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Spatial variability of snowpack stability on small slopes studied with the stuffblock test

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Приведены результаты экспериментальной оценки пространственной изменчивости устойчивости снежного покрова на склоне.

Introduction

The spatial variability of an alpine snowpack strongly influences and maybe even controls avalanche formation through links to processes such as fracture initiation and fracture propagation. Despite its obvious importance, spatial variability has been included in neither large-scale avalanche-forecasting models nor in smaller scale models for avalanche release.

Operational avalanche-forecasting models, such as the French Safran-Crocus-Mépra chain described by Durand et al. [7], generally assume that spatial homogeneity exists in larger regions. In the case of the Safran-Crocus-Mépra chain, these regions are mountain massifs of about 500 km^2. All the models for dry-snow slab-avalanche release reviewed by Schweizer [17] assume that deficit zones with low shear strength in the critical weak layer exist, although these deficit zones have not been unambiguously proven by field data. Conversely, the models reviewed do not include spatial variability in the properties of the critical weak layer and in the overlying slab although field studies by Conway and Abrahamson [4, 5], Fuhn [9], Jamieson and Birkeland [1, 11] have shown that such variability exists.

It is assumed that spatial variability exists on different scales, depending on the processes that act on the snow cover. On the micro-scale (0.1 mm — 1 cm) the conditions during the snow deposition and the snow metamorphism processes are the dominant causes of spatial variability. On the meso-scale (1 cm — 10 m) small topographic features and wind effects are dominant, and on the macro-scale (10 m — 10 km) the dominant factors are large-scale topography and meteorological parameters. On larger scales, which we here call regional (> 10 km), climate factors are the dominant causes of spatial variability in the snowpack.

Studies by Conway and Abrahamson [4, 5], Föhn [9], Chernouss [3], Jamieson [11] and Birkeland [1], have focused on the spatial variability of snow stability and mechanical properties, but no final conclusions on the length of spatial correlation have been reached. This lack of consensus is due to (i) different interpretations of the measurements, (ii) different stability tests and measurement methods used, (iii) the problematic preparation of snow samples and the resulting uncertainty of the results, and (iv) different sampling scales. In order to overcome these problems, measurements with the following characteristics are needed: (a) sampling intervals spanning the micro, meso, macro and regional scale, (b) simple, consistent and operator independent measuring methods, and (c) consistent interpretation of results at all scales.

This paper presents preliminary results from field measurements of the spatial variability of snowpack stability as well as some general observations about the stuffblock stability test gained over the winter 2000/2001.

Methods

Fieldwork during the winter 2000/2001 was mainly carried out in a 2 km x 2 km area north-west of Davos, Switzerland. Despite the relatively easy access from ski-lifts, the area is not as heavily used by backcountry skiers as most other places near Davos. The area provided many undisturbed slopes with a wide choice of slope angles and slope aspects. On each field day a slope or a level area was selected for the measurements.

Nearly all measurements were within a distance of 500 m from an automated weather station. The station records snow and air temperature, snow depth, radiation, humidity as well as wind speed and wind direction. On each field day one manually observed full snow profile [10], 12 to 15 stuffblock tests [2] and 120 to 140 penetrometer measurements [15] were made. On days when the measurements took place on a slope, one rutschblock test was made as a part of the full snow profile. The measurements were placed in a grid as indicated in Fig. 1. Two grid types were used. Measurements made in January and February spanned 18 m (grid type 1) while the measurements made in March spanned 36 m (grid type 2). The measured slopes were normally 30 to 100 m in width and length. As an example, the grid from 16 March 2001 is shown in Fig. 2.

In both grid types, the distance between two stuffblock tests was 6 m, while the distance between two penetrometer tests was at most 2 m. At each location of a stuffblock test there was also a penetrometer measurement. The density of the penetrometer measurements was increased in the middle of each grid, where the minimum spacing between two penetrometer measurements was 0.5 m. The number of stuffblock tests and penetrometer measurements was the maximum a field team with 3–4 persons could

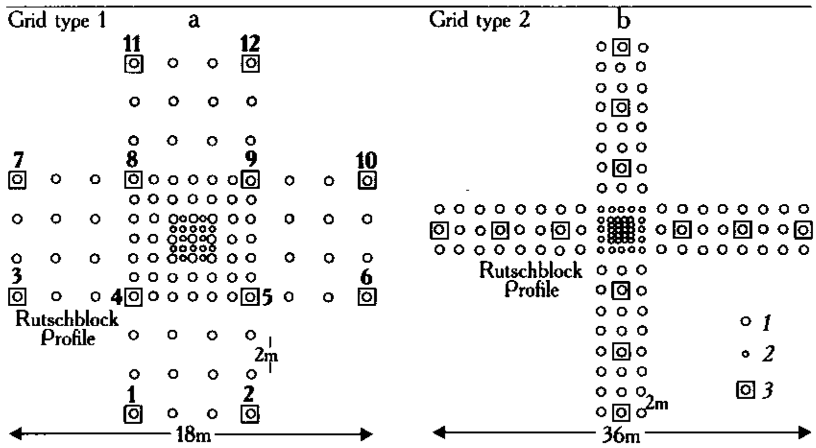


Fig. 1. The two types of grids used in the study. Small and large circles indicate penetrometer measurements, while squares indicate locations of stuffblock tests. The location of the manual profile and the rutschblock test is shown. (a) Grid type 1, (b) Grid type 2

Рис. 1. Два типа сеток измерений, использованных в работе: 1, 2 — точки измерений с помощью пенетрометра, 3 — места проведения стаффблок-тестов. Показаны также места шурфований снежного покрова и проведения рутчблок тестов. Сеть первого (a) и второго (b) типа

reach in a day. The cross-shaped grid was preferred over a square grid due to its longer maximum span.

The different types of measurements were combined in order to compliment the traditional snowpack analysis with stratification data from the penetrometer measurements and the stability rating from the stuffblock and rutschblock tests.

With one exception, each grid was finished in one day, typically within 5–7 hours. On a few occasions it was observed that the upper few centimeters of snow changed hardness during the day, typically from hard in the morning to softer around midday, and back to hard when the incoming radiation decreased in the late afternoon. No diurnal changes in snow-properties were noticed in snow more than 5 cm below the surface.

The stuffblock stability test. The stuffblock test provides an index for snow stability [2]. It is similar to the compression test [12, 13] and believed to be as good as the rutschblock test described by Föhn [8] for locating weak layers which have potential for failure when loaded [2]. The stuffblock test is, however, faster than the rutschblock test.

The stuffblock tests were carried out as described by Birkeland and Johnson [2]. A nylon sack filled with 4.5 kg hard-packed snow was dropped on a shovel resting on top of an isolated vertically standing snow-column with an upper surface of 30 cm × 30 cm. The drop-heights used were from 0 m to 100 cm with 10 cm increments. If the snow depth was sufficient, the isolated columns were around 100 cm in height, as suggested by Jamieson [12]

Fig. 2. The grid from 16 March 2001. Slope angles ranged from 20° in the lower part of the grid to 44° in the upper part. The upper arm of the grid is still not measured. Holes can be seen where the stuffblock test was carried out

Рис. 2. Сеть измерений, проведенных 16 марта 2002 г. Угол склона изменяется от 20° в нижней части до 44° в верхней. В верхнем ответвлении сети измерения еще не проводились. В местах проведения стаффблок-тестов видны отверстия в снежном покрове for the compression test. When a failure occurred, notes were taken as described below, and the snow above the failure removed. This procedure was continued until a drop-height of 100 cm was reached or the isolated column failed at the bottom. Stuffblock tests were carried out both on slopes and on level plots. Birkeland and Johnson [2] recommend a minimum slope angle of 25° for the stuffblock test, but for the compression test, Canadian Avalanche Association [13] states that it might be used on level snow.

It is recognized that rutschblock failures with clean shears indicate a lower stability than failures with only partial and/or non-clean shears, provided the same rutschblock score [20]. For the compression test, failures with clean shears are better related to snow stability than failures with non-clean shears [12]. During the field work we observed that the stuffblock test also produces different types of failures. Therefore we assume that for the stuffblock test, failures with clean shears are good indicators of instability.

For each recorded stuffblock failure, the following was recorded:

Failure depth. The vertical distance from the snow-surface to the failure-plane.

Drop height. The distance from the bottom of the stuff-sack to the shovel, in 0.1 m increments.

Failure type. A primary and a secondary failure type as well as Broken (B) could be assigned to the types if necessary. The failures were divided into the following groups, along the lines of Jamieson [12]: Clean, smooth and pla-

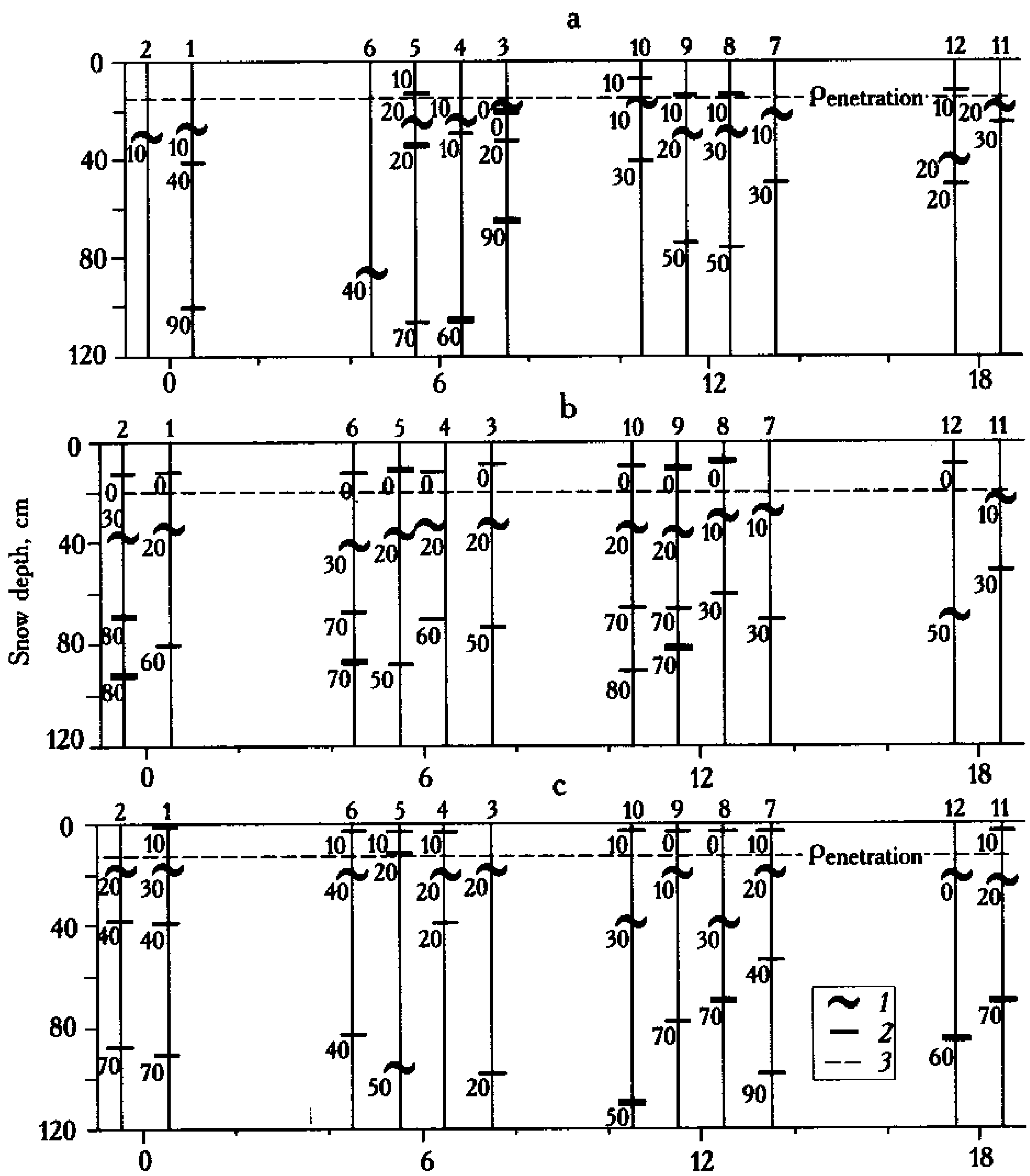


Fig. 3. All stuffblock failures for each grid are shown from the side. The vertical scale is the snow depth in cm. Each vertical line represent one stuffblock test. The number above each vertical line refer to the stuffblock number and the corresponding stuffblock location in Figure 2. Failures defined as primary failures are shown with tildes (~), all other failures are shown with a horizontal dash (-). The drop height in cm for each primary failure is printed near the failure. The initial penetration of the ramsonde is shown with a dashed line. (a) Grid from 31 January 2001, (b) grid from 2 February 2001 and (c) grid from 16 February 2001

Рис. 3. Разрушения в слоях, полученные с помощью стаффблок-тестов, для всех сеток измерений указаны сбоку. Каждая вертикальная линия представляет один стаффблок-тест и ее номер соответствует номеру места проведения испытания на рис. 1 и 2: 1 — разрушения, определенные как первичные, 2 — все прочие разрушения, 3 — первоначальное проникновение пенетрометра. Высота, с которой сбрасывался груз, для каждого первичного разрушения указана рядом с ним (в см). Сетки измерений, проводившихся 31 января (a), 2 февраля (b) и 16 февраля (c) 2001 г.

nar shear (C); Partially clean shear (PC) was assigned when the failure was primarily clean, but irregularities, such as a small broken corner was present; Collapse of a snow-layer (COL); Large irregularities in the failure plane (LIR) if any present irregularities were more than 10 mm deep; Small irregularities in the failure plane (SIR) if any present irregularities were less than 10 mm deep; Stepped between two clean shears (STP).

Comment. Any special observations regarding the failure were described here. Further, the amount of compression below the shovel and the distance from the shovel to the failure plane were recorded but not used in this paper.

Rutschblock test. When the measurements took place on a slope, a rutschblock test completed the manually observed full snow profile. The rutschblock stability test is described by Föhn [8] and Jamieson [11]. One of the stuffblock tests was always close to the rutschblock test and snow profile.

Penetrometer profiles. The penetrometer used was a SnowMicroPen manufactured by Swiss Federal Institute of Snow and Avalanche Research. The SnowMicroPen is described by Pielmeier [14] and Schneebeli et al. [15]. It consists of a rod which is pushed through the snow cover with a constant speed, which in all our measurements was 20 mm s^{-1}. At the tip of the rod is a force-sensor that measures the resistance of the snow on the tip of the sensor. The sampling frequency was 50 kHz, resulting in a measurement every 0.004 mm in our measurements. After a profile was measured, the compressed data was transferred to a field-notebook.

Manually observed full snow profile. For each grid a manually observed full snow profile including ram resistance and temperature was carried out. For each layer crystal shape, crystal size, hand hardness index, liquid water content and density, was recorded [10].

Primary failure. With a few exceptions each stuffblock test failed more than once. The resulting three dimensional data-set is not easily investigated with standard spatial statistics although a qualitative visual interpretation is possible (Fig. 3). For the preliminary analysis presented here, we therefore focus on the primary failure for each stuffblock test. We have defined the primary failure as the first failure below 10 cm and below the initial penetration of the ramsonde. We suggest that this failure is the most critical for skier triggered avalanches, since slabs less than 10 cm thick are not critical for skiers and shears in depths above the ski penetration are not normally triggered by skiers.

The variogram. The variogram is a tool for investigating the autocorrelation of spatial data (e.g. [6]). For a given set of measured values in space, the semi-variance (moment of inertia) is calculated for all possible lag-distances between the measurement points. The variogram displays the semi-variance as a function of the lag-distance. The lower the semi-variance, the higher correlation exists between the values at the point pairs. Values from adjacent observations, i.e. short lag distances, are in many geophysical applications better correlated that more distant points. Often, above a certain lag-distance the measured values are no longer well correlated, and the semi-variance reaches a constant maximum known as the sill. The lag distance at which the sill is reached is called the range. The range is interpreted as the largest distance for which spatial correlation between observations can be found.

Results

In the following we focus on only the results from the stuffblock tests from the 13 grids mentioned in Table 1. First some general results from all the stuffblock tests will be presented. Here the only spatial information included is the slope angle at which the stuffblock tests were carried out. Afterwards follows a presentation of the spatial continuity of the primary failures for three selected grids.

Non-spatially related results. Over the winter 162 stuffblock-tests resulting in 478 failures were carried out in the thirteen grids presented in Table 1.

Effect of slope angle on the number of stuffblock failures. 49 stuffblock-tests with 173 failures were on level snow. Slope-angles on the resulting 113 tests and 305 failures were distributed between 20° and 45°. It appears that a larger fraction of failures were noted in the stuffblock-tests carried out on level snow than on slopes. 36% of all failures were from the 30% of the stuffblock-tests that were done on level snow. A chi-squared test of the number of failures on slopes versus failures on level snow yields $p = 0.17$, indicating that the difference is not significant but incidental.

Failure depth. The median of the failure depths observed was 35 cm, while the mean was 42 cm. For the primary failures, a mean failure depth of 38 cm and a median of 31 cm was found. For investigated slab avalanches in Switzerland, a median fracture depth of 45 cm for reported human triggered slab avalanches was found by Schweizer and Lبtschg [19]. A median of 30 cm for reported Canadian cases was found by Schweizer and Jamieson [18]. The median depth of primary failures found in our study is therefore in accordance with failure depths from skier triggered slab avalanches. This suggests that our definition of a primary failure is appropriate for defining the most critical failure for a stuffblock test.

Failure type. Failures with clean shears compose 70% of all 478 failures in our study. None of the other failure types constitute more than 10%. The same is the case for the primary failures. This indicates that most weak layers or interfaces found by the stuffblock test were critical to snow stability. There is no significant difference between clean and non-clean shears for all failures on level snow and on slopes (chi-squared test, p=0.08) and also no significant difference if only primary failures are considered ($p = 0.33$).

Spatial continuity of primary failures. Analysis of the spatial continuity of failure depth and drop height for primary failures was done for three selected grids. The grids were selected because they were thought to represent different levels in continuity. The grid from 31 January 2001 was selected because the failure depths seemed to be at very different levels as shown on Fig. 3 a. On 2 February

Table 1

Summary of the variability measurements made during the winter 2000/2001

Date	Slope aspect	Slope angle	Rutschblock score, description	General description
18 Jan. 2001	ENE	20–29	6, only corner	
19 Jan. 2001	ENE	Level	6, only corner	
29-30 Jan. 2001	ENE	Level	6, only corner	
*31 Jan. 2001	E	29–34	4, clean below skis	Failure-layers not continuous
* 2 Feb. 2001	NW	30–36	5, clean below skis	Spatially continuous layers and drop heights
12 Feb. 2001	N	25–34	5, clean	
13 Feb. 2001	N	Level	5, clean	
*16 Feb. 2001	E	33–39	4, clean	Rather discontinuous below 10 cm. Snow surface very inhomogeneous. 50 m beside grid from Jan. 31, 2001
19 Feb. 2001	NNW	28–36	4, clean below skis	30 m beside grid from Feb. 12, 2001
21 Feb. 2001	SSW	30–35	6, clean	
16 Mar. 2001	N	20–44	4, one corner not released, otherwise clean	
19 Mar. 2001	N	Level	4, one corner not released, otherwise clean	
28 Mar. 2001	NE	26–41	5, clean below skis	

Dates marked with a star (*) are the grids selected for analysis of spatial continuity.

2001, there seems to be two very continuous failure layers in the upper 50 cm of the snowpack (see Fig. 3 b). The grid measured this day was therefore thought to represent a snowpack with continuous failure depth and drop height. The third grid from 16 February 2001 had a seemingly continuous failure layer in the upper 50 cm of the snowpack, whereas the drop heights for the next layer around 20 cm, where most of the primary failures are, seemed rather variable (see Fig. 3 c). The three selected grids do in no other way stand out from the remaining ten measured grids.

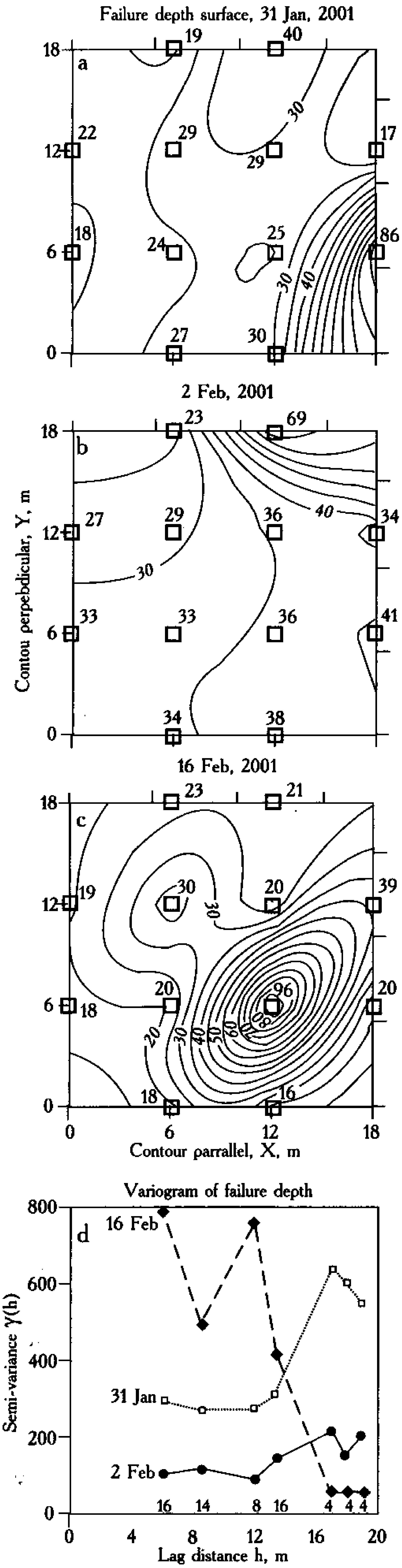
Depth of primary failure. The spatial distribution of the failure depths are shown in Fig. 4 a-c and the variograms for the three grids are shown in Fig. 4 d. By looking at the kriged surfaces in Fig. 4 a-c, it is clear that a large part of the surface roughness is created by only one of the twelve tests. On 31 January 2001 the failure at 86 cm is clearly deeper than the rest. On 2 February 2001, it is the 69 cm deep failure and on 16 February 2001, it is the failure at 96 cm that are different from the rest of the failure depths. Due to our definition of a primary failure depth, and since we are interested in the variability of the shown surfaces, we can not discard these outliers as might be done in a normal statistical analysis.

Because of the limited number of combinations for the three highest lag distances, the semi-variance for these distances should be taken as an indication only, and certainly not be used for creating a model of the variogram.

Two of the variograms shown in Fig. 4 d are all relatively flat when the three highest lag distances are ignored. None of these variograms display features which can be interpreted as a sill. The third variogram, from 16 February 2001, is not flat, but does also not display any significant sill. It therefore seems as if there is no autocorrelation for any of the selected grids for the possible lag distances. This might indicate that the scale of the variability of the failure depths is either higher or lower than the lag distances obtainable with the spacing of our stuffblock tests. It might, however, also indicate that no specific scale of variability exists in our measurements. To investigate if specific autocorrelation lengths exist, it will therefore be necessary to space the stuffblock tests further apart and/or closer together. This would make the calculation of semi-variances for longer and shorter lag distances possible. However, it might be that the range is smaller than the size of the stuffblock columns. In that case it might therefore be necessary to include additional information from the penetrometer, where measurements can be spaced closer.

Although no typical scales of variability exist on the three variograms in Fig. 4 d, the level of the semi-variance of each grid are different. The grid from 2 February 2001 shows the smallest semi-variance whereas the grid from 16 February 2001 shows the highest semi-variances. The semi-variance calculated for the depths of the primary failures thus confirm our qualitative visual analysis of the failure depths shown in Fig. 3.

Drop height at primary failure. The drop height recorded for a stuffblock failure indicates how much energy is needed for that failure to occur. The spatial distribution of the drop heights associated with the primary failures are shown in Fig. 5 a-c. The variograms for the three selected grids are shown in Fig. 5 d. Again the three last points in the variograms should be used with caution due to the limited number of combinations. The semi-variance for the drop height for the three grids does not show



such a large difference between the grids as was the case for the failure depths. Still, the grid measured on 16 February 2001 shows larger spatial variability in the drop heights than the other two grids, which are both at similar levels of semi-variance.

The grid recorded on 16 February 2001 was estimated to have the largest discontinuity in the drop heights. The variograms confirm this qualitative visual impression by placing this grid on a higher semi-variance level than the two other selected grids. As for the failure depths, no apparent scale of variability of the drop heights is apparent. The result of this finding is the same as for the failure depths, that either more stuffblock tests are needed at shorter and/or longer lag distances, or no scale of variability exists.

Discussion

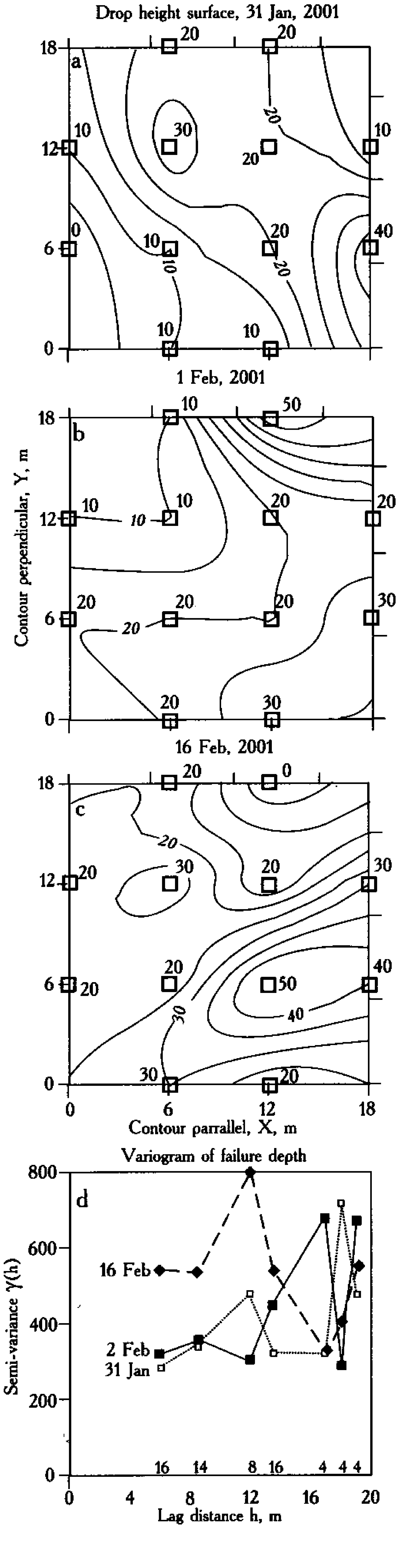
The spatial continuity of a weak layer or interface is of large importance for fracture propagation in that layer. But just knowing if a specific fracture plane is continuous on a certain slope or not, only brings us a little closer to our goal of predicting the snow stability on the slope. Where a weak layer is present, we also need to know the mean strength, the variation of the strength as well as the spatial variability of the strength of the weak layer to predict the stability. To complicate things further, looking at the weak layer properties alone is not enough. The properties of the overlying slab has to be taken into consideration as well [16].

Despite the complex interactions in the snowpack, we suggest that snow slope stability might be estimated based on the continuity of the failure plane and, the average stability and the variability of the stability as shown in Table 2.

By using the primary failures in the grids investigated and the stability indicators shown in Table 2, it is possible to come to some conclusions about the stability of the slopes investigated. The variogram of primary failure depth gives us an indication of the spatial continuity of the failure layer. The grid from 2 February 2001 has a rather continuous weak layer, whereas the grid from 16 February 2001 has a rather discontinuous weak layer. The continuity of the 31 January 2001 primary weak layer is between that of the two other grids. The drop height for the pri-

Fig. 4. (a), (b) and (c) Surface maps of the depth of the primary failure for the three selected grids. The location of the stuffblock tests are shown with squares. Above each square is the depth of the primary failure in cm. The equidistance is 5 cm in all plots. (d) Variogram of the depth of the primary failure for the three selected grids. For each lag distance, the number of combinations is shown at the bottom of the graph

Рис. 4. Карты глубины первичного разрушения для трех отобранных сеток измерений (a, b, c). Расположение стаффблок-тестов показано квадратами, над каждым из которых указана глубина первичного разрушения в см. Интервал между соседними изолиниями в 5 см. Вариограмма глубины первичного разрушения для трех выбранных сеток измерений (d)



mary failure is a stability index, and can thus be used to estimate the variability of the stability over the grid area by looking at the variogram in Fig. 5 d. Here the grid from 16 February 2001 has the largest variability, whereas the variability in the other two grids is rather small.

For the average stability, the average drop height of the primary failures might be used. These are given in Table 3 for the three investigated grids. Birkeland and Johnson [2] reported that drop heights less than 20 cm were generally associated with an unstable snowpack. Drop heights between 20 cm and 50 cm were generally associated with a moderately unstable snowpack. Their interpretation was based on correlations between the stuffblock and the rutschblock test. Based on the average drop height, the average stability in the grid from 31 January 2001 might be considered relatively low. The average drop height in the two other grids indicate that the average stability was moderate. Since in Table 2 only two average stability classes are suggested, and the stability of the two grids measured in February is above low, we will here rate the average stability of these two grids as high. Table 3 shows the results of the slope stability evaluation based on the suggestions in Table 2, as well as the rutschblock score and failure type recorded for each of the grids.

The rutschblock score is generally accepted as a good indicator of snow stability of the tested slope, although one rutschblock is by far not enough to come to a conclusion about the snow stability. A verified degree of avalanche danger from a combination of the official avalanche bulletin and observations in the field is needed for further analysis and verification of the proposed stability rating scheme. Moreover, it has to be kept in mind that a rutschblock test covers only 3 m^2 whereas the proposed rating scheme takes measurements from a larger area into account. However, for the verifications presented here, the rutschblock scores will be taken as the best available estimation of slope stability.

In the three investigated grids the slope stability estimated with the above mentioned procedure is not consistent with the recorded rutschblock scores. There might be more reasons for the lack of agreement. First of all, the rutschblock test assesses the snow stability based

Fig. 5. (a), (b) and (c) Surface maps of the drop height associated with the primary failure for the three selected grids. The location of the stuffblock tests are shown with squares. Above each square is the drop height in cm. The equidistance is 5 cm in all plots. (d) Variogram of the drop height of the primary failure for the three selected grids. For each lag distance, the number of combinations is shown at the bottom of the graph

Рис. 5. Карты высоты падения груза, соответствующей первичному разрушению, для трех выбранных сеток измерений (a, b, c). Положение мест проведения стаффблок-тестов показано квадратами, над каждым из которых указана высота падения груза в см. Интервал между изолиниями составляет 5 см. Вариограмма высоты падения груза при первичном разрушении для трех выбранных сеток измерений (d). Число комбинаций для каждого расстояния между пунктами измерений показано в нижней части рисунка

Table 2

Slope stability estimated from the continuity of the weak layer, the average stability and variability of stability + indicates stable, — indicates unstable

Low average stability		Spatial continuity of weak layer	
		Continuous	Discontinuous
Stability index	Large variability	–	+/–
	Small variability	––	–
High average stability		**Spatial continuity of weak layer**	
		Continuous	Discontinuous
Stability index	Large variability	+/–	+
	Small variability	+	++

Table 3

Evaluation of slope stability for the three selected grids

Date	Average drop height, cm	Average stability	Variability of stability	Continuity r of weak laye	Estimated slope stability	Rutschblock score and fracture type
31 Jan. 2001	17	Low	Small	Semi-continuous	–/––	4, clean below skis
2 Feb. 2001	26	High	Small	Continuous	+	5, clean below skis
16 Feb. 2001	24	High	Large	Discontinuous	+	4, clean

on the strength of a single weak layer. This is not the case in our analysis where we investigate the general variation of snow stability with the primary failures. Assigning a failure depth and a drop height to each weak layer at the measured points in the snowpack, and then investigating the mean strength, the variation and the spatial variability of each weak layer, might give results more comparable to the rutschblock score. Secondly, the stability estimation procedure presented in Table 2 might be too simple for the complex interactions between weak layer and slab properties that take place in the snowpack.

The analysis of spatial variability of stability on small slopes has only been carried out for three out of thirteen measured grids. The same analysis for the remaining ten grids is needed to get more knowledge about the stability variation on the scales investigated. Further, each weak layer in a grid should, if possible, be followed through the snowpack by using additional information from the penetrometer profiles measured.

Conclusions

The following are the main conclusions after one winters field work, which resulted in measurements on nine small slopes and four level sites in a 2 km × 2 km area north-west of Davos, Switzerland. A total of 162 stuffblock tests were made. The number of persistent weak layers was lower than normal. For three of the thirteen measured grids, variability analysis is presented.

In the stuffblock tests carried out, there was no significant difference in (a) the number of failures and (b) the failure type between tests on slopes and tests on level sites was found. A variogram of primary failure depths in a grid provides quantitative information that agrees with visual analysis of the continuity of weak layers associated with the primary failure. A variogram of the drop heights of the primary failures in a grid provides quantitative information that agrees with visual analysis of the continuity of the stability in the grid. No spatial correlation length was found for the drop heights and the failure depths of the primary failures in the grids investigated. A draft stability rating scheme based on mean stability, stability variation and continuity of the weak layer did not show consistent results when compared with the associated rutschblock scores.

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ИССЛЕДОВАНИЕ ПРОСТРАНСТВЕННОЙ ИЗМЕНЧИВОСТИ УСТОЙЧИВОСТИ СНЕЖНОГО ПОКРОВА НА НЕБОЛЬШИХ СКЛОНАХ С ПОМОЩЬЮ СТАФФБЛОК-ТЕСТОВ

Пространственная изменчивость устойчивости снежного покрова на склонах оказывает существенное воздействие на образование лавин — возможно, даже управляет этим процессом и проявляется в разных масштабах в зависимости от ситуации. Тем не менее до настоящего времени эту характеристику не учитывали при прогнозах лавин, а также не включали в соответствующие модели. Масштаб пространственной изменчивости до сих пор определить не удавалось. Мы установили ее значения в диапазоне от 1 м до 1 км и более и определили, что они зависят от таких факторов как расстояние от места сбора образцов, тип испытаний на устойчивость и интерпретация результатов измерений. Были проведены полевые измерения в диапазоне малой-средней шкалы (0,5—36 м) зимой 2000/01 г. В качестве индикатора устойчивости снега использованы стаффблок-тесты, а механические свойства определены с помощью пенетрометра с высокой степенью разрешения. Изменчивость устойчивости снежного покрова и механические свойства будут оценены с помощью геостатических методов, при этом будет учтена топография по ГИС и метеорологические условия по данным ближайшей автоматизированной метеостанции. Предварительные результаты будут представлены.