VEÐURSTOFA ÍSLANDS

Report
03046

Guðmundur Hafsteinsson

Report on weather conditions over Snæfellsnes by evening 25 May 2001

Report prepared for Aircraft Accident Investigation Board

VÍ-ÞJ07
Reykjavík
Desember 2003

Report - Greinargerð
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Content

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Introduction

When the Icelandic Coast Guard's helicopter, TF-SIF, was flying south over Snæfellsnes by evening 25 May 2001 it was thrown about in the air with the result that the main rotor struck the tail and damaged it. The incident happened just before 21 UTC over a ridge extending east-northeast from Elliðatindar towards Urðarmúli (64,9°N 22,9°W). According to the pilots the nose of the helicopter was lifted abruptly when it passed at a rather low altitude over a marked ridge in the landscape. The pilots succeeded to get the aircraft under control again and landed a few minutes later near road 54 just south of the place of the incident.

The synoptic situation

On the synoptic map from midnight, three hours after the incident (fig. 1), one can see that a low-pressure center, 1001 hPa, was some 400 km south of Iceland and a high was over Northeast-Greenland. The low was moving slowly west and the high was increasing. As a result of this development the easterly winds, which were blowing in most parts of Iceland, became gradually stronger, but this process was very slow.

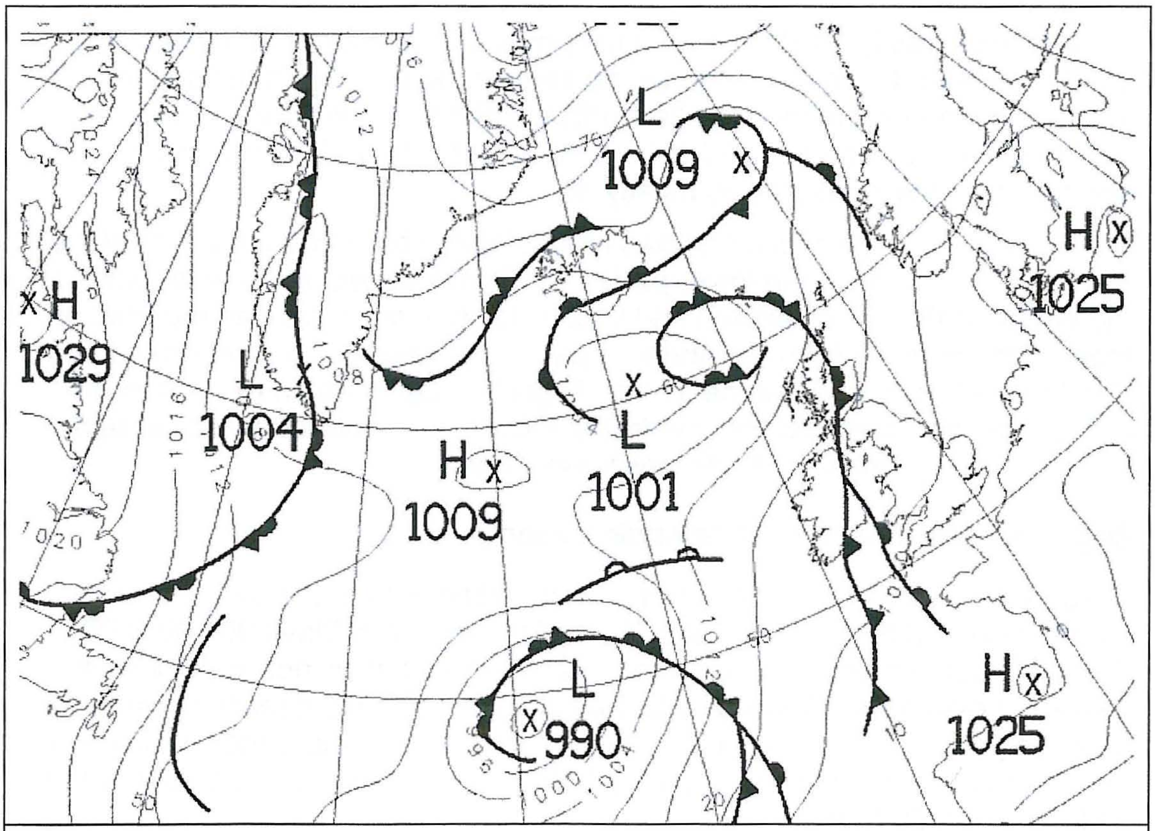

Fig. 1 - Synoptic weather map 26 May 2001 00 UTC. The map is issued by the British Meteorological Office (UKMO)

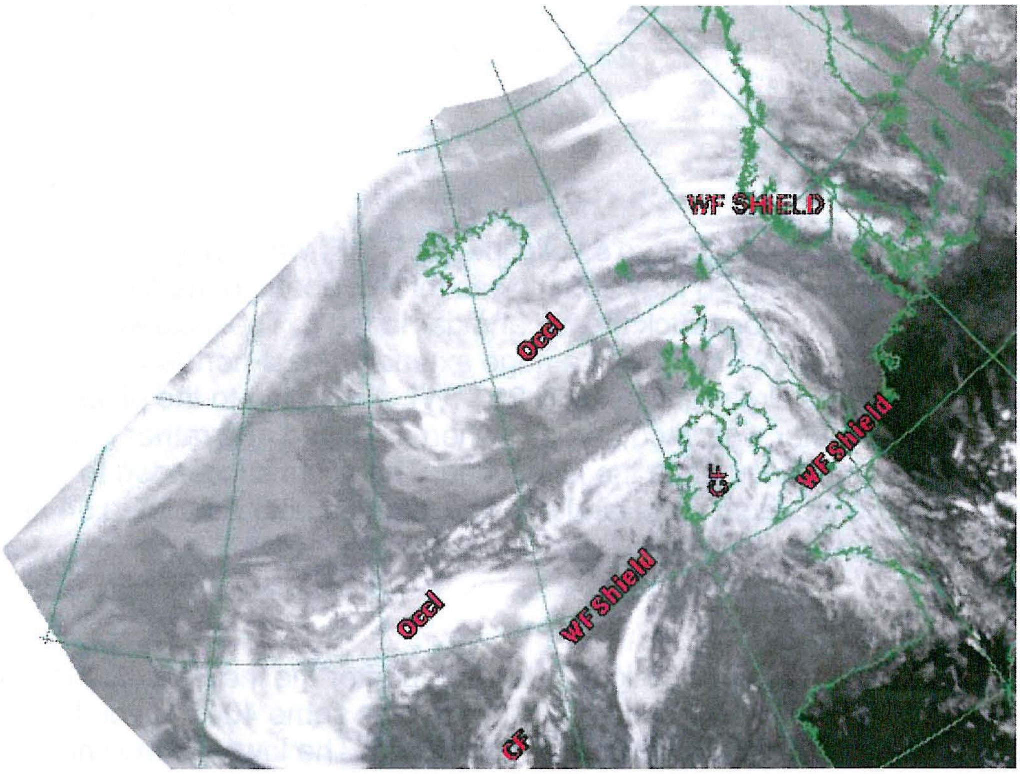

Fig 2 - Infrared cloud image taken 25 May 2001 21 UTC from the satellite METEOSAT. The picture is copied from a web page hosted by the dutch weather service (KNMI), http://www.knmi.nl/satrep/.

A weak front was lying almost stationary over the southern part of Iceland. The front caused some rain as may be seen in the upper part of fig. 3. Fig. 2 shows the cloud systems over the North Atlantic and there we can see that the cloud layers following the front extended over most of Iceland but in the northern part the weather was mostly dry.

The weather in western Iceland was characterized by very calm winds at the time of the incident. In the lower part of fig. 3 we can see from the isobars that the pressure field was very flat and light winds or even calm was reported on most of the stations from the northern part of Faxaflói to the southern part of Vestfirðir. We can say that the station Ásgarður (see map on fig. 7) was the only exception. Northeasterly winds, 13 knots, were reported there but earlier in the day the weather had also been calm there.

Upper air observations at Keflavík Airport

In figures 4 and 5 we can se upper air observations from Keflavík Airport made at noon (25 May 2001 12 UTC) and midnight (26 May 2001 00 UTC). The observations show easterly and later northeasterly winds in the lowest levels but over approximately 5000 feet altitude southerly directions were more dominant. The wind speed was very slow, hardly more than 10 knots. In the latter observation winds stronger than 15 knots were not found below the altitude of 20000 feet.

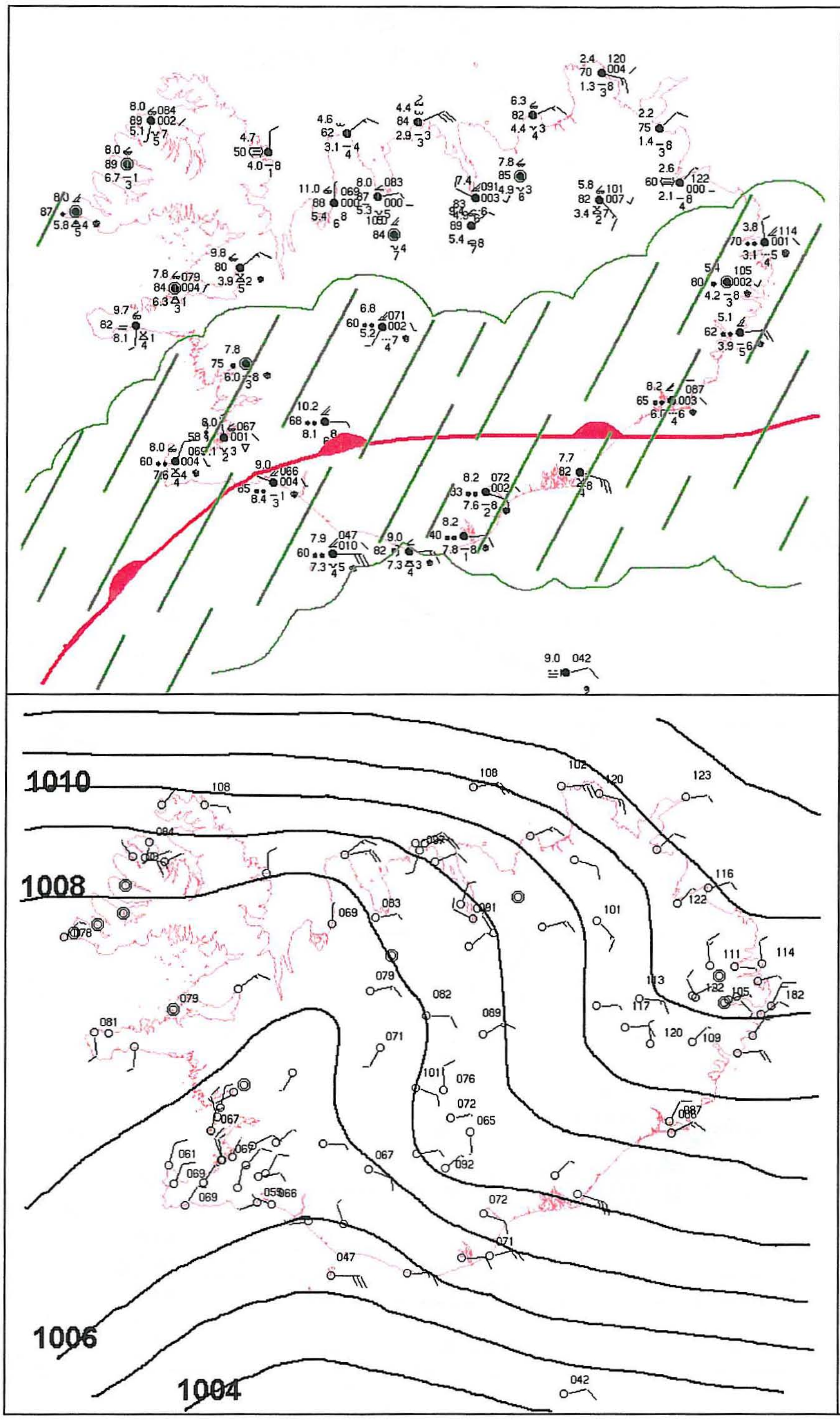

Fig 3 - The weather in Iceland 25 May 2001 21 UTC. Manned synoptic stations, warm front and precipitation area shown in the upper part. Wind and mean sea level pressure from manned and automatic stations together with isobars in the lower part.

Winds aloft

On the maps in fig. 6 we can see calculations of winds aloft made with the HIRLAM G45 numerical weather prediction model run at the Danish Meteorological Institute. This result is in a good agreement with the wind measured over Keflavík Airport. According to the model we should have had light southerly winds over Snæfellsnes in both levels (FL050/850 hPa and FL025/925 hPa), but later in the evening, as shown by the calculation at midnight, the southerly winds should have been replaced by easterly winds. As far as can be seen from observations, f.ex. from Ásgarður as earlier mentioned and from other stations as will be shown later, it seems to be a fact that during the evening, from 18 UTC to midnight, easterly and northeasterly winds have been advancing slowly against the southerly winds which were prevailing earlier in the inner part of Snæfellsnes.

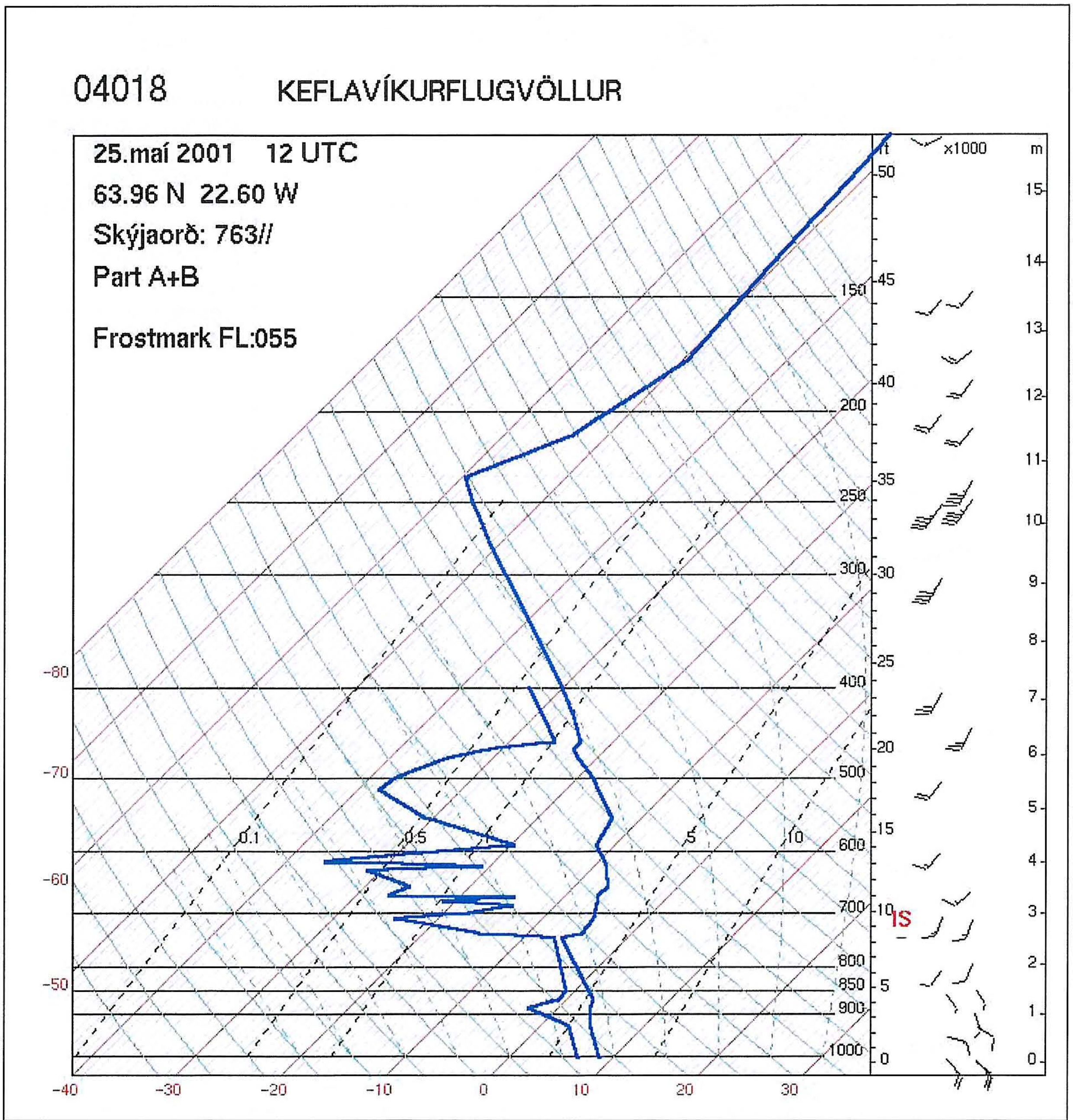

Fig. 4 - Upper air observation made at Keflavík Airport 25 May 2001 12 UTC

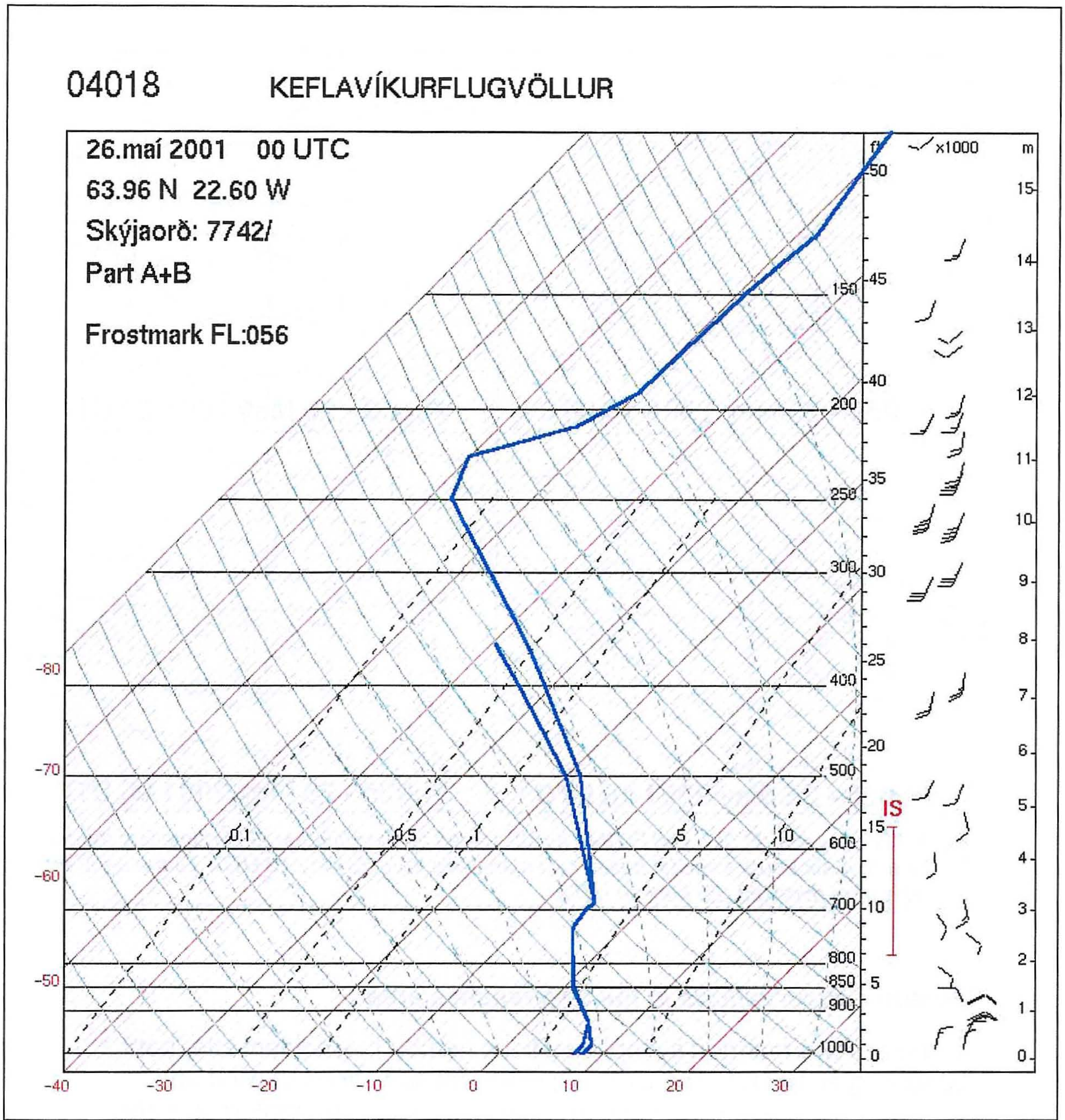

Fig. 5 - Upper air observation made at Keflavík Airport 26 May 2001 00 UTC, three hours after the incident

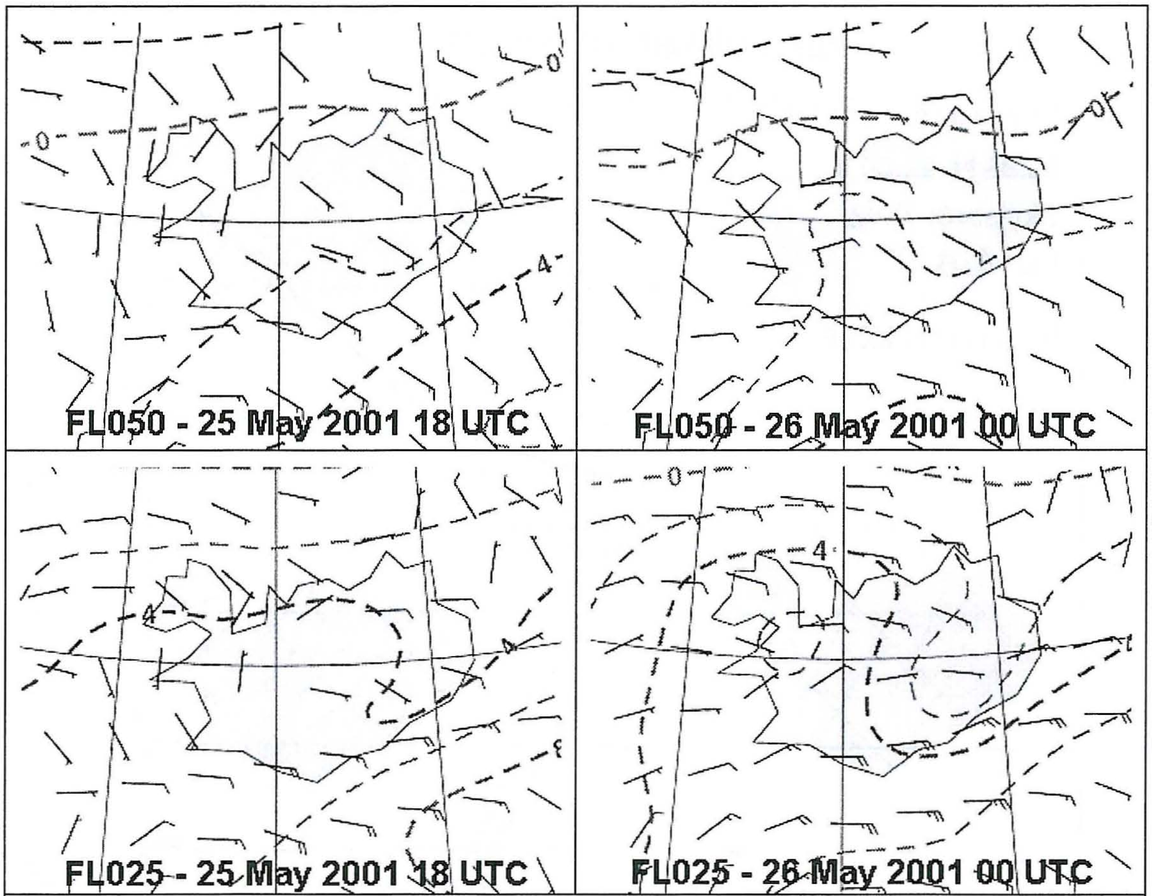

Fig. 6 - Winds aloft (FL025 and FL050) as calculated by the HIRLAM G45 numerical model. To the left: A six hours forecast based on an analysis from 25 May 12 UTC. To the right: An Analysis from midnight (26 May 00 UTC)

Weather observations in the Snæfellsnes area

There are two manned synoptic stations nearby the incident site, both observing at 18 UTC and 21 UTC. Hourly observations of wind and temperature are also available from several automatic stations in the Snæfellsnes area. Most of them are operated by the Icelandic Public Road Administration but one station is operated by the Icelandic Meteorological Office (IMO). The position of these stations is shown in fig. 7.

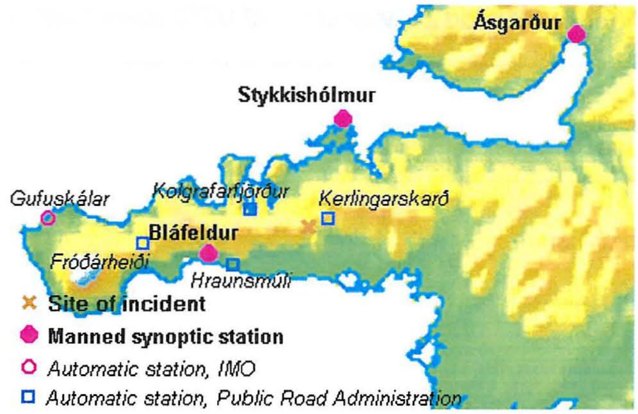

Fig. 7 - Weather stations in the Snæfellsnes area

On the maps in fig. 3 only the IMO-stations are displayed. Observations from the stations operated by the Public Road Administration are not inserted in the forecasters working environment and are therefore not shown on the map.

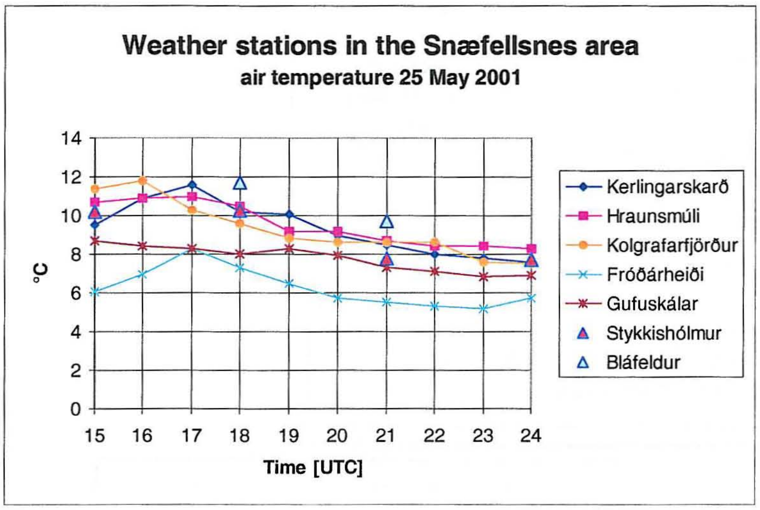

Fig. 8 - Air temperature. Time series from weather stations in the Snæfellsnes area. For positions of the individual stations see fig. 7

Time series from all the relevant weather stations are shown in figures 8-10. In fig. 8 one can see that there does not seem to have been great difference in temperature between stations on the northern side and the southern side of the mountains. Certainly the temperature at Bláfeldur at 21 UTC was approximately two degrees higher than in Stykkishólmur at the same time. But the three stations closest to the incident site, Kolgrafarfjörður, Kerlingarskarð and Hraunsmúli, report almost exactly the same temperature.

Fig. 9 and fig. 10 should be looked at together to get an overview of the fluctuations in the wind. The most interesting stations are Hraunsmúli, Kerlingarskarð and Kolgrafarfjörður. At Hraunsmúli, on the southern side, there had been continuous southwesterly wind during the afternoon but the wind speed was rather low, 5 to 8 knots most of the time. At Kolgrafarfjörður rather fresh and gusty winds from the south were observed early in the afternoon (15 UTC), then the winds turned to moderating northerly or north-westerly winds. At the time of the incident there was almost calm at Kolgrafarfjörður. At Kerlingarskarð light southerly winds were blowing until 16 UTC but after that the wind direction turned to northwesterly. By 20 UTC there was a marked change in the wind as the wind direction turned towards east-northeast with increasing wind speed. At the time of the incident the wind at Kerlingarskarð was northeasterly 16 knots, gusting to 19 knots.

The weather near the incident site

Apparently the weather was exceptionally calm and it is difficult to imagine that it could give rise to any significant turbulence, and it is very unexpected that it could actually throw the helicopter around as seems to have happened here. There was hardly any sunshine at all so strong thermics and eddies connected to deep convection can be excluded. According to almost all weather observations the wind was also very light in the area, both at ground level and aloft. The conditions were therefore very far from what is assumed necessary for mountain waves or rotor stream and it is very farfetched to use such phenomena as an explanation to what happened.

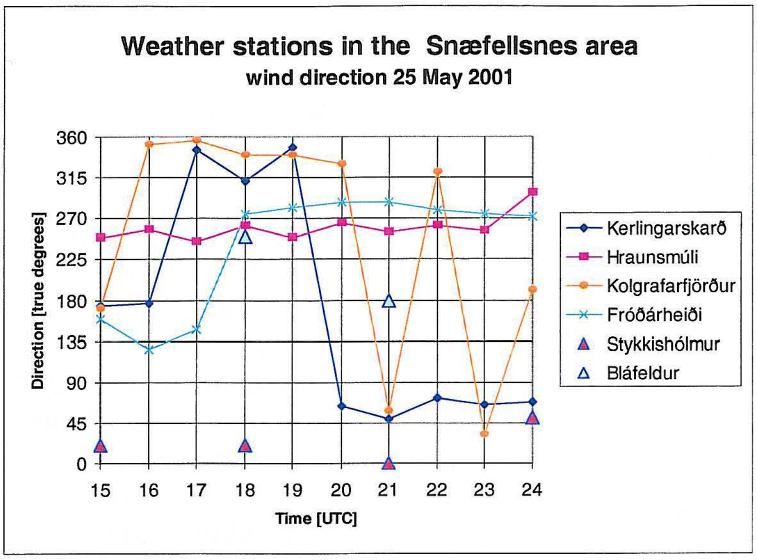

Fig. 9 - Wind direction (true). Time series series from weather stations in the Snæfellsnes area

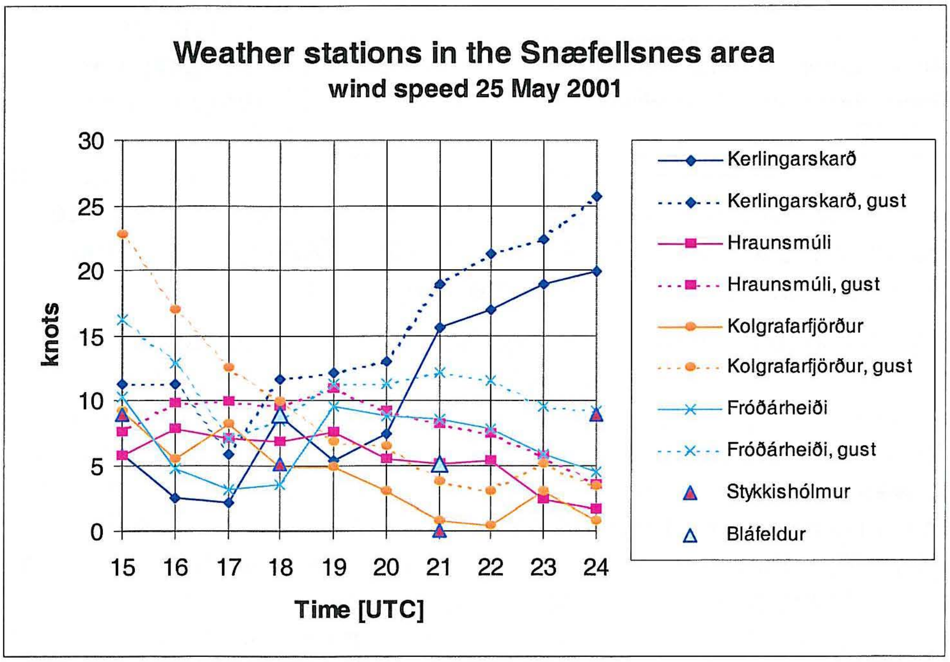

Fig. 10 - Wind speed in knots (10 minutes average and gusts). Time series series from weather stations in the Snæfellsnes area

Weather observations from the Snæfellsnes area show that around the time of the incident there were light winds blowing from directions between south and west on the southern side of the peninsula. Informal observations at landing site of the helicopter shortly after the incident indicated the same. Upper air observations (figures 4 and 5) indicate also southerly winds and the numerical calculations shown in fig. 6 support this idea. But on the northern side of the peninsula we do not see much of the southerly winds. There we had calm winds on most of the stations, even light winds from the northerly directions. One station is an exception and it is the station closest to the incident site, Kerlingarskarð. As already mentioned very light southerly winds were prevailing there until 16 UTC. The next three hours the wind blew gently from northwest but near 20 UTC the wind direction turned to east-northeast with increasing wind speed. At 21 UTC northeasterly 16 knots were measured at Kerlingarskarð. This change could very well be a consequence of the development shown by the forecast maps in fig. 6, and which has already been mentioned, that the easterly winds were gradually taking over later in the evening.

It seems normal to conclude that some kind of fronts must have developed between the air which advanced from the east and the rather calm air which was drifting mostly from the south or southwest. It is not possible to find a big difference between the physical properties of these two currents of air on each side of the front. The air on the southern side of the peninsula seems nevertheless to have been slightly warmer as indicated mainly by the

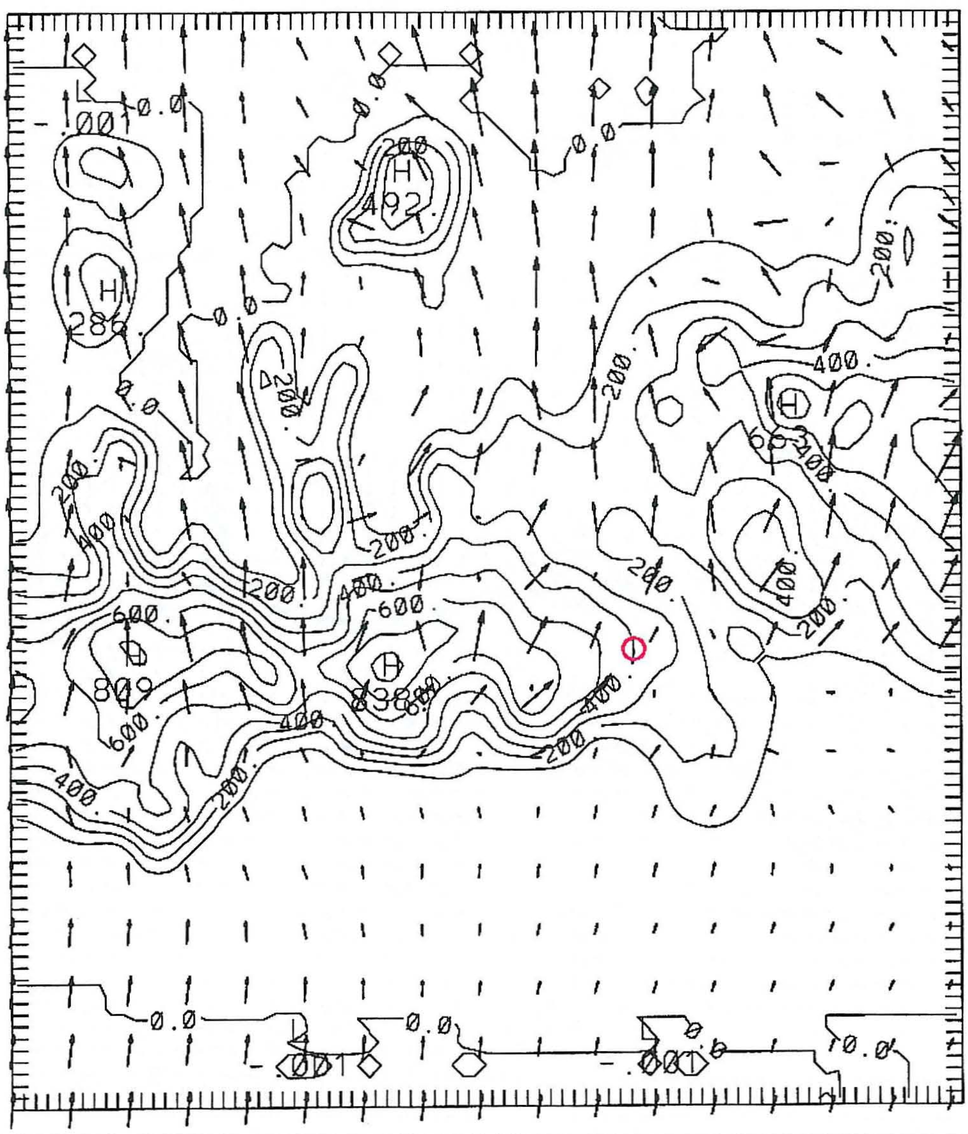

Fig. 11 - Winds at approximately 2500 feet abowe sea level (925 hPa) at 18 UTC, calculated with the MM5 numerical model. The approximate sit of the incident is shown with a red circle.

observations from Bláfeldur but the temperature at the three automatic stations closest to the incident site, Hraunsmúli, Kolgrafarfjörður and Kerlingarskarð, was reported almost exactly the same (fig. 8).

It is impossible to give an exact and definite description of such fronts but many details seem to support the hypothesis that will be put forward here.

It is most likely that the air advancing from northeast has penetrated under the slightly warmer air, which was dominant in the area previously. In the beginning we have not had any clear frontal zones but the air advancing along the surface has been conducted firmly by the orography and developed various currents and eddies. Northeasterly or easterly winds could hardly be found in observations until 20 UTC at Kerlingarskarð. In fig. 3 we see that fresh northeasterly wind was also reported at Ásgarður at 21 UTC as already mentioned but earlier in the day the winds had also been calm there.

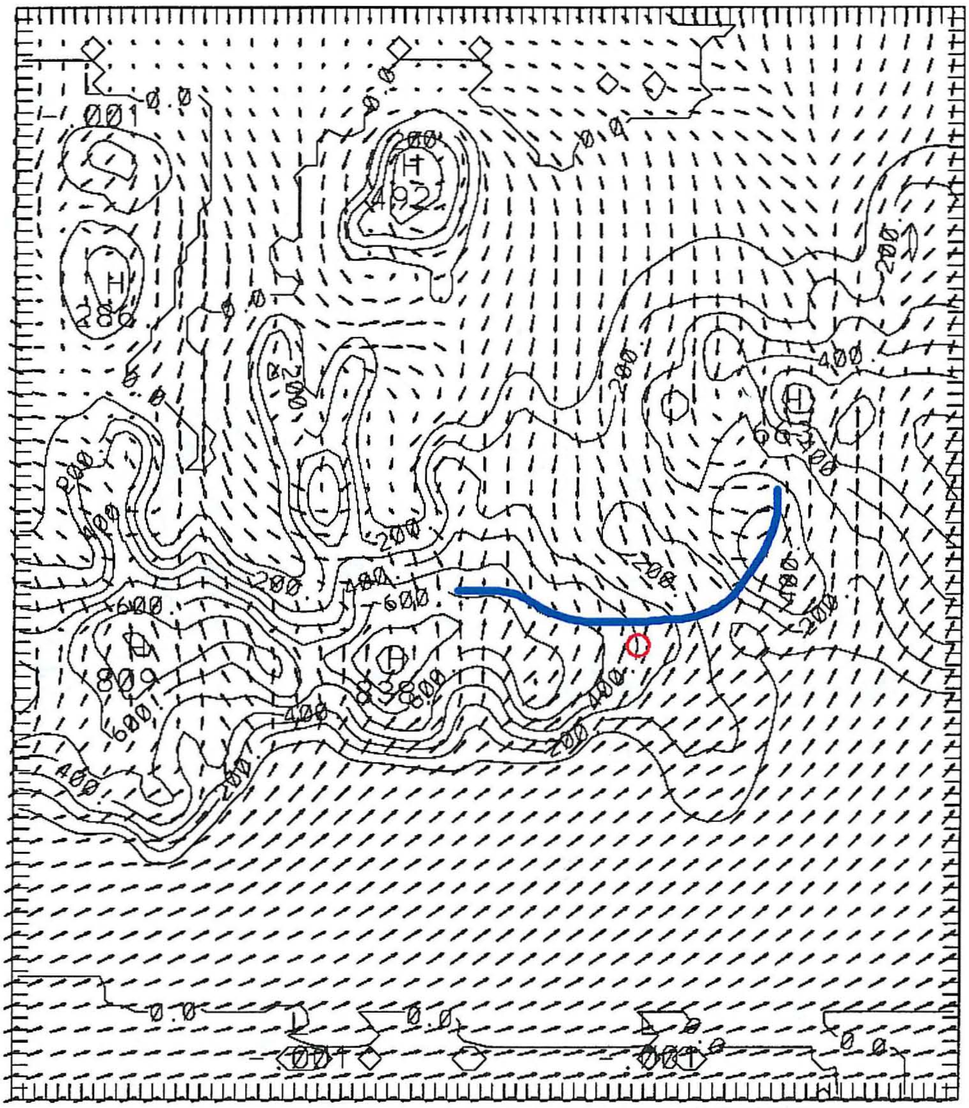

Fig. 12 - Winds at surface at 18 UTC, calculated with the MM5 numerical model. The front ahead of the cooler air penetrating south through Dökkólfsdalur is shown with a blue line. The approximate site of the incident is shown with a red circle

Calculations done with the numerical model MM5 support the hypothesis. On figures 11 and 12 we can se results of these calculations which were made at "Reiknistofa í veðurfræði ehf". The air currents over Snæfellsnes are simulated in a very fine grid, which makes it possible to see the effect of the orography in detail. The calculations are based on an analysis from noon and stop six hours later, at 18 UTC, and that is the situation shown on the maps. In fig. 11 we see the calculated wind in an altitude of approximately 2500 feet above sea level (925 hPa) but fig. 12 shows the calculated wind at surface level.

These maps indicate that at the height of the mountaintops (approximately. 2500 feet) southerly winds have been prevailing but the wind speed was variable due to the influence of the orography. Near Elliðatindar the wind direction seems to have been southwesterly and the wind velocity higher than in most other places. Probably one can conclude that in fact fresh southwesterly surface winds have blown around and over Elliðatindar spreading out over the area to the northeast where the incident happened.

The other map, showing calculated surface winds, gives a quite different picture. Here we can see rather slow but constant southwesterly winds on the southern side of the peninsula but on the northern side we have eddies which are very much formed by the orography. Generally the air seems to be streaming from north in between the mountains where it converges with the air coming from the south. This must have led to upgoing vertical motion and we know that clouds were lying on the highest mountains and somewhat down along the hillsides. One of the strongest northerly currents seem to have been lying in Kolgrafarfjörður and another one to the east of Bjarnarhafnarfjall, over Berserkjahraun and extending further south over Vatnaheiði. In the northeast sides of Elliðatindar this current has become more northwesterly and according to the calculation valid at 18 UTC the front between this current and the air coming from the south should have been just north of the site of the incident. Over the front at surface the previously mentioned southwesterly winds have been blowing.

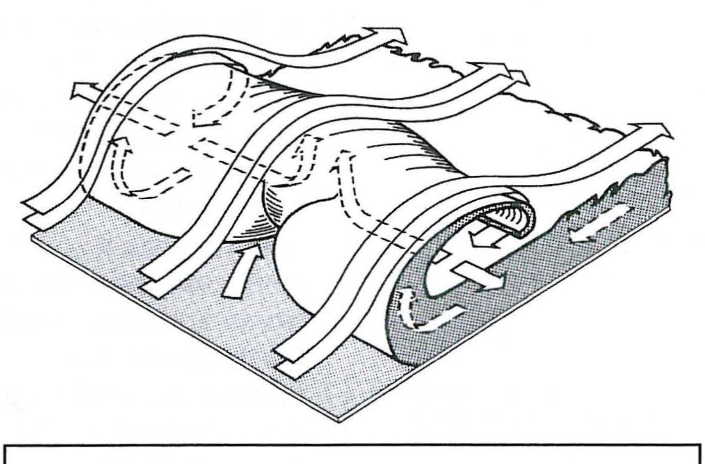

Fig. 13 - Schematic representation of the flow at a gravity current head. The picture is taken from "Meso-scale Atmospheric Circulations" by B.W.Atkinson (1981)

Structure sea-breeze fronts

To understand better the behavior of such fronts it is natural to look at conceptual models of sea-breeze fronts, which have been investigated quite well. In fact the flow here could be classified as some kind of sea breeze since the air coming from north advanced against the southerly winds which were over the land in the beginning. In fig. 13 we can see a simple schematic drawing of a sea-breeze front where the sea breeze penetrates under the slightly warmer air mass. These ideas are supported by experiments in laboratory tanks and in fig. 14 we can see the results of one such experiment. The dense fluid is moving from right to left under the less dense fluid. Over the frontal head and just behind the "surface front" we have a layer with well developed eddies. The simplified image in fig. 13 reflects this quite well.

Fig. 14 - Flow patterns inside a laboratory gravity head, showing successive positions of a dye patch inserted in the dense fluid moving towards the head (Simpson,J.E. et al., 1977)

As already has been mentioned and appears clearly from fig. 12 the surface winds on the northern side of Snæfellsnes were very much formed by the orography. The front ahead of the air advancing from the east has therefore not been of such nature that we could indicate it with a regular line, straight or curved, as on a traditional weather map. It has been in patches of different length and their orientation and direction of movement has been dominated by the landscape. They have been sharpest where a current met another current but very weak and even invisible where the wind was very slow.

To get an idea on how the fronts might have been influenced by the orography we could look at fig. 15. There we can see how a sea breeze and wind blowing from the opposite direction could behave when they meet at a salient edge on a hilltop. Marked eddies develop near the edge under the discontinuity between the two currents. The conditions illustrated on the picture are not in every detail like what we would expect to have been in the Snæfellsnes area this evening but nevertheless it could clarify why sea-breeze fronts and other similar fronts can be much sharper near hill edges than elsewhere. The front will be by far sharpest very close to the edge and flying through it very low

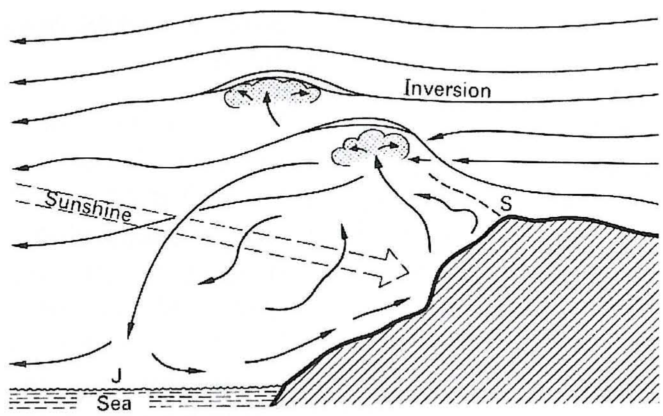

Fig. 15 - Separation of the flow by a salient edge of a hill. Here the ascending sea breeze is assumed to be caused by heating of the hillside. The picture is taken from "Environmental Aerodynamics" by R.S.Scorer (1978)

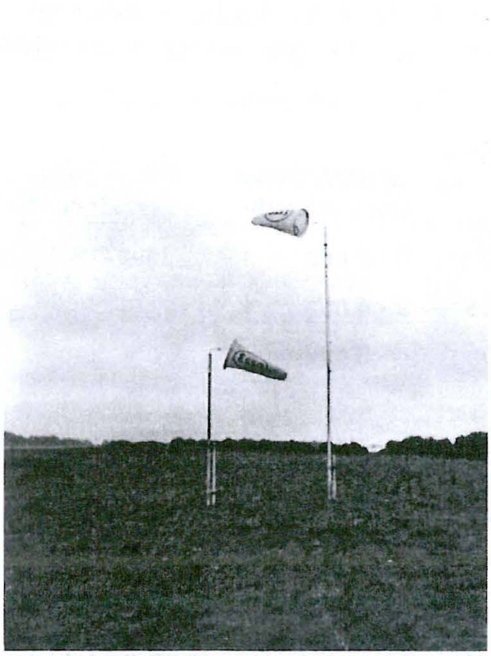

Fig. 16 - Wind socks positioned at the top of a steep wind facing slope. The height of the wind socks is 2 and 4 metres over the ground. The picture is taken from "Clouds of the World, a Complete Colour Encyclopedia" by Richard Scorer (1972)

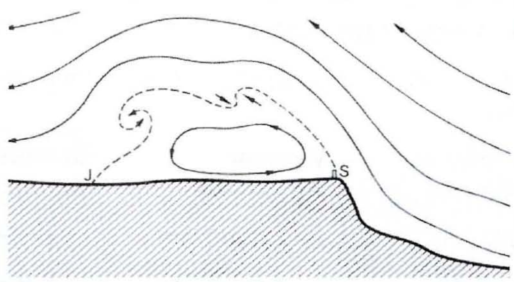

Fig. 17 - A separation of the flow may occur when the wind blows up a steep hill face. The size of the eddy formed depends on the slope of the ground. The picture is taken from "Clouds of the World, a Complete Colour Encyclopedia" by Richard Scorer (1972)

over the edge would be experienced as a very sharp wind shear. At higher altitude the two air currents would have had time to mix and flying through the front there would be experienced more like turbulence rather than wind shear.

Figures 16 and 17 have been put in here to give an idea about how sharp such wind shear can be near the edge. Fig. 16 is a photography of real conditions; one of the wind socks is at 2 m over the ground but the other one at 4 m. The drawing in fig. 17 shows a similar situation.

Some conclusions

In these deliberations we may sometimes have tried to illustrate "the worst case" and looked after what could be possible rather than the most probable solution. But nevertheless it may be considered as likely that at the time and site of the incident sharp wind shear could be found near salient edges of hills and turbulent eddies connected to fronts where the slightly cooler air from north and east penetrated under the air blowing slowly from the south or southwest. But it is almost impossible to give any quantitative statements on the strength of these phenomena; by far denser network of wind measurements would be needed for that. But we could perhaps guess that where the southwesterly current over Elliðatindar and the north-northwesterly current in the western sides of Dökkólfsdalur met the wind speed in each current could have been in the order of 10 to 15 knots. The magnitude of the vector difference between these two currents could then have been 15 knots or even more.

In table 1, which is originally taken from a Swedish-Soviet research report, the strength of wind shear is classified and the probable effect on aircraft control is given. If we realize how sharp wind shear can be near salient edges of hills it is not impossible that we could here find wind shear, vertical or horizontal, which would be classified as "Strong" or even "Severe" according to the table.

Table 1 - Classification of wind shear (originally from Trunov, O.K. and Turesson, L-O., 1986)

Intensity of windshear	Vertical windshear	Horizontal windshear	Updraft/Down-draft velocity	Effect on aircraft control
Light	0 - 2 m/s/30m	0 - 2 m/s/600m	0 - 2 m/s	Little
Moderate	2 - 4 m/s/30m	2 - 4 m/s/600m	2 - 4 m/s	Significant
Strong	4 - 6 m/s/30m	4 - 6 m/s/600m	4 - 6 m/s	Considerable difficulty
Severe	> 6 m/s/30m	> 6 m/s/600m	> 6 m/s	Hazardous

The weather this evening would generally be characterized as very good for any kind of flight and as free from any kind of hazards as possible. All observations indicate the same calm weather but a careful analysis of all available observations together with numerical simulations lead to the conclusion that wind shear or well developed eddies might have been found near low level frontal heads. It is even possible that the generally light winds could have lead to sharper wind shear than we would have found with stronger and more turbulent winds and it is not unlikely that the absence of low level turbulence made the effect of wind shear or the encounter with well developed eddies more unexpected than usually. One should therefore, even in the calmest weather, bear in mind that the airflow in the lowest levels can be influenced significantly by obstacles on the surface but the effect of the disturbances would decrease with increasing height over the ground.

Here we have come to the conclusion that even this very innocent looking weather could hide some unpleasant surprises. Nevertheless pilots should not expect that any kind of warnings would be issued for turbulence or wind shear in similar weather in the near future. The scale of these phenomena is far to small to be handled with the tools the forecaster on duty has available in his daily work.

On the longer sight it is possible that routine runs of numerical models on a very fine scale, similar to the MM5 model, could be useful to localize areas where local fronts and wind shear might possibly develop. A more thorough study of this situation than was possible to carry out now would therefore be very interesting.

Reykjavík, 30. september 2001

Guðmundur Hafsteinsson

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Simpson, J.E., Mansfield, D.A. and Milford, J.R., 1977: Inland penetration of sea-breeze fronts. *Quart. J. R. Met. Soc.*, **103**, 47-76.

Trunov, O.K. and Turesson, L-O., 1986: *On the problem of low level wind sh*ear. Report from the Swedish-Soviet working group on scientifical-technical cooperation in the field of flight safety.

Appendix A

From text books on aviation meteorology

A helicopter is very strongly affected by turbulence because both rotors and the suspended fuselage are differently affected, with the result that interaction occurs between these parts of the aircraft. Sometimes the effects are inphase and reinforce each other. Pilots therefore prefer not to fly when even moderate turbulence is anticipated.

(Manual of Meteorology, Part 2, Aviation Meteorology. Australian Government Publishing Service, Canberra 1981)

Components of the turbulence, which approximate the aircraft size, or are somewhat smaller, can produce strong non-uniform forces over the aircraft surface. This can result in yawing, pitching and rolling as well as other erratic motions. Sometimes resonant effects can cause vibrations in flexible portions of the aircraft.

(Compendium of Meteorology, Vol. II Part 2 – Aeronautical Meteorology. WMO – No. 364, 1978)

Appendix B

Flight weather conditions over Iceland, a general forecast

Eftirfarandi spá um flugveðurskilyrði yfir landinu frá kl. 17 til kl. 23 var gerð á Veðurstofu Íslands um kl. 16:30.

2001-05-25 16:31:44
Flugveðurskilyrði yfir Íslandi 25. maí 2001
Kl. 1700 til 2300

HÁLOFTAVINDAR OG HITI:
FL050: 11015KT +01
FL100: 14010KT -06
FL180: 23015KT -18

YFIRLIT: Um 500 km suður af landinu er 1002 mb lægð sem þokast norður, en um 300 km norðaustur af Langanesi er 1009 mb smálægð, sem þokast austur. Lægðardrag er við suðurströnd landsins, á vesturleið.

VINDUR NÆRRI YFIRBORÐI: Austlæg átt, 10-15 hnútar.

SKÝJAFAR, SKYGGNI OG VEÐUR: Skýjað í 1000 til 1500 fetum og víða takmarkað skyggni í rigningu og súld við suðurströndina og færist úrkomubeltið yfir Suðvestur- og Vesturland í kvöld. Um norðanvert landið er brotin skýjahula í 2500 til 3500 fetum og skyggni gott. Ský lagskipt sunnanlands upp í 24 þúsund fet, en toppar nesta langs er í 9-11 þúsund fetum.

SJÓNFLUGSSKILYRÐI Á MILLI LANDSHLUTA: Ófært um sunnanvert landið, en sæmileg eða góð annars staðar.

FROSTMARKSHÆÐ: Um 5-6000 fet.

ÍSING: Dálítil frá 6000 fetum í skýjum við suðurströndina.

KVIKA: Lítil.

ANNAÐ: NIL