the extent of 500 m at 20 m a.s.l. Several marks of both old and recent debris flows are visible on the cone.

Runout area

The lower part of the debris cone is the runout area. It has an inclination of about 7° to the shore. The width is 500–600 m and covers the whole area of the lower debris cone. There are no indications of large dry avalanches in the area. There are a number of residential houses in the runout zone.

4.2 Local climatic conditions

Snow can accumulate in the gully by drift in wind directions from SW, NW to NE. It is not likely that snow accumulates on both of its faces simultaneously except in a heavy snowfall in calm weather.

4.3 Chronicle

Debris flows and slushflows occur in the area. In two recent cases, two slushflows have been released with 15 minutes (1997) and 1 hour and 21 minutes (1999) interval.

4.4 Assessment

The occurrence of big avalanches from this gully with long runout distances is not considered to be likely. This assessment is based on several arguments. The roughness in the starting area is high and only 2 ha on the inner side and 3 ha on the outer side should be considered as uninterrupted continuous starting areas (areas no. 2 and 3 on Map 3). The roughness of the deepest part of the gully is high (10–20 m) making the release of a large slab there impossible. Furthermore, as mentioned above, snow accumulation is most likely at only one side in a single snowstorm. Because of the depth of the narrow gully, and its undulating form there will be considerable loss of energy by deflection of an avalanche from the sides to the main direction. The subgullies are directed slightly upwards forming an large deflection angle which can be up to 50°. The convex form of the tip (upper part) of the debris cone may be expected to lead to a spreading.

Based on these arguments, the release of a big dry avalanche that endangers the settled area is considered rather improbable. This is further supported by the fact that no records of avalanches exist and no obvious marks of large avalanches, which have reached the settled area can be observed.

4.5 Model estimates

The results of the model calculations are shown on Map 3 and the longitudinal section of profile `bild04` on Drawing 4.

The β-point is located close to the contourline of 20 m a.s.l. or just above the street Dalbraut at runout index $r = 12.5$. According to the SAMOS simulation an avalanche originating on the outer face of the gully follows more or less the creek on the debris cone and for Run 1 it reaches runout index $r = 13.5$ and Run 4 beyond the shoreline. Avalanches released from the starting area on the inner side (no. 2) hit the steep outer face above the mouth of the gully and are thrown back and by that deflected inwards. They reach runout indices $r = 11$ and $r = 12.5$ for Runs 2 and 3 respectively.

4.6 Conclusion

Due to the arguments described in the assessment section it is not considered likely that avalanches from the gully have as long runout or as high frequency as in Búðargil. Two recent avalanches released there have not been accompanied with avalanches from Gilsbakkagil. Furthermore, these arguments are partly confirmed by the SAMOS simulations although it is not certain how well the model simulates avalanche flow in the deep, narrow and undulating low part of the gully.

Recent slush- and debris flows have more or less followed the creek on the debris cone. The slushflow in 1997 overflowed the creek and a branch of it took a path to the inside of the main track. That part stopped at about 50 m a.s.l. In principle, the flows can come down anywhere on the debris cone. But the direction of the lowest part of the gully and the even area in the middle of the cone make it more probable that large flows will be more forceful and have longer runout on a 200 m wide zone around the present creek.

Outside the zone around the creek the hazard zoning is mainly based on avalanche hazard and the hazard line C is close to the runout index $r = 13$. Hazard lines B and A are close to runout indices $r = 13.4$ and $r = 14.2$, respectively. In the 200 m wide zone near the creek, the hazard lines are at greater distance from the mountain and this amounts to approximately 1/2 runout index. Along the creek there is about 40 m wide category C hazard zone to the shore. The uncertainty of this zoning is estimated to be 1–2.

5 Milligil

The area between Búðargil and Gilsbakkagil is collectively called Milligil in this report. There are three main gullies in the area of which two have names. The outmost one, closest to Búðargil is called Klofagil. It branches into two subgullies above 120 m a.s.l. The middle one is called Merkigil and the innermost one, closest to Gilsbakkagil, does not have a name. Furthermore, a couple of smaller gullies or depressions are found in the area.

5.1 Topographic description

Starting area

Taking into account that the whole mountainside is steep enough for avalanche release we selected 7 smaller areas with higher probability due to topographical conditions (areas no. 4–10 on Map 3). These areas are the uppermost part of the gullies (no. 5–9 on Map 3) and two areas adjacent to the large gullies Búðargil and Gilsbakkagil (no. 4 and 10 on Map 3).

The gullies are small but rather deep and the mountainside faces SE. Due to their depth, which is up to 20 m, and the rough cliff ridges between the gullies, it is not considered likely that the slope as a whole is a starting area for a large avalanche (areas 5–9 on Map 3). The starting areas in the gullies extend from about 450 m a.s.l. down to about 280 m a.s.l. The average width is 60 to 80 m and the surface is made of cliffbelts interrupted by weathering debris.

The potential starting areas adjacent to the large gullies are shallow depressions between 320 and 150 m a.s.l. The surface of those areas is a scree and it is smoother than the other starting areas.

The inclination of the delineated starting areas is 37–40° and and each of them has a surface area of 1–2 ha.

Track

The tracks extend from 150–200 m a.s.l. for the inner- and outmost areas and 280–350 m a.s.l. for the other areas and down to about 15–20 m a.s.l. where the inclination becomes lower than 10°. The profiles start with an inclination of about 39°. They are generally parabolic in shape but the tracks from the inner and outmost areas cross the debris cones of the large gullies. The tracks are formed by the small gullies in the cliffs and the screes and debris cones below. They are slightly confined except for the outmost and innermost ones. The ground is covered with vegetation in the lower part and some dams have been constructed for protection against debris flows and torrents.

Runout area

The inclination from the β-point to the shore is similar along the slope and it is 9° on average and it is residential area.

5.2 Local climatic conditions

The plateau above the edge can be considered as a catchment area for snowdrift. Snow can accumulate by drift when wind directions are around NW. Drift along the slope can also cause accumulation in the starting areas.

5.3 Chronicle

In this area there are mainly debris flows that have occurred. Three of them reached beyond the street Dalbraut. One avalanche is recorded.

5.4 Assessment

Due to the roughness of the upper part of the hillside it is not expected that an avalanche will be released from the whole area simultaneously. Consequently, large avalanches (more than 50 thousand m^3) are not likely to occur. Also, the debris cones can cause some spreading for small avalanches. The probability of snow accumulation is higher in the upper starting areas since, in addition to drift along the slope and snowfall, snow can drift from the plateau and accumulate there.

5.5 Model estimates

The results of the model calculations are shown on Map 3 and longitudinal sections of profiles `bild05` to `bild10` on Drawings 5–10.

The β-point is located just below 20 m a.s.l. and the 20 m contourline is immediately above the uppermost line of houses at the street Dalbraut. The β-point is at runout index $r = 10$–11. According to the SAMOS simulations, even small avalanches reach the sea and the shoreline is located close to runout index $r = 12.5$.

5.6 Conclusion

Prevailing weather conditions do not favor snow accumulation in the starting areas and therefore it is to be expected that the frequency of avalanches is low in this area. Furthermore, since it is not expected that the whole area will act as one large starting area the avalanches will not be large. Due to the expected small size of the avalanches, the debris cones will most likely spread the avalanches to some extent and by that decrease their runout distance and force.

Similar arguments are valid regarding debris flows and slushflows. Large hazardous debris flows are not likely to occur due to the limited size of individual gullies and corresponding watersheds. Typical starting areas for slushflows are not found in the gullies.

One avalanche is recorded in the area and several slushflows and debris flows. The avalanche hit a house which was located on the debris cone of Gilsbakkagil. It was probably released in area no. 4 on Map 3 or close to it. The runout zone for avalanches released from starting area no. 10 on Map 3 is similarly on the debris cone of Búðargil. In both the cases the hazard delineation is influenced by the hazard due to debris flows, slushflows and avalanches from the large gullies.

In the area between the debris cones, the hazard line C is close to the β-point or at runout index $r = 10.5$. Hazard line B is close to runout index $r = 11.3$ and hazard line A at runout index $r = 12.5$ which is close to the shore. The hazard line B is drawn down to line A around the debris flows tracks. The uncertainty of the zoning is estimated to be between 1 and 2.

Figure 4. *Búðargil (Photo: © Mats Wibe Lund).*

6 Búðargil

Búðagil (Fig. 4) is a huge gully and during the settlement history of Bíldudalur avalanches, slushflows, flashfloods, debris flows and rockfalls have been released in it. On several occasions they have caused severe damage. A large part of the settlement is located on the debris cone of the gully, both residential houses, industrial buildings and official buildings.

6.1 Topographic description

Starting area

The potential starting areas for avalanches in Búðargil are between 250 and 450 m a.s.l. on both sides of the gully. This gully has a shape of a big rounded wedge which is 400 m wide and 250 m deep and reaches an altitude of 450 m a.s.l. The inclination is about 40°. Both sides of the gully are slightly concave and consist of stepped cliffs which interrupt the profile considerably. Two of these cliffbelts are significantly higher than the others. They are at approximately 300 and 400 m a.s.l. Some loose material has accumulated between individual cliffbelts. Further, the sides are cut by deep and narrow subgullies. The outermost parts of the gully, *i.e.* in the proximity of the rim to the main mountainside, are smoother than the inner parts. The whole area of the gully is about 19 ha.

Three separate areas are considered to have higher probability for releasing avalanches than others (areas no. 11, 12 and 13 on Map 3) but larger areas are potential starting areas. On the inner side of the gully one area is delineated and two on the outer side. The separation on the outer side is based on the surface roughness where the one closer to the rim has smoother surface as mentioned above. The size of individual areas is similar, *i.e.* approximately 2 ha.

Track

The track extends from the lower part of the bowl, at 250 m a.s.l., to to about 15 m a.s.l. on the lower part of the debris cone or 150–200 m from the shore. In the upper part the track is a steep and narrow canyon interrupted by cliffbelts. At 100 m a.s.l. the gully opens out to the convex debris cone, which has an inclination of 17–20° in the upper part. The debris cone spreads out to the extent of more than 500 m at 15 m a.s.l. Several marks of both old and recent debris flows are visible on the cone. Two dams have been constructed at the tip of the debris cone in order to deflect debris flows and slushflows inwards. There are many residential houses in the area.

Runout area

The runout area is on the debris cone where the average inclination to the shore is about 6°. Domestic houses, industrial buildings and official buildings are located in runout zone.

6.2 Local climatic conditions

Snow can accumulate in the gully by drift in wind from SW, NW to NE. But it is unlikely that this happens on both of its faces simultaneously except in heavy snowfall in calm weather.

6.3 Chronicle

Several avalanches and slushflows have been released from the gully. Furthermore, debris flows, flashfloods and rockfalls occur.

6.4 Assessment

The gullies Búðargil and Gilsbakkagil are similar in many respects. Still there are some differences that make the hazard evaluation different and in general, the hazard potential of Búðargil is considered to be higher than of Gilsbakkagil.

Due to the surface roughness it is not considered probable that the whole gully acts as one contiguous starting area. The roughness of the deepest part of the gully (10–20 m) is even higher than on the slopes above making a release of a slab there unlikely. Furthermore, the main path of the gully is narrow and wiggled and the side gullies form a considerable deflection angle, particularly in the outer part of it, to the main gully. For the inner part this deflection angle is about 30°. The convex form of the tip (upper part) of the debris cone would normally be expected to lead to large spreading as in Gilsbakkagil. But the existence of the dams below the opening of the gully can lead to a splitting of an avalanche towards the edges which can decrease the otherwise expected spreading. Furthermore, as mentioned above, intense snow accumulates only expected at one side in individual snowstorms.

Many of the abovementioned observations are favorable in the sense that the assessment based on them indicate shorter runout. The main difference between Gilsbakka- and Búðargil gullies is that the starting areas in Búðargil are on the average smoother, the line of the gully is straighter and the opening to the slope is larger. Therefore we are of the opinion that avalanches may be expected to go farther down than in Gilsbakkagil, particularly on the middle and outer part of the debris cone. This opinion is confirmed by the avalanche chronicle.

Large avalanches and slushflows will only to small extent be affected by the deflecting dams at the cone's tip. Due to the pronounced convexity of the upper part of the debris cone large avalanches and flows can come down with full force in any direction.

6.5 Model estimates

The results of the model calculations are shown on Map 3 and longitudinal section of profile `bild11` on Drawing 11.

The β-point is about 10–12 m a.s.l. at runout index $r = 12.5$ between the streets Langahlíð and Tjarnarbraut. The outer part of the debris cone is steeper than the inner part below the 20 m contourline. For the inner part, the shore is at runout index $r = 15$, which is close to the α-point. Further outwards the shore is at runout index $r = 14$.

According to the SAMOS simulations, avalanches released from starting area no. 11 on Map 3 reach runout index $r = 13$ on the inner and middle part of the debris cone. Avalanches released from areas no. 12 and 13 are inclined to split and run down inner and outer part of the cone. The runout for the inner tongue is similar or slightly longer than the avalanches released from starting area no. 11. The outer tongue reaches the shore, even for small avalanches (Run 1).

6.6 Conclusion

In the twentieth century two avalanches stopped beyond runout index $r = 12$ and three beyond $r = 11.5$. This corresponds to an annual frequency at runout index $r = 13$ of about 0.006 ($F_{13} = 0.006$).

Based on this estimated frequency, the results of the RiskEst calculation place the hazard line C at runout index $r = 14.7$ or approximately 50 m above the shore on the middle of the cone. The gully Búðargil is not a typical avalanche track as has been described above. First, the starting areas are rough and avalanches are deflected at relatively large deflection angles in order to follow the main course of the gully. Secondly, the debris cone has a pronounced convexity and width. The convexity causes spreading which reduces the runout distance. In spite of the expected spreading, the width of the runout zone is so great that the width of an avalanche tongue is expected to cover only a small proportion of the width of the total runout area in individual avalanche. A smaller proportion than is ordinarily assumed in the RiskEst calculation.

Due to these effects, it is considered reasonable to locate the hazard lines due to avalanches closer to the mountain by a distance which corresponds to about 0.5–1 runout indices. The delineation of the hazard zones is concentric on the cone with hazard line C around runout index $r = 13.3$. Hazard lines B and A are located near runout indices $r = 14.3$ and $r = 15.2$ respectively.

It is considered that the hazard due to slushflows and debris flows does not exceed the avalanche hazard except along the present brook from the gully where the hazard line C is extended all the way down to the shore. The uncertainty of the zoning is estimated to be 1.

7 Outside(NE) of Búðargil

This area is outside of the debris cone of Búðargil where the houses at the street Langahlíð no. 34–43 are located.

7.1 Topographic description

Starting area

The starting area is between 200 m and 300 m a.s.l. (area no. 14 on Map 3). It is about 60 m wide and only 0.7 ha. The average inclination is 42°. The area has a shape of a small bowl and the surface is mainly built up by cliffs and weathered material. The aspect is ESE.

Track

The track extends from 200 m a.s.l. to the β-point which is reached just above the street Langahlíð. It has a parabolic shape and the inclination in the upper part is 38°.

The surface is a scree which is covered with grass in the lower part Many rockfall boulders are found in the lower part.

Runout area

The runout area is from the street Langahlíð to the shore. Four domestic houses are in the runout zone.

7.2 Local climatic conditions

Because of the location, shape and aspect of the starting area, snow accumulation is most likely by drift in SW and NW winds.

7.3 Chronicle

There are no records of avalanches that have reached the settlement in the area. Small avalanches have occurred which have stopped on the slope above the settlement. Two debris flows have hit the house at Langahlíð 43 (Jaðar).

7.4 Assessment

Because of the steepness of the avalanche track even, small avalanches would reach the shore. On the other hand, the starting area is not typical and the conditions for snow accumulation are poor.

7.5 Model estimates

The results of the model calculations are shown on Map 3 and longitudinal section of profile `bild12` on Drawing 12.

The β-point is just above the street Langahlíð at runout index close to $r = 10$. The α-point is in the sea close to runout index $r = 12$. According to the SAMOS simulations, a narrow tongue reaches the shore just outside of the house at Langahlíð 31–33, even for small avalanches.

7.6 Conclusion

It is not expected that snow accumulates in great amount in the starting area. Consequently, the hazard lines are relatively close to the mountain and the situation with respect to avalanches is similar to *e.g.* areas in Ísafjörður (Gleiðarhjalli) and Siglufjörður (Gimbraklettar) (Arnalds *et.al.*, 2000). Debris flow and rockfall hazard is significant.

The combined risk due to these hazards leads to the subjective estimate that hazard line C is located close to the β-point or at runout index $r = 10$. Hazard line B is at runout index $r = 11.2$ and hazard line A at runout index $r = 12.5$ which is off the shore. The uncertainty of the zoning is estimated 2.

8 Conclusion

Most of the settlement of Bíldudalur is located within hazard areas and a significant proportion of the village is within the category C hazard zone. The majority of domestic houses which are within the category C zone are located below the gully Búðargil. Inside of Gilsbakkagil there is a large area where the risk is within acceptable limits.

The main problem in the hazard zoning is the limited data available and therefore the hazard zoning for Bíldudalur is to large extent based on a subjective estimate. In this context the importance of detailed recording of avalanches, debris flows and rockfall is stressed. The observations are the base for evacuations, design of defence constructions and an eventual reevaluation of the hazard zoning.

Rockfall and debris flows pose a serious threat to the settlement. In addition to the threat to human lives, those processes can cause inconvenience and material damage in the category A and B hazard zones and have to be taken into consideration in town planning. Defence constructions for avalanches and slushflows will presumably also protect the settlement from debris flows and rockfall.

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A Technical concepts and notation

α**-angle:** The slope of the line of sight from the stopping position of an avalanche to the top of the starting zone (see Figure 5).

β**-angle:** The slope of the line of sight, from the location in the avalanche path where the inclination of the slope is 10°, to the top of the starting zone (see Figure 5).

α/β**-model:** A topographical model used to predict avalanche runout or to transfer avalanches between paths. The model uses the β-angle to predict the α-angle of the longest recorded avalanche in a given path. The model was first derived by Lied and Bakkehøi (1980). The version of the model used in this project was derived by Tómas Jóhannesson (1998a, 1998b) using data on 45 Icelandic avalanches. The formula of the model is

$$\alpha = 0.85 \cdot \beta, \qquad \sigma = 2.2^\circ$$

where σ is standard deviation of the residuals from the model. It is customary to denote an avalanche with an α-angle $n\sigma$ lower than the predicted α-value as an avalanche with runout of $\alpha - n\sigma$ and conversely $\alpha + n\sigma$ if the α-angle is higher than given by the above equation. Note that as the α-angle is lower the runout is longer, and therefore $\alpha - \sigma$ corresponds to an avalanche with a longer runout distance than α.

PCM-model: A one-dimensional physical model used to simulate the flow of avalanches. The model has two parameters, μ, a Coulomb friction coefficient, and, M/D, an inverse drag coefficient. It was developed by Perla *et al.* (1980).

Runout index: The runout measured in hectometers of an avalanche that has been *transferred* (Sven Sigurðsson *et al.*, 1997) to the *standard path* making use of some transfer method. The runout index in this report is obtained by using the PCM-model with parameters lying on a predefined parameter axis. An avalanche that has a runout index of r_0 is referred to as an avalanche with $r = r_0$. The method was developed by Kristján Jónasson *et al.* (1999).

$F_{r_0}(F_{13})$**:** The expected frequency of avalanches with a runout index greater or equal than r_0. The value F_{13} is most often used, *i.e.* the frequency at the runout index $r_0 = 13$.

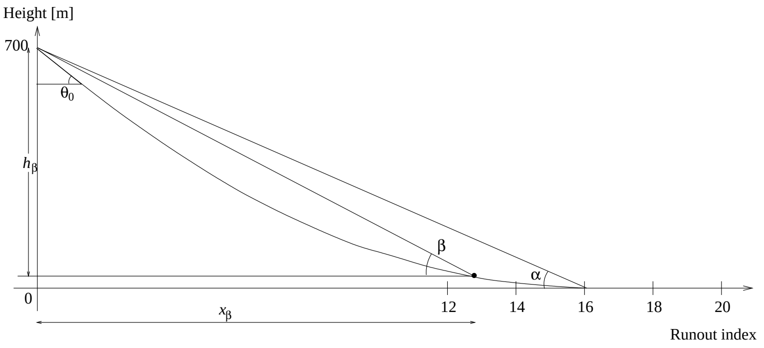


Figure 5. *The standard path. The α-angle is the expected runout angle of an avalanche according to the α/β-model.*

B Chronicle

This appendix lists recorded avalanches, debris flows and rockfall in the mountain Bíldudalsfjall above the village of Bíldudalur. Further, slushflows and flashfloods are also listed. The database number, date and a short description is given for each event. Runout indices are given for snow avalanches where the runout distance is known. A more detailed description is given in the avalanche and landslide chronicle for Bíldudalur (IMO, 2003).

Number Date *Runout index*	**Description**
7501 15.1.1902 *12.2*	An avalanche hit a house which stood just outside of the present house no. 7 of Langahlíð. It was moved on its fundament by the avalanche and later moved to different location and is now no. 27 by the same street.
7502 eftir 6.6.1920	A flashflood from Búðargil reached the shore damaging goods.
7503 22.12.1931	A debris flow fell from Klofagil breaking a window and causing some damage.
7504 22.12.1931	A debris flow fell from the innermost Milligil.
7505 22.12.1931	A debris flow fell from Merkigil.
7507 in the 30s	A small debris flow fell over the area where the houses no. 30 and 32 at Dalbraut are located.
7506 beginning of May 1937	A debris flow fell to the house Jaðar.
7508 after 6.2.1939	A slushflow was released from Búðargil. It caught a man and carried him out to the sea were he was rescued.
7542 autumn 1942	A debris flow fell to the house Jaðar. One woman needed assistance to get out of the house.
7509 late winter 1950	A flashflood fell from Búðargil during spring thaw.
7510 late winter 1950	A debris flow fell from Merkigil but did not reach the settlement.
7512 17.2.1959	A debris flow fell from Gilsbakkagil causing damage to the house Sælundur. Further, the road was damaged as well as some fields.
7511 17.2.1959	A flashflood and debris flow from Búðargil caused some material damage.
7513 24.8.1968	Two debris flow fell from Klofagil. The larger one went down between the houses no. 20 and 22 at the street Dabraut and deposited about 1 m thick debris on the road.

Number Date *Runout index*	**Description**
7514 24.8.1968	A debris flow fell from Merkigil but did not reached the settlement.
7515 13.3.1969 *10.7*	An avalanche was released from the hillside just outside of Gilsbakkagil. It hit the house no. 32 at Dalbraut and caused damage there and in some other houses by flooding as well.
7516 30.12.1971	A rock fell from Bíldudalsfjall and stopped in a bed inside of the house no. 20 by the street Langahlíð.
7517 19.11.1976	Two debris flows fell from the gully Klofagil. The larger one went down between the houses no. 16 and 18 at Dalbraut.
7518 19.11.1976	A debris flow fell from Klofagil.
7519 26.1.1981 *11.9*	An avalanche hit the site for electrical distribution which is located at about 45 m a.s.l. on the debris cone of Búðargil. A transformer was toppled and the settlement was without electricity for a while.
7536 22.1.1983	A few small slushflows fell from the hill above the settlement.
7520 22.1.1983 *12.0*	A large avalanche from Búðargil hit two sheepsheds and a workshop. It killed over 30 sheeps and broke powerlines. The avalanche stopped just above the uppermost houses of the settlement.
7521 22.10.1985	Two debris flows fell from the Milligil area. One went over the street Dalbraut and between the houses no. 20 and 22 above the street and between the houses no. 19 and 21 below the street.
7533 22.10.1985	A debris flow fell from the innermost gully in the Milligil area.
7522 12.2.1989 *12.4*	An avalanche fell from Búðargil in a similar location as the avalanche in 1983. It broke powerlines and stopped below the street Tjarnarbraut.
7535 10.5.1990	A large slushflow was released from Búðargil and caused considerable material damage in the village.
7523 28.1.1997	A slushflow fell along the present brook on the south side of the debris cone.
7524 28.1.1997	Two slushflows fell from Gilsbakkagil. The first one, which was larger, piled up by the bridge at the street Dalbraut and caused damage in a garage adjacent to the brook. The flow reached the shore.
7525 28.1.1997	Two slushflows fell from Gilsbakkagil.
7526 14.3.1998	Two slushflows were released from Gilsbakkagil. The first one stopped at the bridge and damaged a garage.
7527 14.3.1998	Two slushflows fell from Gilsbakkagil.

Number Date *Runout index*	**Description**
7528 22.2.1999	An avalance fell down to the road about 100–200 m north of the settlement.
7529 23.2.1999	A few small and wet avalanches fell from the lower part of the hill above Bíldudalur.
7530 23.2.1999	A small wet avalance was released in the lower part of Búðargil.
7531 23.2.1999	Small and wet avalanches fell from the Milligil area.
7532 23.2.1999	A small and wet avalanche fell from the hillside about 50 m outside of Gilsbakkagil.

C Maps

Map 1. An overview of the village of Bíldudalur and surroundings and the boundary of the investigated area (A4, 1:15 000).

Map 2. Recorded avalanches, slushflows, debris flows and rockfall in the mountain above Bíldudalur. (A3, 1:7 500).

Map 3. Results of model estimates in the mountain Bíldudalsfjall above the village of Bíldudalur. (A3, 1:7 500).

Map 4. Proposed hazard zoning for the investigated area (A3, 1:7 500).

D Climatic data

Summary statistics: Temperature and wind

Climatic data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Bíldudalur (AWS no. 2428)						**1999-2002**							
t, °C	1.3	-1.3	-1.0	2.5	6.5	9.9	11.3	10.9	8.6	5.1	2.5	1.7	4.9
t_max, °C	10.4	10.3	10.2	12.7	16.0	22.8	22.1	18.4	18.7	17.0	14.6	11.5	22.8
t_min, °C	-9.6	-12.4	-13.3	-7.8	-4.1	0.5	3.3	1.1	-1.7	-5.8	-10.0	-11.7	-13.3
f, m/s	5.5	5.2	4.5	3.5	3.7	2.8	2.7	2.6	3.0	3.4	4.6	4.3	3.8
fx, m/s	22.6	35.7	21.4	20.2	18.2	14.5	15.3	13.7	15.5	14.7	26.8	26.2	35.7
gust, m/s	43.5	50.0	30.7	26.7	29.4	31.7	19.1	22.0	30.8	30.1	35.7	42.2	50.0
r, mm	134.3	103.1	86.0	51.1	79.1	25.4	58.7	57.6	62.8	79.9	112.4	103.4	953.8
r_max, mm	42.1	53.3	76.4	13.9	22.7	15.2	23.8	38.8	26.9	38.3	39.6	39.0	76.4
Patreksfjörður (AWS no. 2319)						**1997-2002**							
t, °C	0.4	-2.1	-1.9	1.9	5.3	8.2	9.9	10.0	8.0	4.4	2.3	1.5	4.0
t_max, °C	9.8	8.2	7.9	11.4	16.9	23.2	19.8	18.9	19.0	16.3	11.9	11.2	23.2
t_min, °C	-11.8	-15.1	-15.2	-8.7	-6.8	-1.3	3.5	2.3	-1.8	-5.9	-9.2	-11.2	-15.2
f, m/s	6.1	6.1	5.6	4.3	3.6	3.4	2.9	3.2	3.9	4.7	5.8	5.8	4.6
fx, m/s	21.7	25.3	21.4	19.6	16.3	16.1	14.9	15.6	18.3	20.8	23.6	21.6	25.3
gust, m/s	39.3	38.1	36.2	28.3	26.1	24.8	26.9	23.1	27.1	31.5	40.8	33.5	40.8
r*	113.7	135.8	117.5	49.8	119.7	43.9	57.5	59.7	99.0	104.1	116.6	89.2	1185.8
r_max*	42.0	43.6	69.3	23.6	43.0	27.7	20.3	20.9	51.4	38.9	39.6	65.0	69.3
* periode 1997-2001													
Hálfdán (AWS no. 32322)						**1997-2002**							
t, °C	-3.7	-6.0	-5.9	-2.0	1.5	5.4	7.3	6.9	4.2	0.4	-1.7	-2.4	0.4
t_max, °C	5.8	4.1	4.3	8.4	11.3	18.4	17.1	19.5	14.1	11.7	9.3	6.7	19.5
t_min, °C	-14.6	-19.3	-19.4	-12.6	-8.7	-4.7	-0.5	-1.2	-3.7	-9.2	-11.8	-15.1	-19.4
f, m/s	10.8	9.5	9.2	6.9	6.7	5.4	5.0	5.0	6.6	7.1	8.7	8.3	7.4
fx, m/s	39.3	35.2	41.1	28.1	26.2	27.5	23.8	24.9	26.0	27.8	43.1	32.0	43.1
gust, m/s	50.1	43.1	49.9	34.4	32.1	33.4	30.4	31.2	31.9	35.8	55.5	41.9	55.5
Kleifaheiði (AWS no. 32224)						**1997-2002**							
t, °C	-2.9	-5.4	-5.2	-1.5	2.1	5.7	7.5	7.4	4.9	1.2	-0.9	-1.8	1.0
t_max, °C	6.4	4.3	5.4	7.3	12.3	18.2	16.9	18.3	15.1	12.7	9.1	7.2	18.3
t_min, °C	-14.1	-18.9	-19.2	-13.4	-8.4	-4.4	0.6	0.6	-3.1	-9.1	-11.2	-14.1	-19.2
f, m/s	8.4	8.2	7.5	6.3	6.0	5.0	4.9	5.2	5.8	6.3	7.4	7.7	6.5
fx, m/s	29.1	32.3	29.1	24.0	24.5	20.8	19.4	21.9	25.4	23.1	23.6	34.7	34.7
gust, m/s	47.9	41.8	37.8	31.6	35.3	27.6	26.9	29.2	33.8	31.5	36.9	36.5	47.9
Kvígindisdalur (Synoptic st. no. 224)						**1997-2002**							
t, °C	0.2	-2.2	-2.1	1.7	5.2	8.2	9.9	9.8	7.7	4.2	2.1	1.4	3.8
t_max, °C	10.0	7.6	7.5	10.4	13.4	21.0	18.6	17.6	18.0	16.2	11.7	11.5	21.0
t_min, °C	-11.5	-13.8	-15.0	-12.0	-5.0	-0.4	2.6	2.1	-1.5	-5.5	-9.2	-11.0	-15.0
f, m/s	5.8	5.4	5.1	3.5	3.5	3.0	2.4	2.7	3.4	4.0	4.8	4.5	4.0
fx, m/s	26.8	30.9	26.8	22.7	22.7	15.4	15.4	19.0	19.0	22.7	26.8	26.8	30.9
r, mm	137.9	122.9	148.5	88.1	130.2	45.6	81.5	74.7	126.3	109.5	140.0	125.0	1304.6
r_max, mm	49.9	32.0	131.6	31.3	74.0	44.8	41.9	29.7	81.0	62.1	62.1	74.5	131.6
Kvígindisdalur						**1961-1990**							
t, °C	-1.2	-0.7	-1.2	1.3	4.7	7.8	9.4	9.2	6.4	3.7	0.7	-0.9	3.3
t_max, °C	10.4	10.5	10.5	12.0	16.5	18.6	19.5	21.0	17.5	14.0	11.2	10.6	21.0
t_min, °C	-17.4	-17.0	-18.5	-18.0	-9.4	-2.7	1.5	0.2	-4.0	-9.2	-12.0	-16.0	-18.5
f, m/s	4.7	4.7	4.2	3.6	2.7	2.7	2.4	2.6	3.2	4.0	4.3	4.6	3.6
fx, m/s	35.0	35.0	30.8	29.8	26.7	26.7	22.6	26.7	32.9	30.8	26.7	30.8	35.0
r, mm	126.5	128.6	124.8	111.8	62.5	79.6	82.2	97.4	116.9	161.9	148.4	137.2	1379.5
r_max, mm	93.1	96.6	85.8	59.6	64.9	71.7	57.4	60.7	71.4	102.4	101.6	73.9	102.4
Mjólkárvirkjun (Precipitation st. no. 231)						**1997-2002**							
r, mm	135.1	86.3	96.7	35.7	80.8	14.0	40.5	49.8	87.2	116.1	101.0	117.3	960.5
r_max, mm	50.2	43.1	68.3	16.6	36.1	18.4	14.9	16.7	61.6	33.7	48.6	35.2	68.3
Mjólkárvirkjun						**1961-1990**							
r, mm	93.2	90.0	81.2	63.4	38.3	37.2	32.8	51.7	72.6	115.5	103.2	84.9	850.4
r_max, mm	69.0	66.7	121.7	53.5	49.5	24.0	28.4	46.7	33.0	82.1	66.4	53.9	121.7

t=average monthly temperature, t_max=highest measured temp., t_min= lowest measured temp.

f=average windspeed, fx=maximum 10min windpeed, gust=maximum 3 sec. gust

r=monthly average accumulated precipitation , r_max=maximum 24hr accumulated precipitation

AWS=automatic weather station

Precipitation, weather stations

	Kvígindisdalur				Mjólkárvirkjun			
1961-1990	precip.,mm	rain %	sleet %	snow %	precip.,mm	rain %	sleet %	snow %
Jan	126.5	32	43	25	93.2	42	36	23
Feb	128.6	28	52	19	90.0	47	37	16
Mar	124.8	33	44	22	81.2	44	37	19
Apr	111.8	47	38	14	63.4	61	28	11
May	62.5	84	15	1	38.3	74	21	5
Jun	79.6	98	2	0	37.2	96	4	0
Jul	82.2	100	0	0	32.8	100	0	0
Aug	97.4	99	1	0	51.7	99	1	0
Sep	116.9	98	4	1	72.6	87	13	1
Oct	161.9	78	19	3	115.5	81	15	4
Nov	148.4	60	34	8	103.2	55	33	12
Dec	137.2	33	46	21	84.9	52	29	19
Year	1379.5	60	28	11	850.4	64	26	10
1997-2002								
Jan	137.9	53	35	12	135.1	66	27	8
Feb	122.9	14	45	41	86.3	21	49	30
Mar	148.5	39	41	20	96.7	42	39	18
Apr	88.1	37	60	3	35.7	61	19	20
May	130.2	92	8	0	80.8	97	3	0
Jun	47.6	93	7	0	14.0	99	0	1
Jul	81.5	100	0	0	40.5	100	0	0
Aug	74.7	100	0	0	49.8	100	0	0
Sep	126.3	99	1	0	87.2	95	5	0
Oct	109.5	77	21	2	116.1	82	15	3
Nov	140.0	70	24	6	101.0	62	26	11
Dec	125.0	51	38	11	117.3	59	31	10
Year	1304.3	68	21	12	960.5	69	22	9

Station nr.	Name	lattitude	longitude	height, m	since year
32322	Hálfdán	65°36'	23°42'	525	1995
2319	Patreksfjörður	65°35'	23°58'	43	1996
224	Kvígindisdalur	65°33'	24°00'	49	1927
231	Mjólkárvirkjun	65°46'	23°10'	8	1959
2428	Bíldudalur	65°40'	23°36'	16	1998
32224	Kleifaheiði	65°30'	23°42'	400	1996

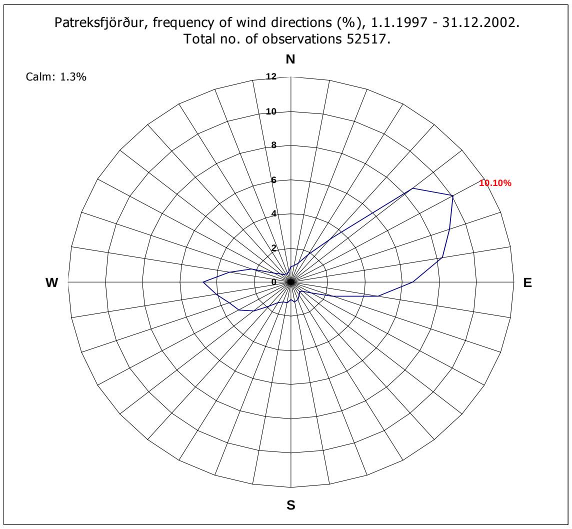
Snow depth

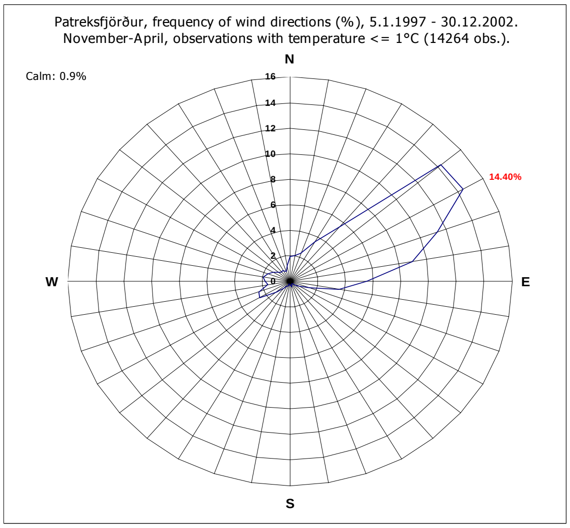
								Kvígindisdalur											
Monthly average snow depth, cm											**Maximum observed snow depth, cm**								
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Sept**	**Oct**	**Nov**	**Des**			**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Sept**	**Oct**	**Nov**	**Des**
1951	5	6	7				3	6	20		**1951**	13	2	1				3	7	5
1952	78	7	4				3	3	2		**1952**	1	4	4				3	5	4
1953	8	2	6	5			3	10	4		**1953**	15	5	2	12			5	2	1
1954	8	14	27						9		**1954**	17	27	36						22
1955	10	10	9	1			5	5	9		**1955**	22	19	23	1				5	2
1956	12	6	5	1			2	4	6		**1956**	16	13	6	1			3	5	1
1957	30	88	62	8			9	7	14		**1957**	8	88	88	1			25	1	25
1958	33	9	23				5	3	2		**1958**	47	1	29				4	4	
1959	2	3	19	9				9	11		**1959**	14	14	32	15				13	2
1960	13		3	0					7		**1960**	32		4						1
1961	6		13	14			1	5	5		**1961**	7		27	2			1	22	11
1962	5	8		3			3	4	5		**1962**	1	19					4	7	9
1963		15			3						**1963**		3			7				
1964		15	8	5			6		9		**1964**		16	2	8			13		18
1965	4						2		0		**1965**	15						2		
1966			4	24					19		**1966**			1	57					26
1967	16	5	5				5	10	8		**1967**	26	15	1				5	25	15
1968		16	6	8					3		**1968**		5	12	11					3
1969	3		8				5	14	5		**1969**	4		35				13	19	1
1970	6	21	3	3			2	5	10		**1970**	7	39	8	7			5	7	19
1971	13			5			1	11	20		**1971**	2			9			1	27	42
1972	35	8	6				2	4	12		**1972**	56	1	19				2	6	28
1973	7	7	18	46				8	16		**1973**	3	13	36	59				15	32
1974	15	8	11					4	19		**1974**	32	12	4					4	43
1975	13	9	3					7	6		**1975**	23	18	1					15	15
1976	11	17	10	15				1	3		**1976**	2	38	25	28				1	9
1977	3	4	2	12				4	9		**1977**	11	7	3	18				7	16
1978	6	4	6	2			6	8	1		**1978**	15	1	12	2			7	22	1
1979	11	11	13	1	5		1	1	5		**1979**	24	2	2	1	5		1	3	8
1980	3	5	9	1							**1980**	12	14	2	3					
1981	11	23	17	4	2	2	1	9	3		**1981**	25	5	25	5	2	2	1	14	8
1982	5	8	13	2	7		3	4	14		**1982**	1	2	26	5	1		5	12	32
1983	42	8	15	27			3	20	8		**1983**	63	16	38	38			4	34	28
1984	36	24	7	4	1		1	3	14		**1984**	5	5	2	8	2		1	6	24
1985	2	3	2	2			0	5	1		**1985**	3	6	4	3				7	3
1986	4	3	12	8			10	4	6		**1986**	1	4	25	16			15	11	12
1987	8	5	8	10	3		8	0	6		**1987**	15	12	18	26	3		11	1	9
1988	10	11	13	18	1		1	3	8		**1988**	24	22	25	25	3		3	4	26
1989	23	0	35	12			2		5		**1989**	45		48	2			2		16
1990	10	13	15	12				3	12		**1990**	21	21	28	24				5	35
1991	12	6	4	5			2	4	8		**1991**	35	19	12	16			3	2	24
1992	10	12	7	2	2			6	5		**1992**	27	25	18	3	2			15	12
1993	31	11	6	2	3			4	2		**1993**	42	27	14	4	3			9	4
1994	5	6	9	6				3	10		**1994**	8	14	17	9			2	8	27
1995	20	39		5		0	6	0	1		**1995**	43	48	61	9			9		2
1996	5	4		4			1	4	2		**1996**	1	8	2	6			1	8	4
1997	3	15						2	5		**1997**	8	33	35					2	8
1998	2	10	6				3				**1998**	5	19	16				5	1	4
1999	6	7	9	1				4	7		**1999**	11	12	11	2				7	14
2000				4				4	5		**2000**	25	29		12				5	15
2001	2	4	6	5				5	13		**2001**	3	15	14	6				12	27
2002	2	3	3				2		3		**2002**	4	8	7	2			2		3
Monthly average snowdepth 1961-1990, cm											**Maximum observed snow depth, cm**								
	12	**10**	**10**	**10**	**3**	**2**	**3**	**6**	**8**			**63**	**88**	**88**	**59**	**7**	**2**	**25**	**34**	**43**

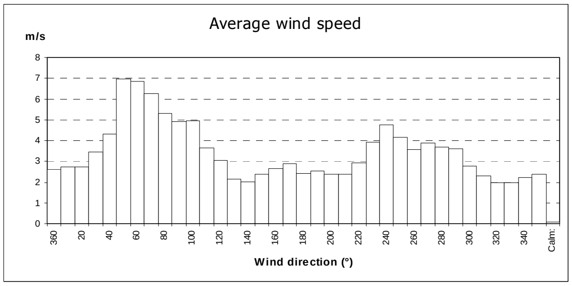
Snow cover

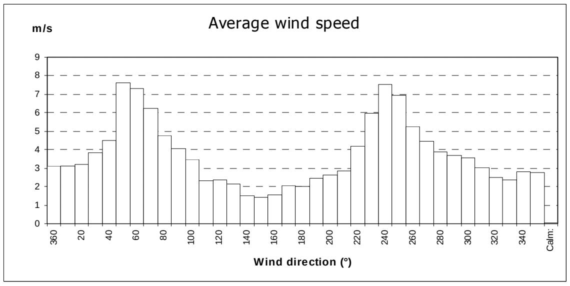
									Kvígindisdalur																	
	Average snow cover in lowland, %														Average snow cover in mountains, %											
	J	F	M	A	M	J	J	A	S	O	N	D			J	F	M	A	M	J	J	A	S	O	N	D
1951	85	94	96	72	1	0	0	0	0	26	12	80		**1951**	85		98	74	1	0		0		29	13	
1952	100	94	46	48	2	0	0	0	0	9	26	49		**1952**	99	93	75	53	3	0	0	0	2	29	65	73
1953	65	71	69	71	3	0	0	0	0	33	63	63		**1953**	86	93	82	88	40	21	0	0	0	61	85	89
1954	54	94	79	38	0	0	0	0	0	17	55	84		**1954**	88	99	87	61	31	11	0	0		46	70	90
1955	77	93	92	12	2	0	0	0	0	0	14	99		**1955**	87	100	97	45	16	0	0	0	0	0	56	100
1956	98	49	30	18	0	0	0	0	0	34	30	60		**1956**	100	65	71	68	35	19	0	0	0	70	48	81
1957	76	100	95	31	0	0	0	0	0	31	47	82		**1957**	88	100	98	64	45	25	0	0	0	55	78	94
1958	98	98	86	42	0	0	0	0	0	3	28	52		**1958**	100	98	89	62	37	21	0	0	0	8	79	87
1959	86	73	34	62	2	0	0	0	0	0	63	24		**1959**	97	88	60	72	30	4	0	0	2	21	78	77
1960	50	56	20	7	0	0	0	0	0	0	0	76		**1960**	65	74	51	52	19	0	0	0	0	0	0	83
1961	44	60	88	71	4	0	0	0	0	10	48	77		**1961**	66	70	89	76	28	3	0	0	0	17	64	81
1962	81	91	43	39	0	0	0	0	0	24	58	69		**1962**	83	96	67	56	14	0	0	0	0	26	58	73
1963	53	74	9	27	18	0	0	0	18	2	42	35		**1963**	70	82	35	42	39	0	0	0	31	56	91	59
1964	29	26	20	13	0	0	0	0	0	13	28	91		**1964**	54	47	25	46	6	0	0	0	0	23	42	94
1965	68	19	33	23	0	0	0	0	0	3	3	78		**1965**	71	21	51	40	0	0	0	2	0	14	16	65
1966	56	57	99	80	1	0	0	0	0	10	64	98		**1966**	56	49	95	70	23	20	0	0	3	20	83	100
1967	73	42	90	58	2	0	0	0	0	10	79	88		**1967**	83	59	93	68	42	3	0	0	1	56	85	91
1968	94	93	81	65	14	0	0	0	0	4	13	40		**1968**	98	96	84	70	48	8	0	4	7	38	17	52
1969	61	86	92	61	3	0	0	0	0	22	76	74		**1969**	77	89	94	79	32	4	0	0	33	69	94	75
1970	58	80	85	75	2	0	0	0	0	34	55	62		**1970**	61	84	94	82	44	18	2	0	7	48	71	81
1971	56	74	35	39	3	0	0	0	0	19	58	81		**1971**	85	88	52	66	22	3	0	0	7	43	77	87
1972	46	39	31	34	0	0	0	0	0	21	74	56		**1972**	53	73	64	52	25	0	0	0	0	27	87	82
1973	55	98	76	39	3	0	0	0	0	18	76	89		**1973**	80	100	83	71	33	25	2	3	0	36	87	94
1974	97	86	19	10	0	0	0	0	0	2	14	100		**1974**	97	97	60	53	25	3	0	2	9	33	78	100
1975	99	63	62	25	5	0	0	0	0	0	48	73		**1975**	100	74	76	66	31	8	0	0		24	61	91
1976	98	89	90	61	9	0	0	0	0	0	17	45		**1976**	99	90	90	71	56	16	0	0	0	15	26	65
1977	70	74	31	44	0	0	0	0	0	3	83	46		**1977**	94	79	65	75	24	0	0	0	3	18	93	73
1978	98	98	69	8	0	0	0	0	0	12	78	38		**1978**	100	98	92	48	33	1	0	0	3	41	94	73
1979	67	54	85	34	12	0	0	0	3	10	33	71		**1979**	82	92	93	79	50	17	0	0		36	98	100
1980	87	68	73	39	0	0	0	0	0	3	28	82		**1980**	100	100	100	88	31	8	0	0	0	0	58	91
1981	93	100	100	33	3	0	0	0	3	16	63	49		**1981**	97	100	100	81	55	18	0	0		88	90	88
1982	69	79	89	42	16	0	0	0	2	10	53	94		**1982**	92	86	92	70	63	15	0	0		39	87	100
1983	98	77	95	92	44	0	0	0	0	23	48	89		**1983**	100	91	98	100	56	42	0	0	0	50	75	97
1984	100	98	76	58	11	0	0	0	0	8	50	82		**1984**	100	100	92	95	66	50	10	0	0	58		100
1985	52	70	60	20	2	0	0	0	0	0	37	45		**1985**	87	96	92	72	35	0	0	0	2	18	70	97
1986	74	27	85	32	0	0	0	0	0	53	65	87		**1986**	98	55	97	82	53	35	0	0	3	68	97	97
1987	40	68	68	57	6	0	0	0	0	44	4	31		**1987**	81	91	97	90	45	0	0	0	2	71	60	74
1988	89	83	90	83	10	0	0	0	0	13	20	81		**1988**	100	91	90	92	40	0	0	0	3	56	77	97
1989	90	100	100	98	48	0	0	0	0	5	0	47		**1989**	100	100	100	100	97	38	0	0	5	15	78	68
1990	87	100	100	90	15	0	0	0	0	0	22	79		**1990**	92	100	100	100	53		0	0		27	42	94
1991	84	75	69	55	0	0	0	0	0	13	58	73		**1991**	92	100	98	100	63	2	0	0	0	50	92	92
1992	61	88	82	51	8	0	0	0	0	0	69	95		**1992**	84	98	100	98	69	10	0	0	3	24	93	100
1993	100	82	81	43	5	0	0	0	0	0	48	55		**1993**	100	100	100	93	66	35	0	2	0	16	77	100
1994	50	80	89	67	2	0	0	0	0	40	35	92		**1994**	100	89	98	75	45	0	0	0	10	61	75	100
1995	98	100	95	62	6	0	0	0	5	24	37	44		**1995**	100	100	100	100	53	32	0	0	22	66		84
1996	44	88	40	17	0	0	0	0	0	11	58	48		**1996**	87	100	66	62	2	0	0	0	0	48	95	
1997	52	96	97	38	0	0	0	0	2	45	8	29		**1997**	95	100	100	65	42	2	0	0	3	0	87	68
1998	16	79	90	32	2	0	0	0	0	48	28	53		**1998**	79	100	94	55	50	0	0	0	2	58		
1999	85	89	68	38	2	0	0	0	0	2	55	89		**1999**	90	93	95	72	16	0	0			29	87	92
2000	66	97	84	23	6	0	0	0	0	0	23	52		**2000**	82	100	92	58	50	15		0		23	95	92
2001	34	57	68		2	0	0	0	0	2	50	46		**2001**	92	93			31	0	0	0		18	63	
2002	31	73	71											**2002**	92	100	98									
Average 1971-2000																										
Kvígi.	**74**	**81**	**74**	**45**	**7**	**0**	**0**	**0**	**1**	**15**	**43**	**67**			**92**	**93**	**89**	**78**	**45**	**13**	**0**	**0**	**3**	**38**	**79**	**89**
Mjólk.	**71**	**72**	**64**	**47**	**13**	**1**	**0**	**0**	**2**	**13**	**39**	**59**			**85**	**88**	**84**	**83**	**60**	**35**	**23**	**18**	**24**	**40**	**66.2**	**81**

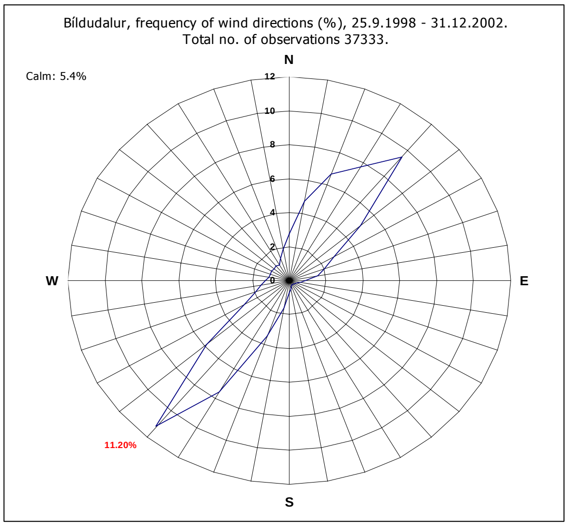
Wind roses

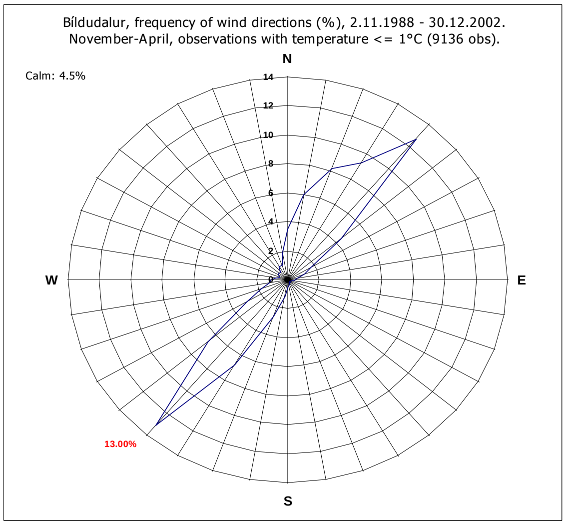

Patreksfjörður, frequency of wind directions (%), 1.1.1997 - 31.12.2002.
Total no. of observations 52517.

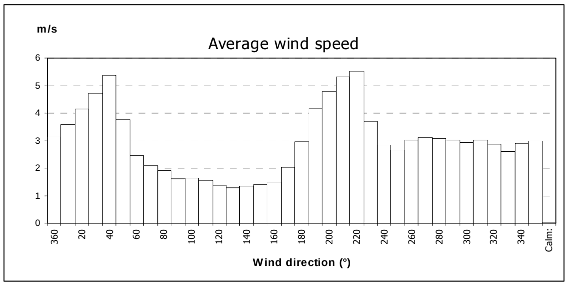

Patreksfjörður, frequency of wind directions (%), 5.1.1997 - 30.12.2002.
November-April, observations with temperature <= 1°C (14264 obs.).

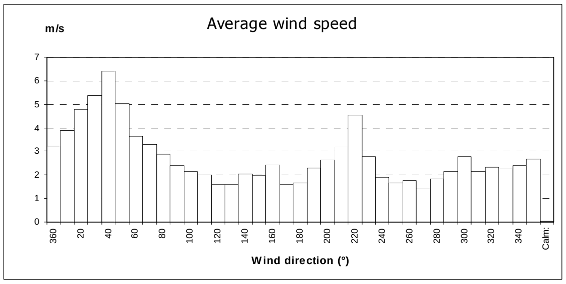

Average wind speed

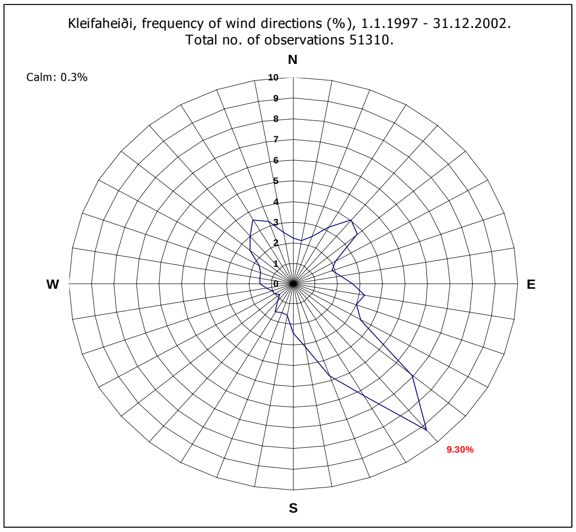

Average wind speed


Bíldudalur, frequency of wind directions (%), 25.9.1998 - 31.12.2002.
Total no. of observations 37333.

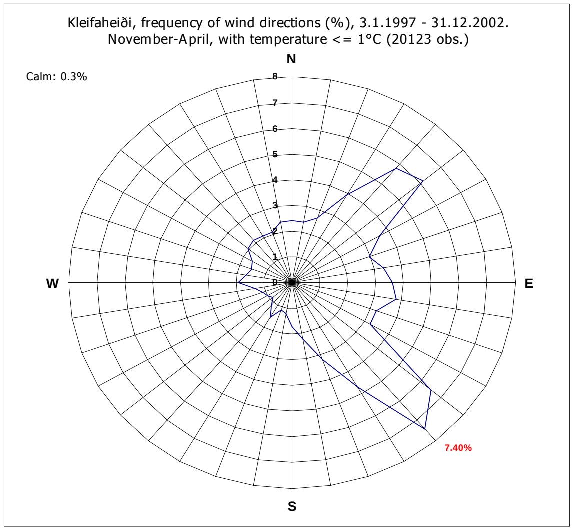

Bíldudalur, frequency of wind directions (%), 2.11.1988 - 30.12.2002.
November-April, observations with temperature <= 1°C (9136 obs).


Average wind speed

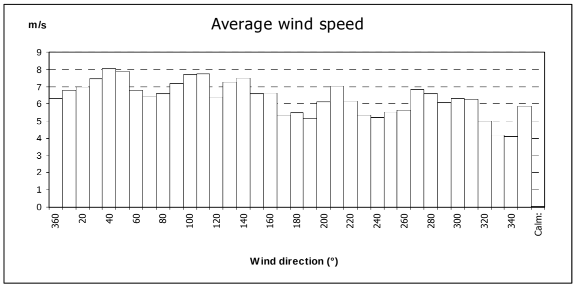

Average wind speed



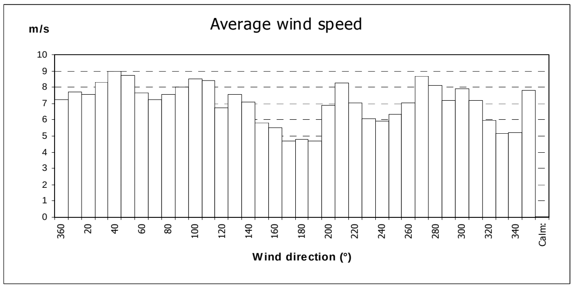
Kleifaheiði, frequency of wind directions (%), 1.1.1997 - 31.12.2002.
Total no. of observations 51310.



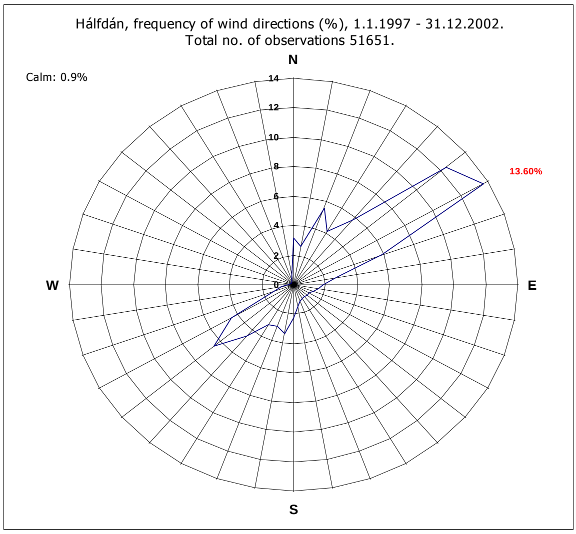
Kleifaheiði, frequency of wind directions (%), 3.1.1997 - 31.12.2002.
November-April, with temperature <= 1°C (20123 obs.)



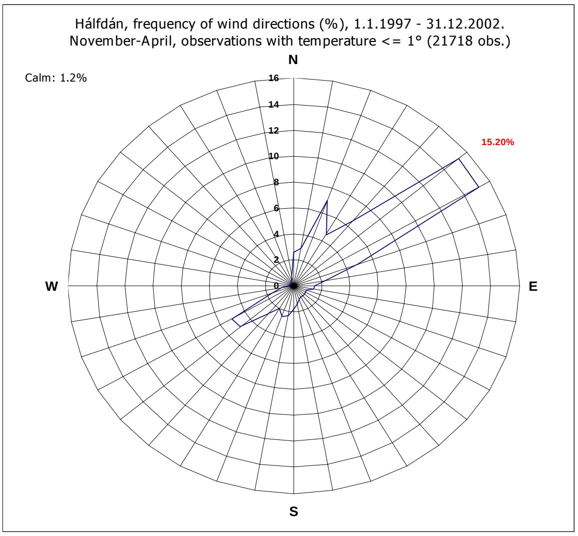
Average wind speed



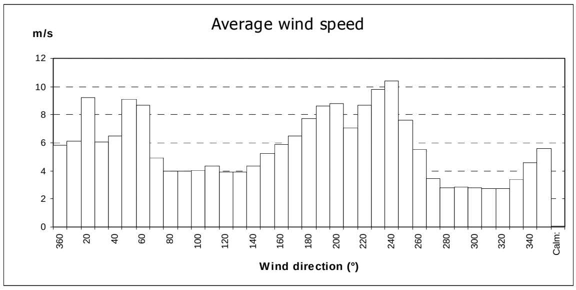
Average wind speed



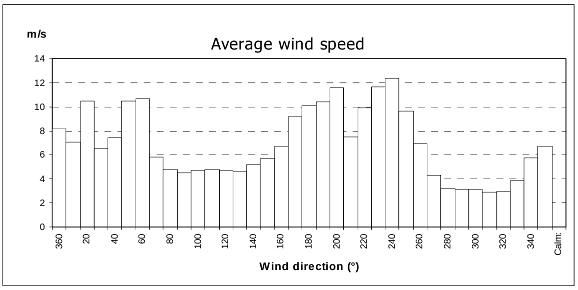
Hálfdán, frequency of wind directions (%), 1.1.1997 - 31.12.2002.
Total no. of observations 51651.



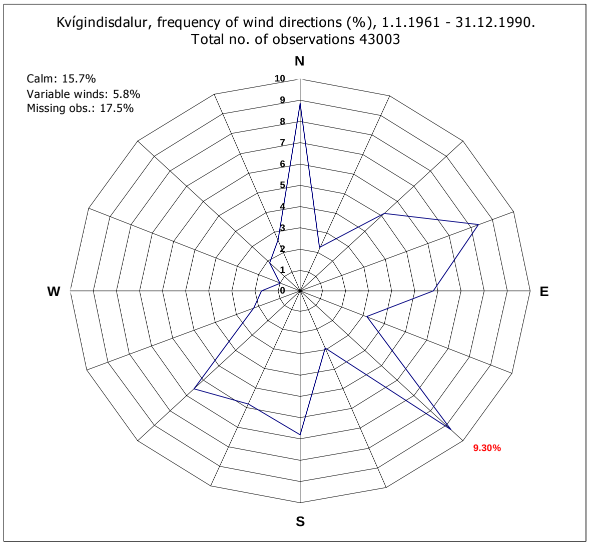
Hálfdán, frequency of wind directions (%), 1.1.1997 - 31.12.2002.
November-April, observations with temperature <= 1° (21718 obs.)



Average wind speed

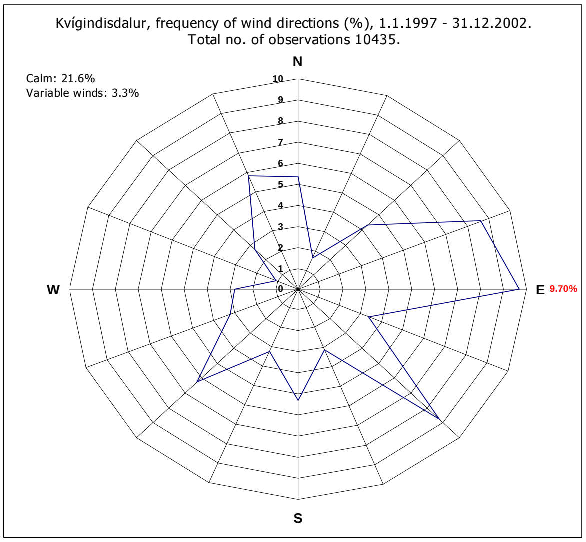


Average wind speed



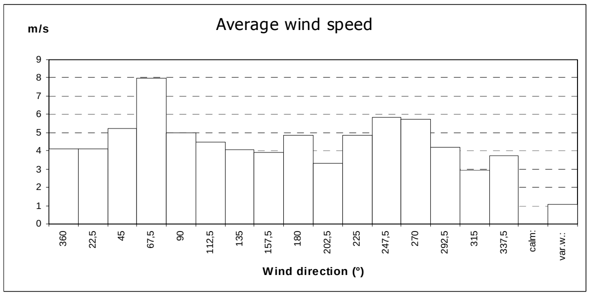
Kvígindisdalur, frequency of wind directions (%), 1.1.1961 - 31.12.1990.
Total no. of observations 43003

Calm: 15.7%
Variable winds: 5.8%
Missing obs.: 17.5%

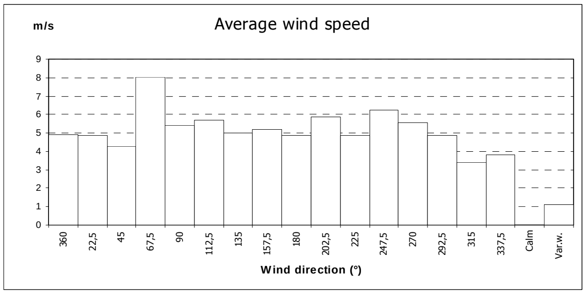


Kvígindisdalur, frequency of wind directions (%), 1.1.1997 - 31.12.2002.
Total no. of observations 10435.

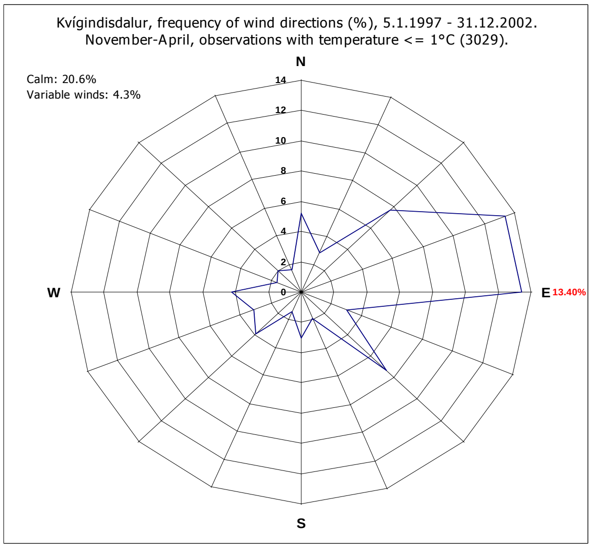
Calm: 21.6%
Variable winds: 3.3%



Average wind speed

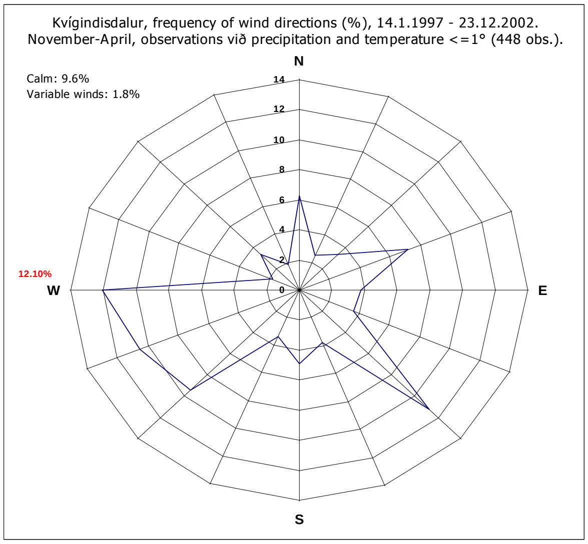


Average wind speed



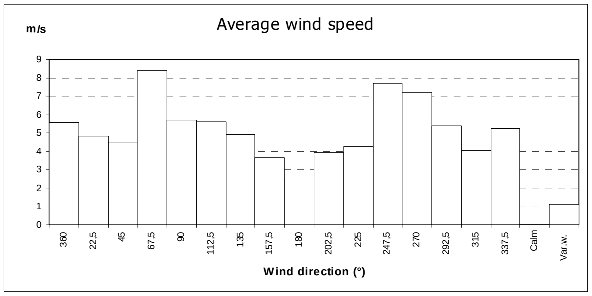
Kvígindisdalur, frequency of wind directions (%), 5.1.1997 - 31.12.2002.
November-April, observations with temperature <= 1°C (3029).

Calm: 20.6%
Variable winds: 4.3%

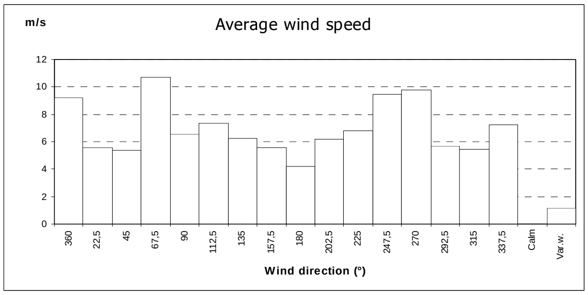


Kvígindisdalur, frequency of wind directions (%), 14.1.1997 - 23.12.2002.
November-April, observations við precipitation and temperature <=1° (448 obs.).

Calm: 9.6%
Variable winds: 1.8%



Average wind speed



Average wind speed

E Profile drawings

Drawing no.	Profile ID	Avalanche path
1	bild01aa	Inside of Gilsbakkagil
2	bild02aa	Inside of Gilsbakkagil
3	bild03aa	Inside of Gilsbakkagil
4	bild04aa	Gilsbakkagil
5	bild05aa	Milligil
6	bild06aa	Milligil
7	bild07aa	Milligil/Merkigil
8	bild08aa	Milligil/Klofagil
9	bild09aa	Milligil
10	bild10aa	Milligil
11	bild11bb	Búðargil
12	bild12aa	Outside of Búðargil