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A manual for monitoring the mass balance of mountain glaciers

by

Georg Kaser, Andrew Fountain and Peter Jansson

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A manual for monitoring the mass balance of mountain glaciers

with particular attention to low latitude characteristics

A contribution from the International Commission on Snow and Ice (ICSI) to the UNESCO HKH-Friend program

Georg KASER, Andrew FOUNTAIN, Peter JANSSON

With contributions from
Erich HEUCKE
Österreichischer Alpenverein
Mathias KNAUS

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Georg Kaser
Institut für Geographie
Innrain 52
A – 6020 Innsbruck
AUSTRIA
georg.kaser@uibk.ac.at

Andrew Fountain
Departments of Geology and Geography
Department of Geology
Portland State University
Portland, OR 97207-0751
USA
andrew@pdx.edu

Peter Jansson
Department of Physical Geography and Quaternary Geology
Glaciology
Stockholm university
S-106 91 Stockholm
Sweden
peter.jansson@natgeo.su.se

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I INTRODUCTION

Glaciers react in a complex manner to climatic variations. Their advances leave behind landscape markers as moraines which serve to help us reconstruct past glacial conditions and past climate. Glaciers store information about past climates in the ice as enclosed air bubbles, layers of dust, and ice chemistry. As water reservoirs they are essential to the regional water supply. The understanding of their changes with changing climate is vital for future water policy and water management. To understand and interpret these different aspects it is necessary to study the mass exchange and growth/shrinkage of glaciers. The methods and theories of glacial processes are predominantly based on results from studies in temperate zones and do not entirely apply to glaciers in other climatic regions. Glaciers of the monsoonal dominated region of Hindu Kush - Himalaya are not well understood and it is unclear how results from the temperate zones apply. The glacier-climate-hydrology interactions in the lower latitudes are of great interest for both global and regional purposes. A network of well-chosen and carefully measured glaciers is important to establish for climate and water related studies.

A well set and maintained glacier mass balance network is of manifold benefit because it provides:

- Information on glacier behaviour on the studied sites.
- Information on the climate fluctuations on the studied sites.
- Results defining the most important climatic processes controlling glacier growth and shrinkage.
- Data defining the hydrological impact of glaciers on local and regional streamflow.
- A way to estimate the behaviour of the non-monitored glaciers in the region. Many of these other glaciers may be important but otherwise impossible to monitor.
- Information on glacial response to climate fluctuations on a local, regional, or global scale.
- Ideal sites to launch other intensive investigations of glacial processes against the background of data collected on the glacier and its environment.

Accordingly, the snow and ice group of the Hindu Kush-Himalayan regional association of countries participating in the Flow Regimes from International Experimental and Network (HKH-FRIEND) argued for the importance of a glacier monitoring program in the HKH region and approached the International Commission on Snow and Ice (ICSI) for technical support. ICSI convened a workshop - held at Kathmandu in March 2001 under the auspices of UNESCO, and outlined the need for a training course to be held in one of the HKH-FRIEND regions. This draft manual for glacier mass balance measurements is provided by ICSI. Our intention with this manual is not as a final product to be closely followed but an initial outline on how to monitor the glaciers of this region. We fully expect the manual to be changed and enlarged as experience in the region grows.

This draft manual provides the theoretical background of glacier mass balance and an outline of definitions and common data formats. An "ideal" glacier for mass balance measurements is presented as a guide. Based on climatological and climate change considerations the design of a Glacier Monitoring Network (GMN) is proposed. The second part of the manual provides practical details of fieldwork, data analysis, and data presentation. The focus is on the peculiarities of glaciers in the low latitudes, the HKH region in particular.

In the past, glaciers were incorporated into a network because they have been monitored. Those monitored glaciers may not have been the best glaciers to include in a network. The proposed HKH-FRIEND glacier network provides an opportunity to design a network and choose the most appropriate glaciers for inclusion.

Training on Chhota Shigri Glacier, Himalchal Pradesh, India, October 2002

II THEORETICAL CONSIDERATIONS

1. Glacier mass balance

1.1. Point thickness changes

The change with time of the thickness of a column of ice at any point on a glacier, $\dot{h}$, can be expressed by the continuity equation in ice equivalent units as

$$\dot{h} = \frac{\dot{b}}{\rho} - \vec{\nabla} q \quad (1)$$

in which $\dot{b}$ is the mass balance rate, ρ is the glacier density and $\vec{\nabla} q$ the horizontal gradient of ice flux (fig. 1).

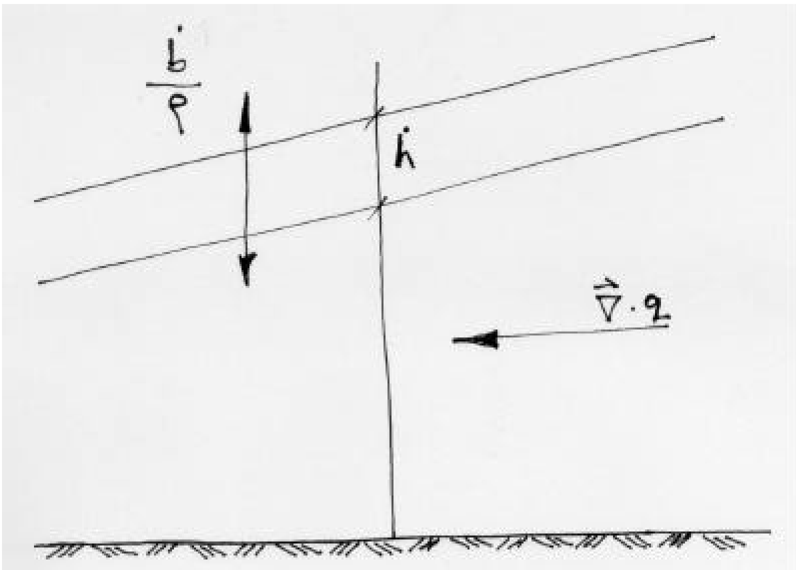


Figure 1: The change with time of the thickness of a column of ice at any point on a glacier.

If equation *(1)* is integrated over the entire glacier surface, $\vec{\nabla} q$ becomes zero and the mass balance equals the thickness change multiplied by the density of the glacier. This is the basis for applying the geodetic method, which measures the elevation of the glacier surface. The surface elevation at two different times are subtracted and given a density the mass is calculated. This method is sensitive to values of the density distribution and accuracy of the elevation models of the glacier surface. It is usually applied in addition to direct methods (below) over large time steps.

If, on the other hand, $\dot{h}$ is zero, which holds for a glacier in equilibrium (non-changing geometry), the mass balance at a point can be determined by measuring the ice velocity from which $\vec{\nabla}q$ can be calculated if the ice depth is known. For advancing or retreating glaciers, which change their geometry, this method fails (Kuhn et al., 1999) because $\dot{h}$ is non-zero.

Based on the most recent availability of both high resolution digital terrain models from laser scanning the glacier surface and from echo-sounding the bedrock first attempts were made to combine the geodetic method with detailed dynamic ice-flow models in order to obtain the spatial distribution of glacier mass balance. In a thorough and comprehensive study Bauder (2001) has shown that the method fails so far because of the inability of the available dynamic models which have particularly problems to derive vertical ice velocities in the necessary order of magnitude. In addition the method depends on annually taken air born data. They are both expensive and not easy to provide under bad weather conditions.

1.2. Accumulation and ablation

Mass gain or loss can take place on the glacier surface, within the body of the glacier, or at the glacier base. At the glacier base, loss occurs by melting due to geothermal heat, but the magnitude on mountain glaciers is usually insignificant in comparison to surface loses. Internally, mass may accumulate as melt water refreezes in cold interior, or mass may be lost when water thermally erodes internal passages in temperate glaciers. However, the mass changes on the glacier surface dominate the mass balance and the internal and subglacial processes are, in most cases, ignored. Surface accumulation processes include snowfall, wind drift, avalanches, resublimation, and condensation. Ablation (mass loss in all its forms) include melting, snow drift, ice avalanches, calving, sublimation.

1.3. The net mass balance at a specific point on the glacier surface

If $\dot{b}(P)$ is the mass balance rate in length units of water equivalent and unit time at any specific point *P(x,y,z)* on a glacier surface, its integration over time gives the net mass balance at that point

$$b(P) = \int_t \dot{b}(P)\,dt \qquad (2)$$

in meter water equivalent [m we]. Note, that this gives 1/1000 of the numbers reached when expressing the mass balance in [kg m^{-2}]. In practice, the time span is Δt between two field visits at the measuring point (fig. 2). The choice of the time span(s) will be discussed in detail in chapter 1.9.

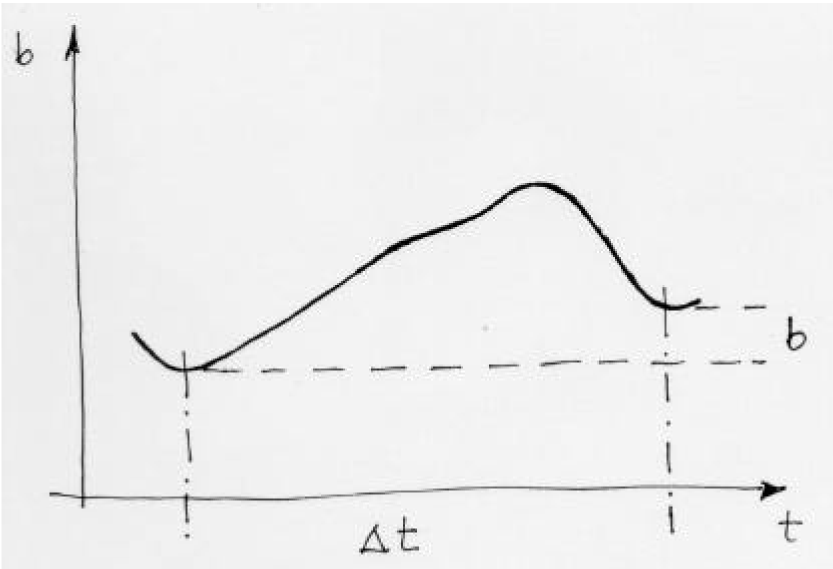


Figure 2: The net balance measured between two field visits.

1.4. The total net mass balance of a glacier (*B*)

The spatial integration of $b(P)$ over the surface area dS leads to the total glacier mass balance

$$B = \int_t \int_S \dot{b}(P) dt dS = \int_S b(P) dS = \rho dV \qquad (3)$$

in [m^3 we] or [kg], which equals the volume change dV multiplied by the glacier density. In practice, the surface area corresponds to the horizontal projection of the entire glacier S_G.. Note that S_G may change with time.

1.5. The mean specific mass balance ($\bar{b}$)

To compare the mass balance between glaciers of different area the mean specific mass balance is calculated as

$$\overline{b} = \frac{B}{S_G} = \frac{\rho \Delta V}{S_G} = \rho \overline{\Delta h} \qquad (4)$$

which links the geometric units of volume change ΔV and mean altitude change $\overline{\Delta h}$ in units of [m we] or [kg m^{-2}].

1.6. The vertical mass balance profile (*VBP*)

If B and subsequently $\overline{b}$ are calculated for individual altitude intervals the mean specific mass balance can be depicted as a function of altitude, *b(z),* showing the vertical mass balance profile, VBP (fig. 3). While the glacier mass balance changes from year to year , the VBP typically exhibits the same shape (Meier and Tangborn, 1965) and only its intercept changes. The VBP characterizes the climate-glacier regime. It should be noted that the VBP will change markedly from season to season.

1.7. The equilibrium line altitude (*ELA*)

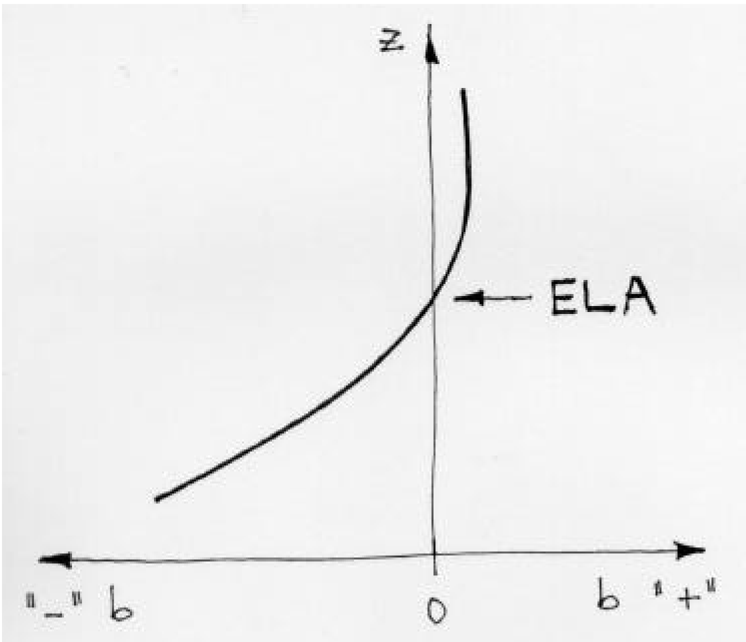


Figure 3: The vertical mass balance profile and the definition of the equilibrium line altitude (ELA).

The equilibrium line altitude (ELA) is defined as the altitude where the VBP is zero (fig. 3). This is the location where net mass change is zero. This is an index of net mass distribution on the glacier. For example, if the ELA increases, then more of the glacier is in the ablation zone and the glacier retreats. Conversely, if the ELA decreases, all else being equal, the glacier advances. The gradient of the mass balance with elevation (db/dz) at the ELA is the activity index or the index of glaciation. A large gradient indicates a large ice mass flux and, thus, a small sensitivity on climate variations.

1.8. The accumulation area ratio (*AAR*)

The *AAR* is the ratio of the accumulation area to the total glacier area, where S_C is the surface of the accumulation area, and S_G the total surface area of the glacier.

$$AAR = \frac{S_C}{S_G} \text{.........(5)}$$

The AAR is applied to the glacier at the end of the balance year. Empirically, the AAR is about 0,6-0.7 for alpine glaciers in the mid latitudes but higher in the tropics (Kaser and Osmaston, 2002). Since the AAR is based on the location of the ELA, the two variables are directly related.

1.9. Mass balance year and mass balance seasons

Ideally, the mass change of a glacier would be monitored continuously but this is currently impractical. Instead, the data is collected during site visits. Generally, the mass balance is determined at seasonal and/or yearly intervals. Two yearly intervals exist. The "natural" mass balance year is defined as the time between one minimum of glacier mass to the next, which, in mid and high latitudes, occurs in autumn. This approach is known as the stratigraphic method because the method is based on the stratigraphy of the snow to determine the minimum. It can be difficult to determine the minimum for several reasons. First, it is not exactly known when the minimum occurs. Only well after the fact can one be certain that the minimum was reached. Hence the need to interpret the minimum is based on snow stratigraphy. Second, not all parts of a glacier may reach the minimum at the same time. This is especially true for large glaciers over an extensive altitude range. In this situation, one tries to achieve the overall glacier minimum. The "natural" year can be longer or shorter than a calendar year depending on the seasonal climatic variations. Over a long time period, the sum of the "natural" years will converge to the sum of the calendar years.

The other yearly interval is the calendar year or "fixed date" system. In the mid latitudes, the time period used is the hydrological (or water) year October 1st to September 30. This approach is useful for practical applications of glacier mass balance data, such as estimating melt water contribution to hydro-electric facilities. The fixed date system does not require any attention to the stratigraphy of the snow and relies only on the mass change between preset dates. In practice however, weather conditions and other factors often interfere with collecting data at fixed dates and some stratigraphic analysis is required. Given the different problems in both yearly methods, most programs use some aspect of each approach, which is generally known as the "combined" method.

In mid latitudes, a seasonal time resolution corresponding to summer and winter is preferred because ablation and accumulation processes dominate in each season, respectively. In addition, it has been very useful to correlate climatic analyses with these seasons to determine the important factors driving changes in yearly mass balance.

In low latitudes, where annual temperature variations are minor, it is useful to look at humid and dry seasons. However, these seasons cannot be seen in the same way as accumulation and ablation seasons as in the mid latitudes, since the humid season typically coincides with the peak period of both accumulation AND ablation, whereas the dry season has little accumulation and significantly reduced ablation (Ageta and Fujita, 1996, Kaser and Osmaston, 2002).

In any case, mass balance measurements made on separate dates can only provide a value of net mass balance but never gross values of ablation or accumulation. Without continuous point measurements of mass balance, modeling may provide the most practical approach to obtain ablation and accumulation values (Ageta and Higuchi, 1984).

2. Why study the mass balance of a glacier?

Glacier mass balance is – if non-climate parameters can be excluded - the link between climate and glacier dynamics and between climate and mountain hydrology (fig. 4). Therefore, a climate history can be reconstructed from former glacier extents defined by landscape changes. Also, prediction of glacier response and landscape change to future climate change can be estimated. This can be of great importance for glacier-related hazard assessment, such as glacier-dammed lakes. Glacier mass losses affect local hydrology because mass is lost generally through melt water runoff. Thus the prediction of mass balance changes is also a prediction of their hydrological effect, which is important for regional water supplies and global sea level rise.

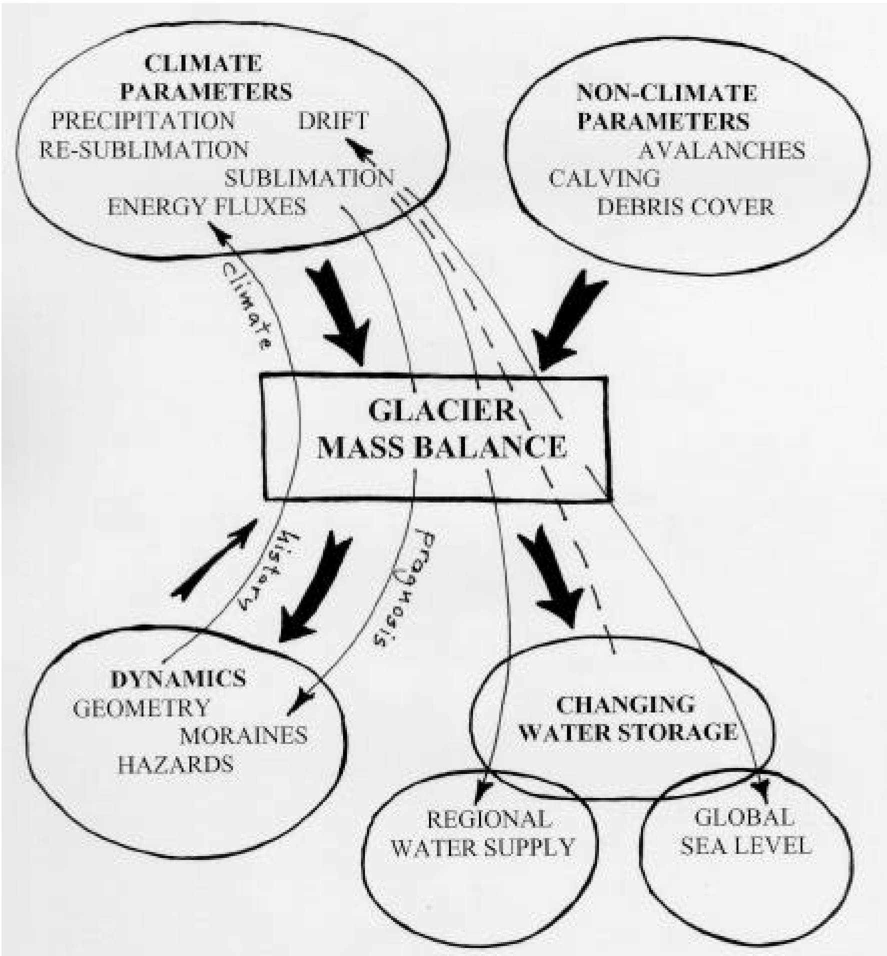


Figure 4: The role of glacier mass balance

2.1. Hazard management

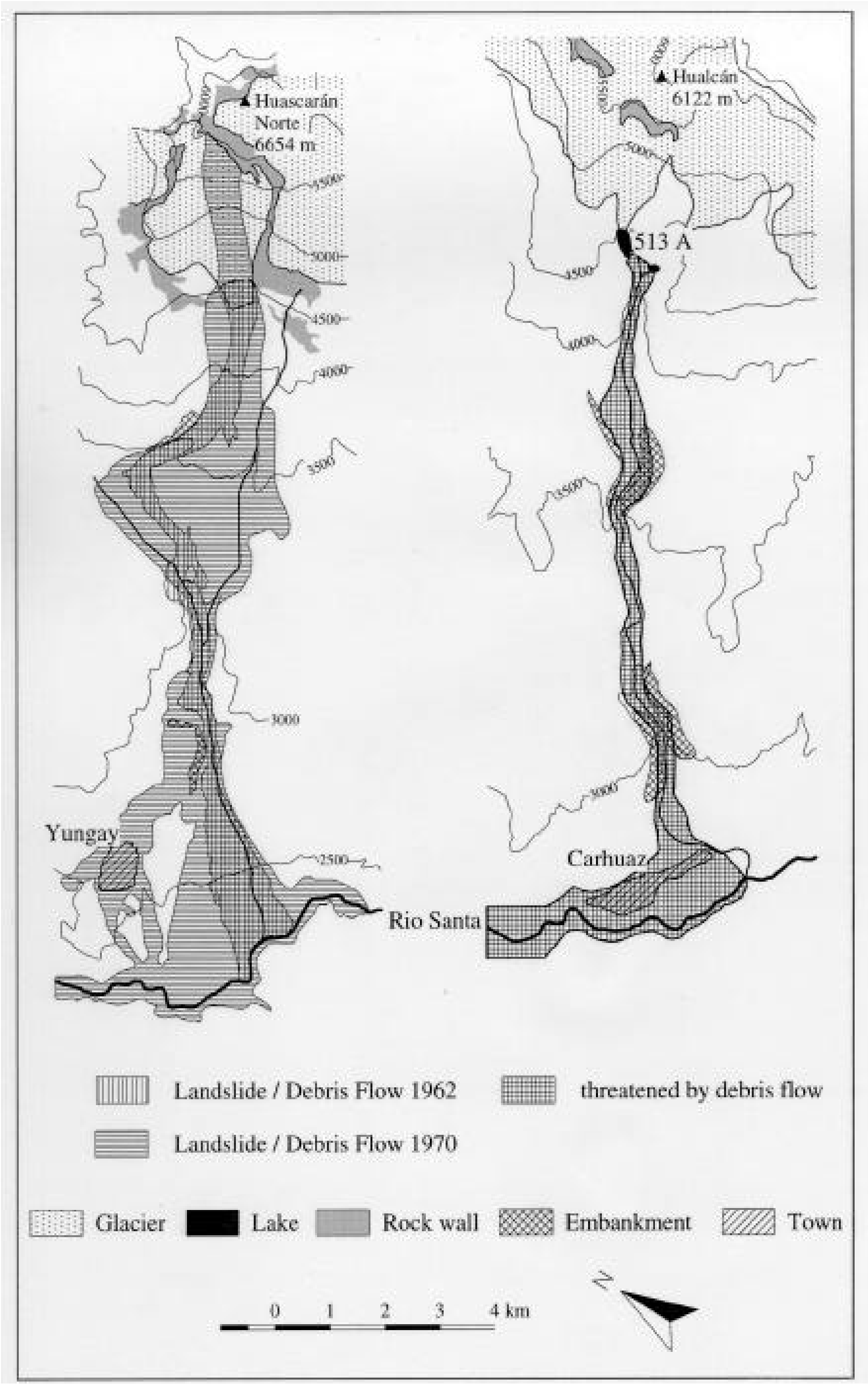


Figure 5: The ice and rock slide on Nevado Huascarán in 1970 and an estimated but prevented one by safety work on Nevado Hualcán (Cordillera Blanca, Perú) (Kaser and Osmaston, 2002)

Glacier-related hazards are well known in the low latitude regions of the HKH and the South American Andes. They include ice avalanches such as the earthquake triggered one from the Nevado Huascarán (Cordillera Blanca, Peru) which killed more than 10 000 people in 1970 (fig. 5). Also hazards develop from pro-glacial lakes, which formed during the glacial retreat of the past century. Several of these lakes have caused significant damage in the Himalayas. Several such lakes have been controlled by extensive safety structures. To assess such hazards, particularly future hazards information is required on the rate of mass loss and subsequent glacier retraction, and meltwater production.

2.2. **The management of regional water supplies**

Glacial runoff is essential to the regional water balance in the mountainous regions of HKH and elsewhere. The glaciers temporarily delay the meltwater runoff due to storage in glaciers and contribute essentially to the runoff during dry periods. In figure 6 the coefficient of variation of runoff as a function of the percentage of glacier cover of a catchment basin indicates the impact of glaciers to the runoff. This storage can reduce peak runoff during periods of intense melt and rain. Alternatively, the stored water can be catastrophically released from reservoirs hidden from view in the interior of the glacier. Knowledge of the glacier ablation is crucial for the planning and management of the corresponding water supply.

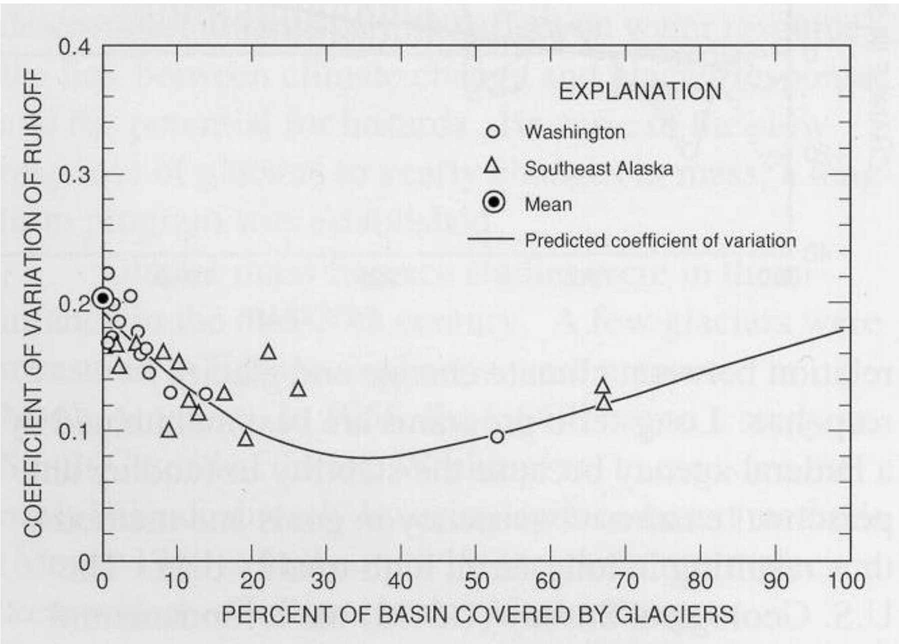


Figure 6: The impact of glaciers on the runoff variability of a mountain catchment area (Fountain and others, 1997).

2.3. The contribution to sea level rise

The observed global sea level rise is a matter of international concern since it threatens vast low-lying areas including numerous highly populated coastal regions. The contribution from retreating mountain glaciers is one of the important factors in sea level rise today (fig. 7). One of the main regions contributing to sea level rise is the HKH region. However, its precise contribution is not well known because little information exists on the magnitude, rate, and spatial extent of change.

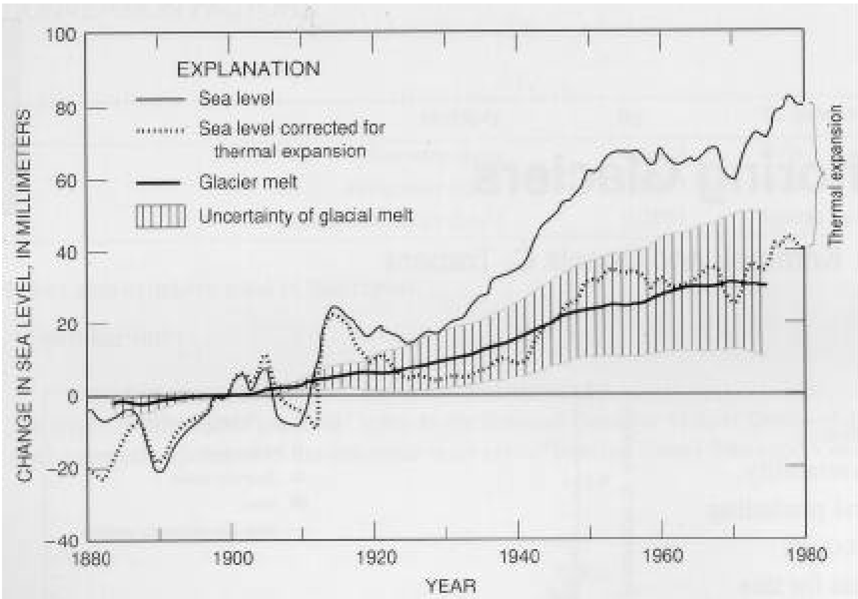


Figure 7: The contribution of mountain glaciers to sea level rise (Fountain and others, 1997; Meier, 1984)

2.4. Climate studies

Like a thermometer, a glacier is sensitive to the climatic environment and the resulting adjustment of mass balance is the direct link between the climate and a glacier. Like a thermometer, a glacier has to be "calibrated" by defining the local relation between mass balance and climate. If the monitored glaciers form a network, they provide a highly useful tool for monitoring spatial and temporal climate and climate change for reconstructing and modeling past and future climate scenarios. The knowledge gained is of essential value for hydrological and hazard assessment and management. In addition, the mass balance series are of crucial use when processes on other, unmonitored glaciers are required. (fig. 8).

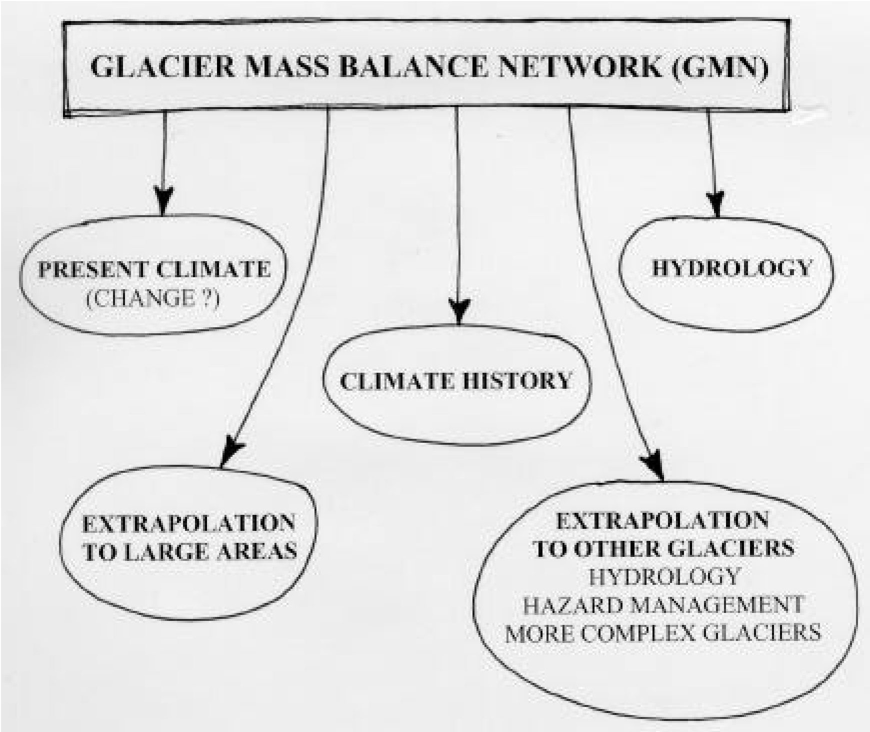


Figure 8: Glacier mass balance input to models.

2.5. A question of scale

One basic question always arises in monitoring programs and that is the question of scale. Does one need to monitor changes over time intervals of seconds and across distances of millimeters, or are time intervals of years and distances of kilometers important? The answer depends on the purpose of the monitoring network. Also, each kind of measurement may have different time scales. For example, for meteorological measurements it is typical to take readings every minute and record the 15 minute average at one station on a glacier whereas mass balance measurements are taken 1-2 times a year at 10-30 locations over the glacier. If the program is designed for assessing effects of climatic influences on glacier mass balance or for assessing glacier hazards will have dramatically different strategies and data collection procedures. One program typically cannot cover all areas of interest because of limited funds and logistical constraints. Therefore, judicious choices must be made early in the program development.

2.6. Summary remarks

Glaciers need to be measured for a variety of purposes including hazard assessment, effects on hydrology, including sea level rise, and to track climatic variations. The mass balance of a glacier is the direct link between climate and glacier advance and retreat. It is also the direct influence on runoff from the glacier. Because a glacier is sensitive to climate variations, it can be used as an indicator of climate change. But like a thermometer, the relation between climate change and glacier response must be calibrated. Not only does this help with a present understanding but is critical to reconstructing past climate change or predicting future glacier responses. Due to climatic variations in a region, a network of monitored glaciers should be implemented.

Glacier selection and measuring methods are included in chapters 3 – 5.

3. How can the mass balance of a glacier be measured?

3.1. The geodetic method

A volume change can be estimated by subtracting the surface elevation of a glacier and the glacier extent at two different times. Knowing the surface density at different parts of the glacier the volume change can be converted into a mass change. This method can be applied using topographic maps, digital elevation models obtained by aircraft and satellite imagery, and by airborne laser scanning.

The application of this method has several limitations. According to equation 1 the geodetic method must be applied over the entire glacier surface. This can be difficult. Surveying the surface by field methods requires that all parts of the glacier are covered, including highly crevassed and steep regions. Remote imagery has problems in the accumulation zone where insufficient surface definition can lead to significant errors in estimating the surface elevation. In addition, the density of the firn and/or ice body must be approximated. This is rather easy for the ice portions but not accurate in the firn areas. Thus, major changes in the accumulation areas are difficult to determine accurately. Also, this method does not yield point values of mass balance, such as its variation with elevation. For example, a glacier in steady state will yield a zero volume (mass) change over time, yet field measured point values will yield positive values in the accumulation zone and negative values in the accumulation zone.

The geodetic method is useful complementary to the glaciological method and over larger time steps (e.g. 10 years) as a check on the field-based methods. This check has proven very useful in numerous circumstances due to non-random errors in the field methods.

3.2. The glaciological method

The glaciological method is the only which is based on in situ measurements. At a number of individual points the change in surface level is measured between two dates. The difference in level (gain or loss), multiplied by near-surface density, yields an estimate of the mass balance at that point. Changes in level are measured in a variety of ways, including stakes drilled into the glacier and snow depths relative to a known stratigraphic surface (e.g. previous summer surface). Density values for ice are assumed constant at 900 kg m^{-3}. Snow density is measured in snow pits, which are dug down to a reference surface. Density can also be measured from cores taken with a drill. Because of the higher reliability, snow pits are used and will be presented in detail in chapter 7.

There are several ways to calculate total mass balance of a glacier. One way is to construct a plot of mass balance as a function of elevation and a plot of the area of the glacier with elevation. A regression equation can be applied to each plot. The mass balance is found by multiplying the values of mass balance and area for specific intervals of elevation and summing the product over all the intervals.

Another method is to contour a map of net mass balance and the total mass balance B is calculated from equation (3) in its discrete form,

$$B = \sum_{1-n} b_n \Delta S_n \qquad (6)$$

where $?S_n$ is the area of the glacier over which net mass balances b_n applies. The practical application is presented in detail in chapters 8 and 9.

This method is considered the most accurate method to date and provides the most detailed information on the spatial variation of mass balance magnitudes. Furthermore, confidence in the results increases after independent checking by the geodetic method. However, although the glaciological method may achieve the greatest accuracy and provides the investigator with a feel for the field conditions, it is based on repeated field measurements, which have to be carried out under sometimes rather challenging conditions. The rate of data acquisition is slow and expenses for logistics and labor can be high.

3.3. Indirect methods diverted from the glaciological method

Previous studies have shown that the vertical balance profile (VBP) maintains a roughly constant profile on an individual glacier from year to year. The profile shifts from positive to negative net balance years. Knowing the equilibrium line altitude (ELA), or the accumulation-area ratio (AAR) the position of the VBP can be determined (figure 9). Together with the altitudinal distribution of the surface area, the total mass balance and following variables can be derived. A long time series of ELA and $\bar{b}$ or AAR and $\bar{b}$ relations are shown in Figures 10 and 11 and indicate that $\bar{b}$ can be determined from ELA or AAR. This is done at the end of each balance year.

Although relatively simple, this method first requires a long time series of data (~5-10 years) and is not suitable for programs without such a background of data. The ELA or AAR may be determined from remote imagery and field visits are not required. However, this assumes that the end of year snowline is identical with the ELA (see chapter 1.7) which may not be the case, particularly on glaciers where refrozen meltwater is substantial. In addition, timing of the imagery is crucial because an early snowfall can blanket the ELA and obscure its position just prior to image acquisition. Also the assumption of a parallel shift of the VBP is seldom as correct as shown in Figure 10.

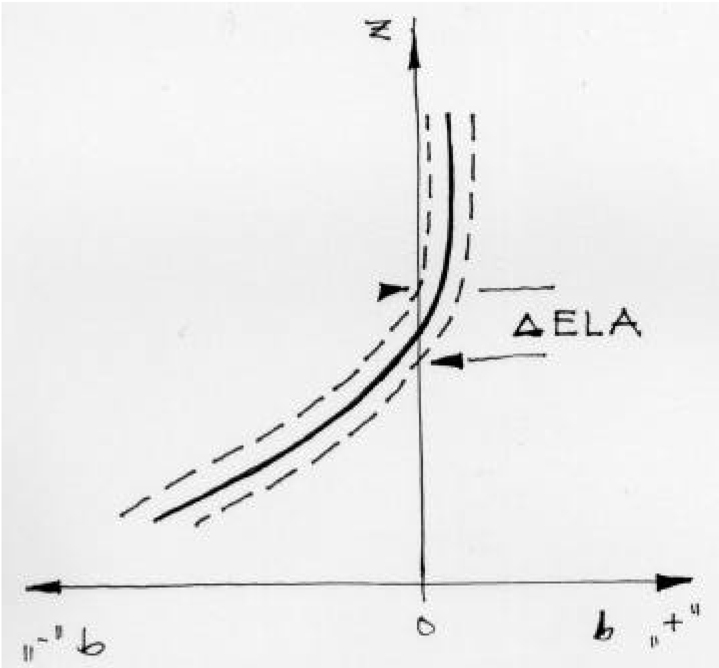


Figure 9: The assumption of a parallel shift of the VBP.

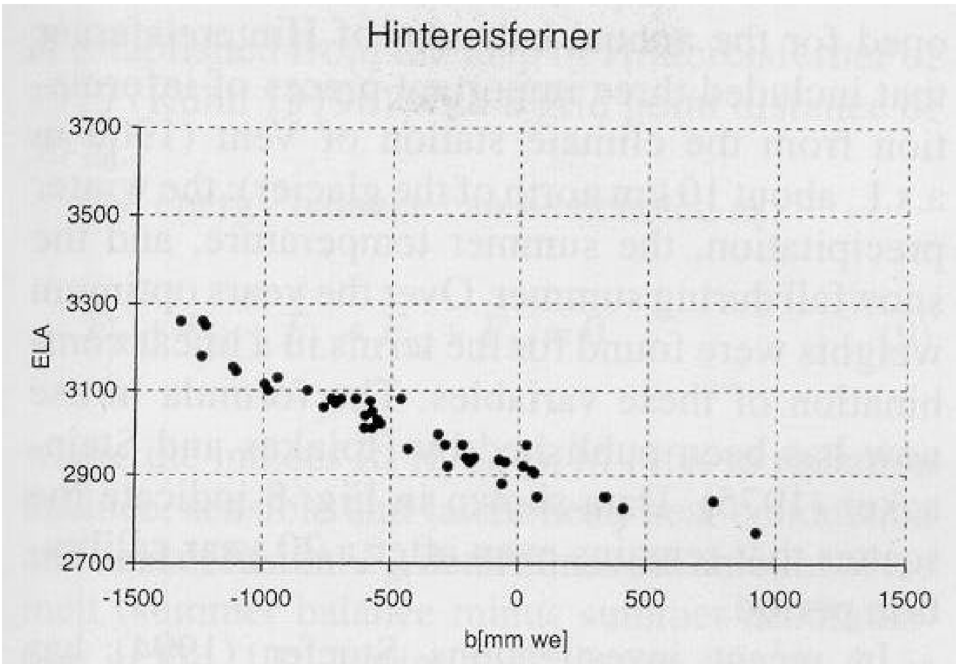


Figure 10: The relation between annual balance and the height of the equilibrium line altitude ELA for the Hintereisferner, Austrian Alps (Kuhn and others, 1999).

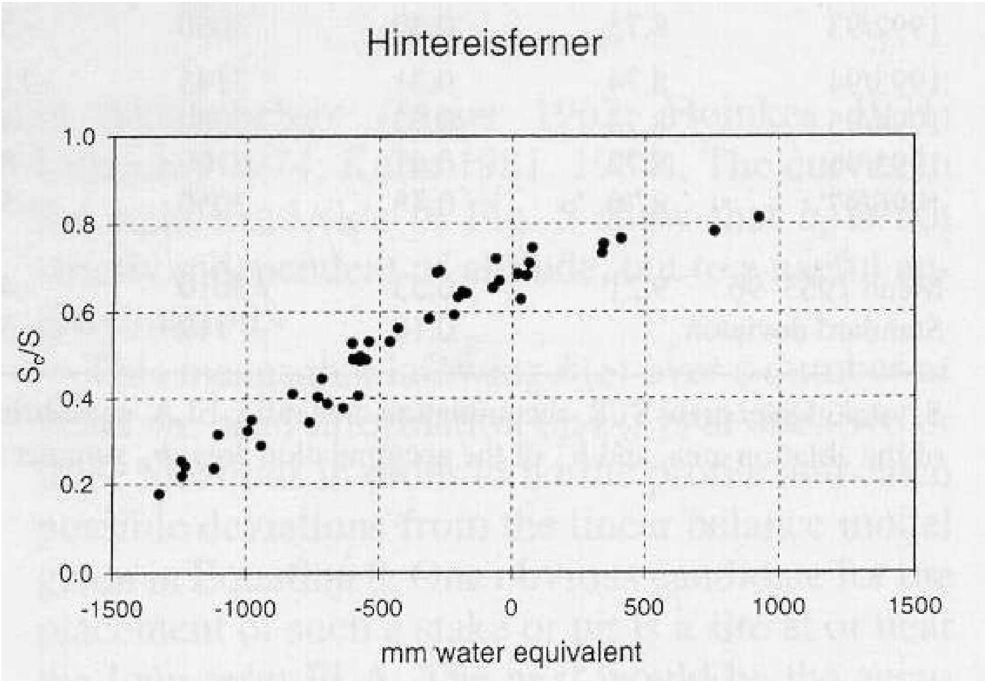


Figure 11: The relation between annual balance and the accumulation area ratio (AAR = S_c/S) for the Hintereisferner, Austrian Alps (Kuhn and others, 1999).

3.4. The flux method

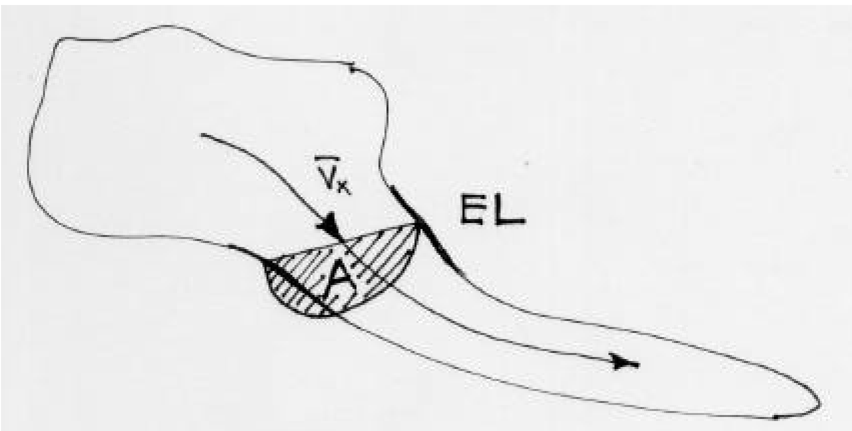


Figure 12: The key variables for the flux method

This method relates to the mass flux through the cross-section under the equilibrium line to the mass balance of the accumulation area. This flux can be calculated from the mean velocity, $\bar{v}_x$, measured at the equilibrium line, EL, and the corresponding cross section, A, determined from radar measurements of the ice thickness (figure 12). The method, however, holds only for steady state conditions with $\dot{h} = 0$ (see equation *1*). Under both acceleration (as a consequence of positive mass balances) and slowdown (negative mass balances) conditions the method fails.

3.5. The hydrological method

From a hydrological point of view, a glacier acts as a reservoir with seasonal gains and losses. Thus, the glacier mass balance is one term in the hydrological balance of a glacierized catchment basin and can be calculated as a residual of all other terms:

$$B = P - Q - E \pm \Delta S \qquad (7)$$

P = precipitation; Q = runoff; E = evaporation; $?S$ = variation of storage elements of the catchment area other than glaciers such as groundwater or interception. This method requires good instrumentation to measure each of the variables. This is a challenging effort for unattended operation in high alpine basins. Maintaining a good gauging station for water discharge can be an expensive and time-intensive operation itself. Also, extrapolation of precipitation from a single gauge to the surrounding mountainous terrain is often inaccurate. Finally, the natural processes of storage and release of water within a glacier can confound this method. Typically, the inaccuracies of the measured variables equal the order of magnitude of B. Thus, the hydrological method is usually applied only in conjunction with other methods.

3.6. The flux-divergence method

Recently, airborne laser scanners have provided both high-resolution digital terrain models of a glacier surface and closely spaced velocity vectors. With basal topography provided by echo-sounding attempts are being made to combine the geodetic method with detailed dynamic ice-flow models in order to obtain the spatial distribution of glacier mass balance. Equation (1) is rewritten to solve for the balance. Although a promising method because of the increasing sophistication of airborne and satellite techniques, Bauder (2001) has shown that it fails because of the inability of dynamic models to derive sufficiently accurate vertical ice velocities. In addition, the method depends on airborne instruments, which are expensive and subject to bad weather conditions.

3.7. Modeling from climate records

The mass balance of a glacier results from climate. If non-climate mechanical processes can be excluded (e.g. surging, kinematic waves, avalanches) the mass balance can be derived from climate records. Depending on the accuracy and availability of climate data a variety of models can be applied. Most models focus on the ablation season using simple degree-day approaches or more sophisticated energy balance methods. Because of the complexity of precipitation distribution and accumulation, most models rely on a simple extrapolation from precipitation data. To date, all of models have to be calibrated for the glacier in question. Thus, mass balance data are needed, at least in the beginning.

3.8. Concluding remarks

To measure long-term mass balance changes and on a suitable number of glaciers in usually harsh environments and under usually limited economic conditions the applied method must be:

- **standardised**
- **safe (regular measurements must be guaranteed)**
- **inexpensive**
- **carried out by local (national) institutions independently from outside support**

Taking these considerations into account and following the theoretical considerations presented in the chapters 3.1 to 3.7 the only method for long term and detailed mass balance monitoring is the **direct glaciological method**, the focus of the remainder of the manual. Additional climatological, ice dynamical, and hydrological data series are of great advantage for extrapolation, more detailed analysis, and better interpretation of the mass balance data.

4. The “ideal” glacier for mass balance investigations – benchmark glacier

Within a glacier mass balance network “ideal” benchmark glaciers (figure 13) should meet the following requirements:

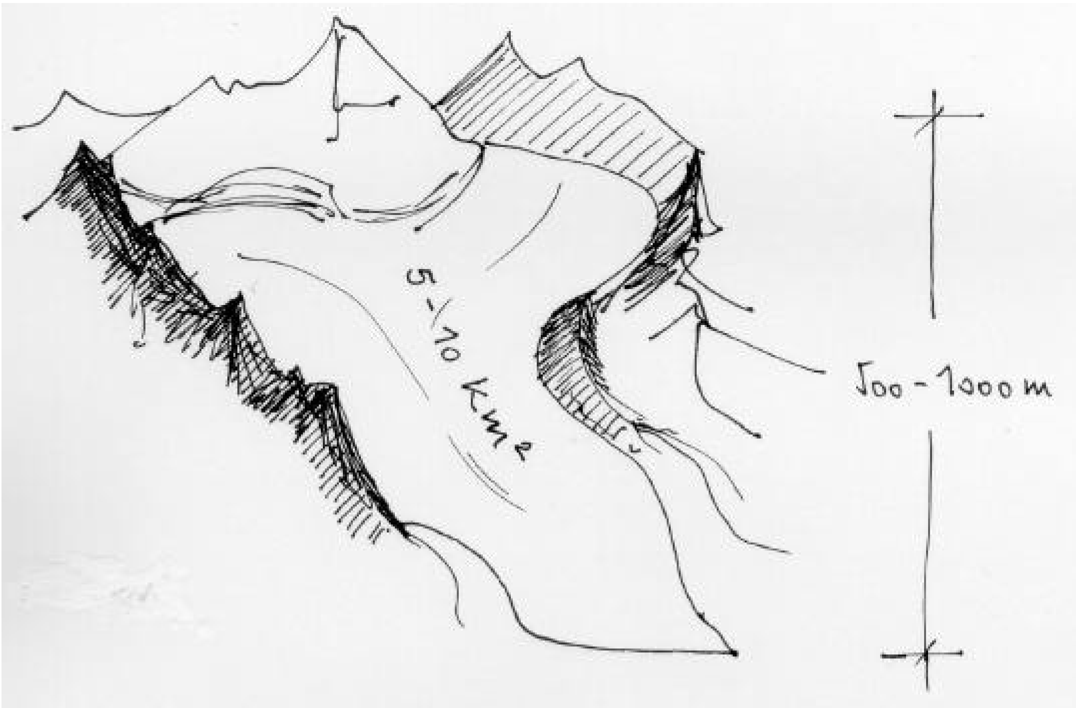


Figure 13: The “ideal” benchmark glacier.

- The **size** of the glacier must not be too small (local climate effects dominate, relative surface area and volume changes are big) and not too large (which increases logistical problems). Usually, glaciers of approximately **5 km^2** meet this requirement, but they should not be much smaller than 2 km^2.

- The glaciers must have an **altitude range** to allow the detection of ELA variability. An altitude span of **1000 m** would, according to a mean atmospheric lapse rate, cover a temperature range of 6 to 7 °C and would meet approximately with the first requirement of the glaciers size. In any case, mass balance benchmark glaciers should **not span less than 500 m** in altitude, unless small glaciers populate the region.

- The **catchment area** of the glacier must be well defined. This is sometimes rather difficult standard because the accumulation area is often connected to another glacier. Steep rock walls that border the accumulation area but are not covered with ice might cause another problem. Snow falling on these high elevation rock walls is usually transported into the glacier system by avalanches. Thus, care must be taken when accounting for the sources of the snow accumulation.

- The **geometry** of the glacier must be simple. In many cases several accumulation areas contribute to a glacier and in some cases more than one tongue emerges. Both cases complicate the fieldwork and analysis. In the best case, a glacier with one well-defined accumulation area and one tongue should be chosen.

- Non-climatic (**mechanical**) processes must be insignificant. Avalanches and calving are not only difficult to quantify but are also not directly related to the climate input (see Fig. 4 and chapter 2). Also surging and large kinematic waves distort the mass distribution of a glacier making mass balance calculations difficult.

- It is most convenient if the glacier is **free of debris cover**. A debris cover, usually limited to the tongues, complicates the interpretation of the climate-glacier interaction. Besides of this theoretical consideration the installation and maintenance of an ablation network (stakes) is difficult. Even if it was installed, the regular visits to such a stake in the middle of more or less loose boulders of each size is dangerous.

- The surface must be quite uniform and smooth. **Sérac** and highly crevassed areas present significant safety problems. Moreover, ablation and accumulation can hardly be measured.

- The access to the glacier must be **easy and safe**. Typically, fieldworkers commute regularly to the glacier, sometimes with heavy loads or in bad weather conditions. In case of health or injuries problems a retreat must be quick and easy.

In practice, all these requirements are hard to meet and they should be considered as guidelines. Further considerations may admit a certain deviation from the "ideal" guidelines:

- With regard to the network requirements the benchmark glaciers must be well distributed (chapter 5).

- Already existing mass balance series are of great use.

- Already existing meteorological and/or hydrological stations may influence the choice of a glacier (chapter 13).

- The availability of high-resolution maps, air photographs and historical data like old maps and pictures may influence the choice between similarly set glaciers.

5. The design of a glacier mass balance network (GMN)

As for each network to provide spatial information over a rather large and complex area a representative number and a "best" distribution of benchmark glaciers must be determined. This design must correspond to the scientific and logistical demands. Summarizing from chapter 2, the reasons for glacier mass balance studies are:

- Hazard assessment and warning
- Management of regional water supplies
- Estimate glaciers contribution to sea level rise
- Monitoring climate.

The glaciers response to climate is the fundamental to all other investigations and, thus, a glacier mass balance network must take spatial gradients and temporal fluctuations. From this point of view a high number of well distributed benchmark glaciers and a high frequency of measurements is desirable.

Still, glaciological fieldwork, analyses of the data, and the particularly time consuming logistics in the high mountain environments, such as the Hindu Kush and Himalaya, limit the number of glaciers investigated. In addition, the time interval in which field measurements have to be taken is rather small (end of the dry season or, as an optimum, at the beginning of both the dry and the humid season). To guarantee a simultaneous collection of data one team of fieldworkers can only investigate one glacier. Thus, the number of monitored glaciers must be optimized according to spatial variation required and to the capacities of the national institutions involved.

Of particular importance when designing a glacier mass balance network are patterns and fluctuations of the regional climate. This is shown on the general global atmospheric circulation patterns (fig. 14) before approaching considerations and recommendations for the more complex HKH region.

The combination of the radiation geometry on the earth's surface and the rotation of the earth lead to generally zonal circulation patterns which are characterized by the Inter Tropical Convergence Zone, the subtropical Trade Wind Belt and the Westerlies of the mid latitudes (figure 14). Each feature characterizes a typical climate. Following the position of the sun, these circulation patterns are compressed or extended on the respective winter and summer hemisphere (Figure 15).

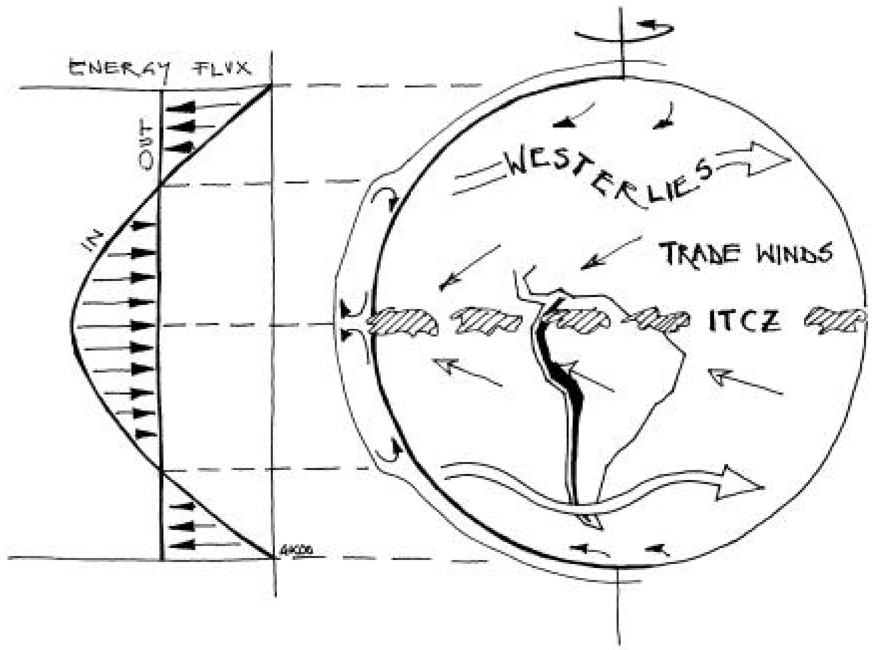


Figure 14: The mechanisms of global atmospheric circulation. Net radiation fluxes and zonal circulation patterns are shown (Kaser, in press).

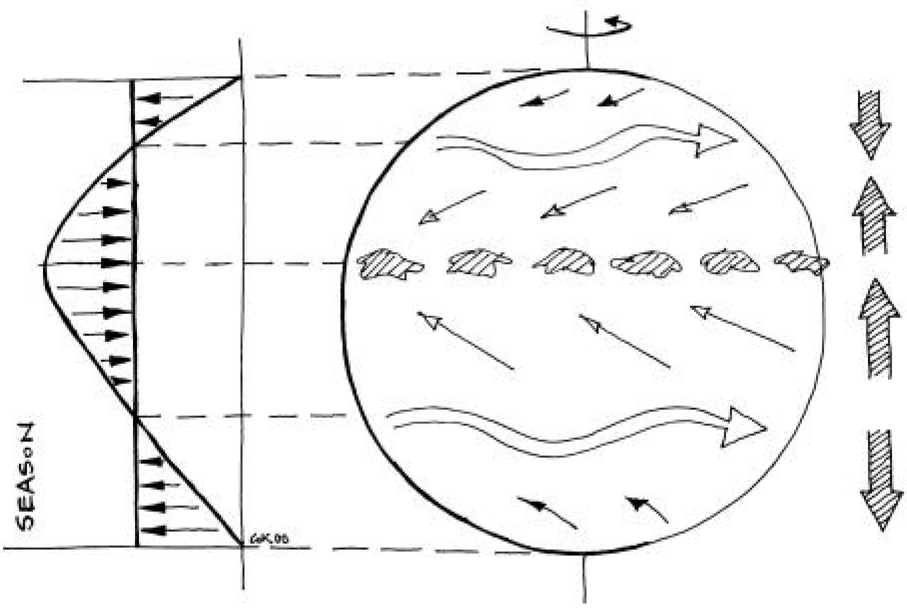


Figure 15: Seasonal shift of global atmospheric circulation patterns (boreal summer) (Kaser, in press).

In Southeast Asia, the global atmospheric circulation patterns are substantially modified by the monsoon circulation turning them into a South – North regime. Generally, moisture is advected from the Indian Ocean toward the Himalayans in summer (June-September) and, in contrast to the mid latitudes, causes accumulation during the warm season. From December to February cold dry air masses from the interior of the Asian continent dominate and prevent any considerable glacier mass change.

The influence of the monsoon circulation is strongest and appears earliest in the eastern parts of the Himalayans and becomes weaker and shorter toward the west. The westernmost areas of the Hindu Kush and the Karakorum are usually characterized by the frontal activities of the westerly winds in winter and by the dry subtropical climate in summer. The high mountain ranges of the Himalayans being barriers to both the Westerlies and the summer monsoon lead to an extraordinarily dry climate on the respective lee sides. This leads to the general climate regime (simplified) over the HKH-FRIEND region as shown in figure 16. Still, fluctuations in the global climate and, in turn, regional climate, cause deviations from the general pattern illustrated in figures 17 and 18.

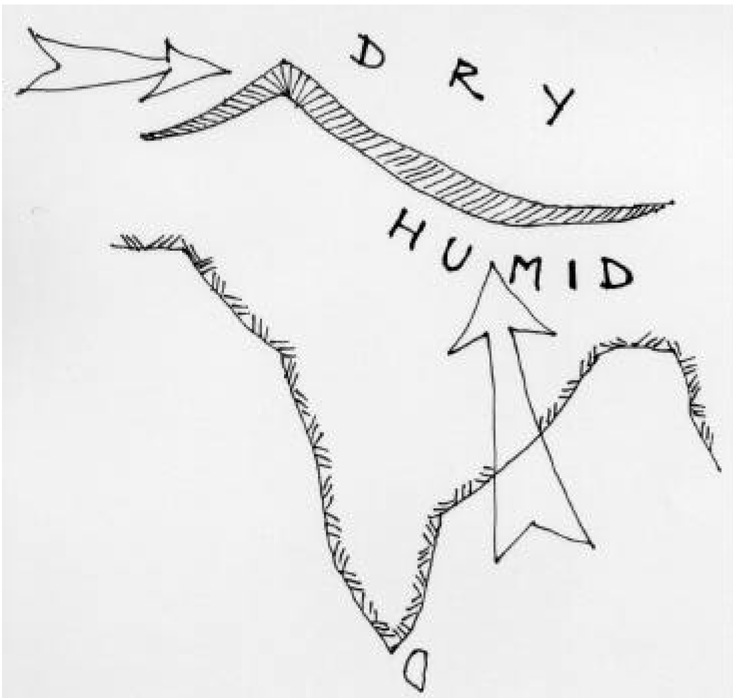


Figure 16: Climate and glacier regimes in the HKH region. Arrows indicate the predominant moisture advection with the westerly winds and the monsoon respectively.

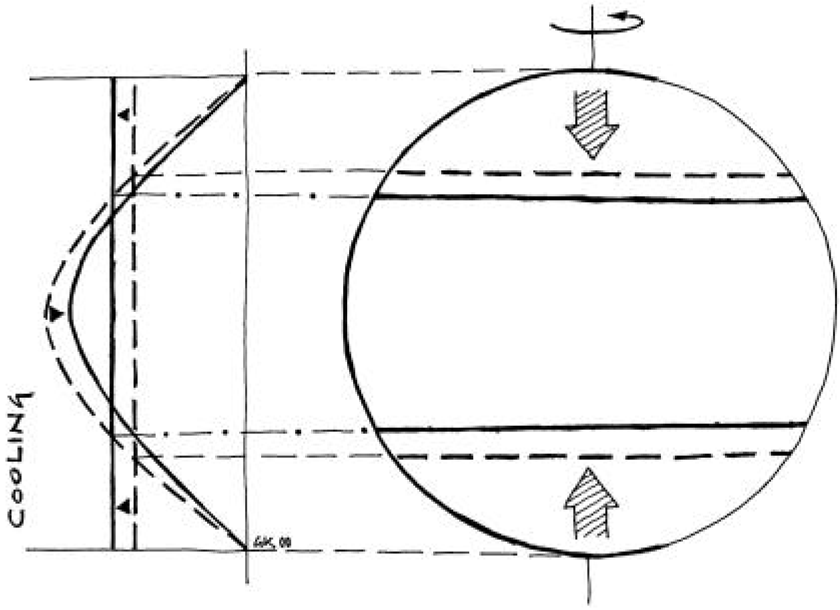


Figure 17: The compressing of global atmospheric circulation patterns due to cooling. The cooling can be either due to a reduction of the incoming radiation or by increased outgoing energy (Kaser, in press).

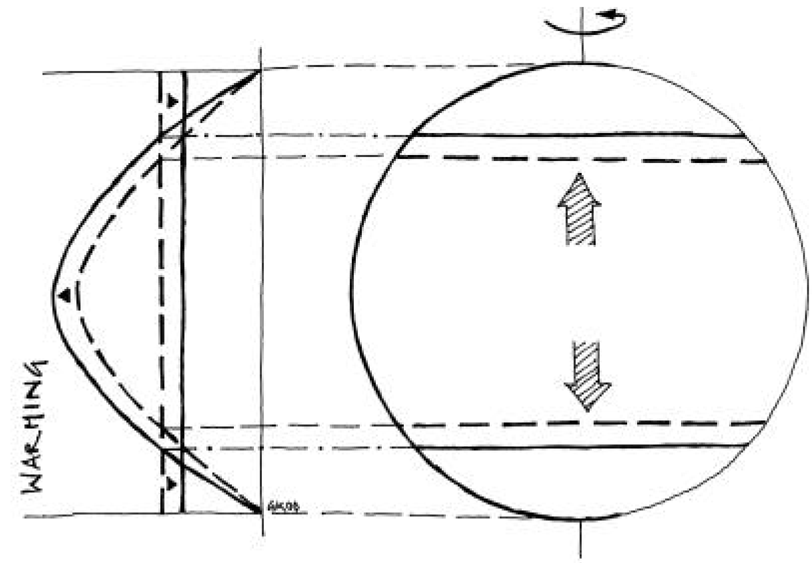


Figure 18: The expanding of global atmospheric circulation patterns due to warming. The warming can be either due to an increase of the incoming radiation or by decreased outgoing energy (Kaser, in press).

Benchmark glaciers, as a matter of course, should not only represent each climatic region but, in the best case, also provide spatial gradients and show temporal changes. Ideally, several cross sections of benchmark glaciers should cover the region (figure 19). This idealization, if never attained, is a guideline when constructing a network of glacier mass balance measurements.

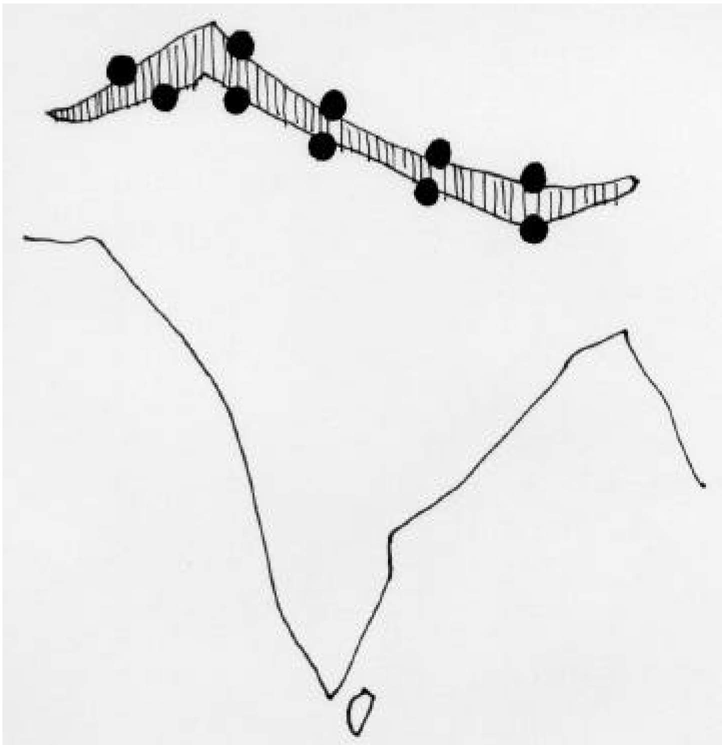


Figure 19: An "ideal" glacier mass balance monitoring network in the HKH region.

III. CARRYING OUT MASS BALANCE MEASUREMENTS

The focus of this chapter is the application of the “direct glaciological method”. This method determines the surface net mass balance over given time periods. As mentioned above, measurements are best carried out twice per year –at the end of the humid and the end of the dry season. More visits may be necessary to maintain instruments and stakes in the glacier. The net mass balance has to be measured on a selected number of sites. For clarity, in subsequent chapters, the two dates of subsequent visits to the glacier are called t_1 and t_2. (t_1, might be October 1st in 2002, and, t_2, October 1st in 2003). Since accumulation and ablation measurements require different techniques these to topics are presented separately.

6. Ablation measurements

Net ablation can occur on bare glacier ice in the ablation zone low on the glacier and, under strong negative mass balance conditions, also from firn in the upper regions of the glacier. Typically, stakes are drilled into the glacier in the ablation zone and changes in surface level are measured against stake height. For ablation conditions, the level, measured (between t_1 and t_2), drops (or the distance from the stake top increases). The density of glacier ice is considered constant at 900 kg m^{-3} and there for the specific mass balance in [m we] or [kg m^{-2}] is calculated from the product of the level change between readings and the ice density.

In the accumulation zone, if firn ablation can be expected, stakes must also be set in those areas. Density of the ablated material must be made prior to the ablation, that is at t_1, at near the stake location but not close enough to the stake to affect measurements.

6.1 Ablation stakes

Ablation stakes can be made from a variety of materials. The stakes must not self drill into the ice by their own weight or by melting due to the absorption of energy. For ablation greater than 0.5 m yr^{-1}, a sectioned stake is usually needed. Plastic or metal pipe in sections about 2 m long have been used. The sections are kept together either by interior plugs inserted into the pipe, by wire or cable ties, connecting each section through holes drilled in the sides, or by exterior sleeves. Metal stakes have one major disadvantage, in areas with high air temperature or high insolation, stakes warm up or absorb energy that cases them to melt out of the bore holes in which they originally were set. Metal stakes will also melt down into the ice, thereby reducing the read ablation values from their true values. This problem can be reduced by inserting a wooden plug at the bottom end of the stake, thereby reducing the thermal conduction from the stake to the ice. Plastic stakes are lightweight and may appear ideal. However, some plastics (e.g. PVC) become brittle at low temperature and splinter easily when winds pick up. Plastic stakes can therefore not be recommended. In many places, including low latitude countries, bamboo stakes have proved suitable: they are easily available, strong, resistant to weather, have a low thermal conductivity and low weight, and they are inexpensive. Wire connections are useful for bamboo stakes. Connecting devices are shown in figure 20. A disadvantage of the wire connection may occur when the lower stake emerges only very little from the ice. The upper stake is then laying on the surface and it can be difficult to find the site, particularly if it is, in addition, covered by lets say a thin autumn snow cover (fig. 21). The advantage of any particular system depends on the availability of materials locally, the cost, and weight.

In places where glaciers can or will be revisited repeatedly during a season, such stakes may be very useful. However, a lost stake from melting out is a severe blow to any mass balance program and the choice of stake material must be made in accordance with the expected frequency of visits to the glacier.

Our recommendation is the use of bamboo-stakes.

We strongly recommend any mass balance program to make their own evaluation of different stake materials in parallel to establish which materials suit their needs the best. *There is no single best way to measure mass balance that is applicable to all glaciers*. However it *is* important that whoever makes decisions on changes to methods of measuring mass balance does so backed up with much knowledge, and perhaps most importantly, much experience from the field.

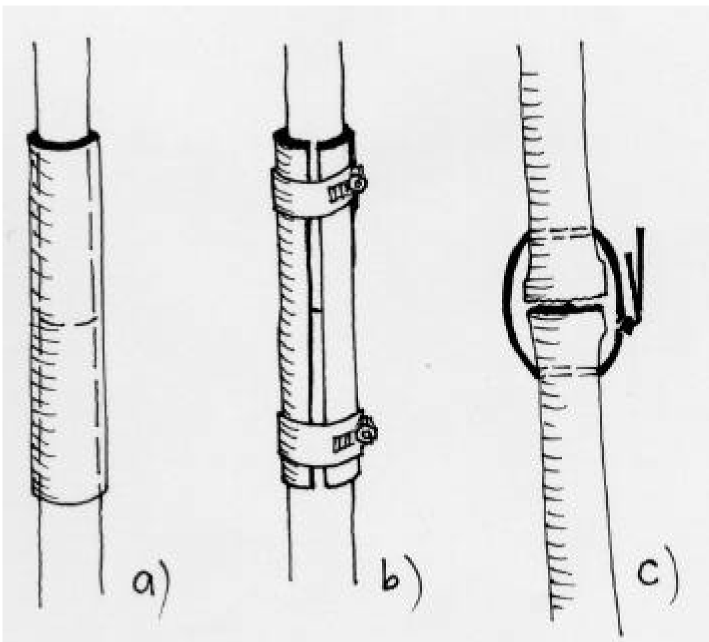


Figure 20: Connection devices for ablation stakes: a) rubber tube, b) metal sleeve, c) wire connecting bamboo stakes.

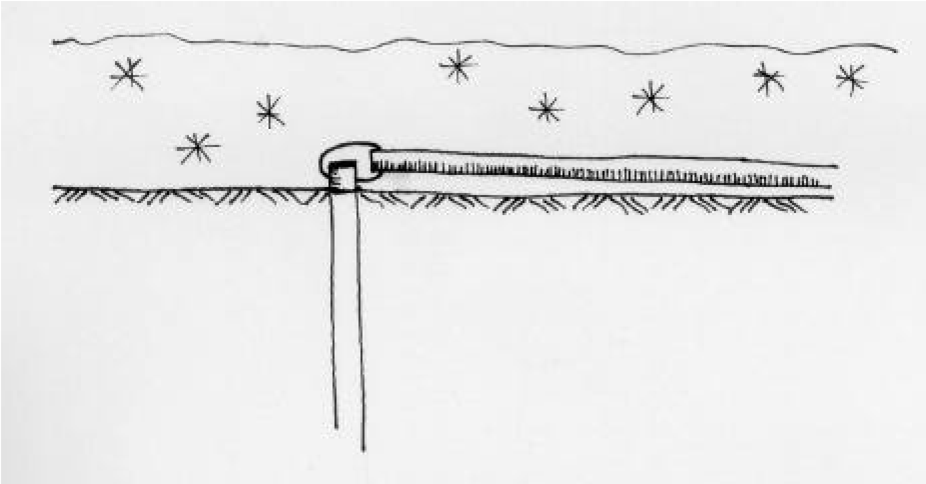


Figure 21: A stake buried by a rather thin snow cover.

6.2. Selecting sites

Ablation, in comparison to accumulation, is rather uniform and point measurements can be representative over large areas. This implies that significant small scale (10^{-2} – 10^{1} m) differences can be averaged out over long periods (>days). Statistical analyses from a variety of studies agree that 10 – 15 ablation stakes are sufficient to estimate a glacier's mass balance, independently from the size of the glacier (e.g. Fountain and Vecchia, 1999). A useful distribution is on a longitudinal axis along the central flow line of the glacier and some additional crosswise profiles where accumulation differences due to wind distribution, shading, or avalanching may be significant (figure 22). On many glaciers, ablation stakes are distributed more or less regularly over the ablation area with no particular structure (figure 23).

Stakes should be established at the same position each year. By "same position" we mean within about 100 m. This means that a stake location is a circle of 50 m radius on the glacier. Within this radius, mass balance is not expected to vary significantly. These values only apply to a larger glacier that is 500-1000 m wide and several km long. On a smaller glacier it becomes more critical to re-establish stakes at the same position. Establishing the location of stakes can be made by either using a hand-held GPS with pre-programmed waypoints or using a sighting compass and landmarks such as peaks, ridges or other features in the surroundings to establish the point by optical intersection. Regular surveying can of course also be made but requires heavy equipment and larger number of personnel.

Establishing stakes at predetermined locations has the advantage that values from different year can be compared directly.

Remember that mass balance is strongly elevation dependent, primarily because melting decreases with altitude since it depends on temperature, which decreases with altitude.

This means that on any glacier which has a large elevation span (ca. 1000 m) the strongest variation in mass balance will be along the long axis of the glacier. The primary goal for setting stakes should therefore be to cover as much elevation as possible, especially important is to maintain stakes at both high and low altitude, near the head and terminus of the glacier, respectively. Lateral variations in mass balance originate from shading of the glacier. If your glacier is located so that there is reason to suspect that certain sites on the glacier receives much less or more energy, lateral stakes should be placed to capture the decreased or increased melt in such area.

Our recommendation is to concentrate on establishing 10-15 stakes along a longitudinal profile covering as much elevation as possible. Stakes should be placed so as to be evenly distributed in altitude, not distance on the glacier. This means closer distance on steeper parts of the glacier and more distance between stakes on flatter areas. Lateral extending of the stake network should be made either in a cross like figure (fig. 22) or in a diamond like figure where lateral stakes are set in altitudes between the central stakes. The latter supports best the contour type evaluation (see chapter 9.2) of mass balance.

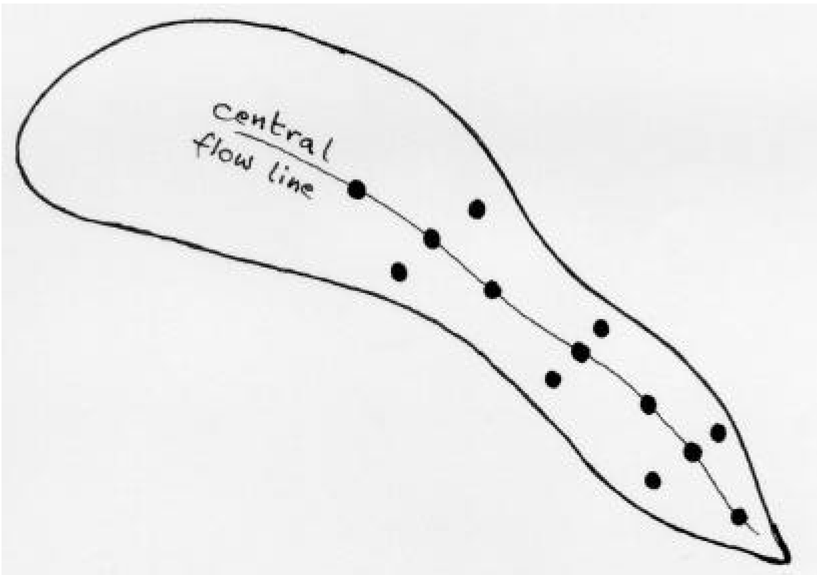


Figure 22: Stake setting along the central flow line of the glacier and some additional crosswise profiles.

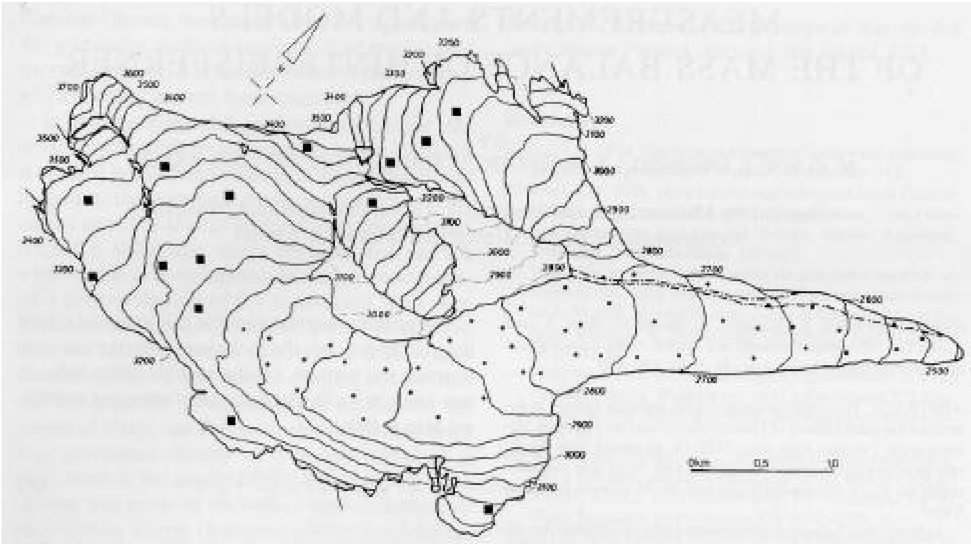


Figure 23: A more or less regularly distribution of ablation stakes (dots) and accumulation pits (squares). Hintereisferner, Austrian Alps (Kuhn and others, 1999).

The stakes should be numbered and tagged by a small metal plate, tied with wire to the upper end of the stake. The stake number is stamped or scratched into the plate together with the year of drilling in the stake (a lost stake may re-appear again). Several numbering systems are practiced from a chronological numbering to spatial numberings that infer stake location. For example, along the central flow line stakes are numbered 10, 20, 30, 40, etc., and lateral stakes are numbered 21, 23, 25 on the left-hand side and 22, 24, 26 on the right-hand side. Note that any numbering system which allows the unambiguous recognition of stakes is of value.

Due to the ice movement stakes are dislocated from their original position after some time. Depending on the glacier velocity the stakes must be repositioned occasionally. Often, this can be conveniently done when the stakes are ablating out entirely.

6.3. Drilling ablation stakes

Ablation stakes are drilled into the glacier using either a mechanical hand auger or with a steam drill (see 6.5). For deep emplacement (>3 m) a steam drill is usually easier. Because of heat loss along the sides, a typical steam dill has a depth limitation of 8-12 m.

The depth of the holes for the stakes depends on the magnitude of expected ablation between the measurement interval. The greatest ablation is usually highest close to the terminus and can reach up to 10m or more per year. Thus, drill limitations may dictate the minimum time interval between visits.

Closer to the equilibrium line the stakes need not be drilled in as deep. The steam drill presented below (chapter 6.5) and in use in the HKH-FRIEND program creates a hole large enough for stakes 2 cm in diameter including the connecting devices.

6.4. The reading of ablation stakes

For net ablation measurements the length of the stake from the free end to the surface, L, is measured at two (t_1, t_2) or more (t_n) successive dates. At t_2, the last measurement of the ablation season, the depth of snow over the ice is also measured. The difference between exposed stake lengths, $L_i(t_2) - L_i(t_1)$ plus snow depth at t_2, gives the net ice ablation at this point. If snow covers the surface during both visits, then it has to be accounted for in each visit.

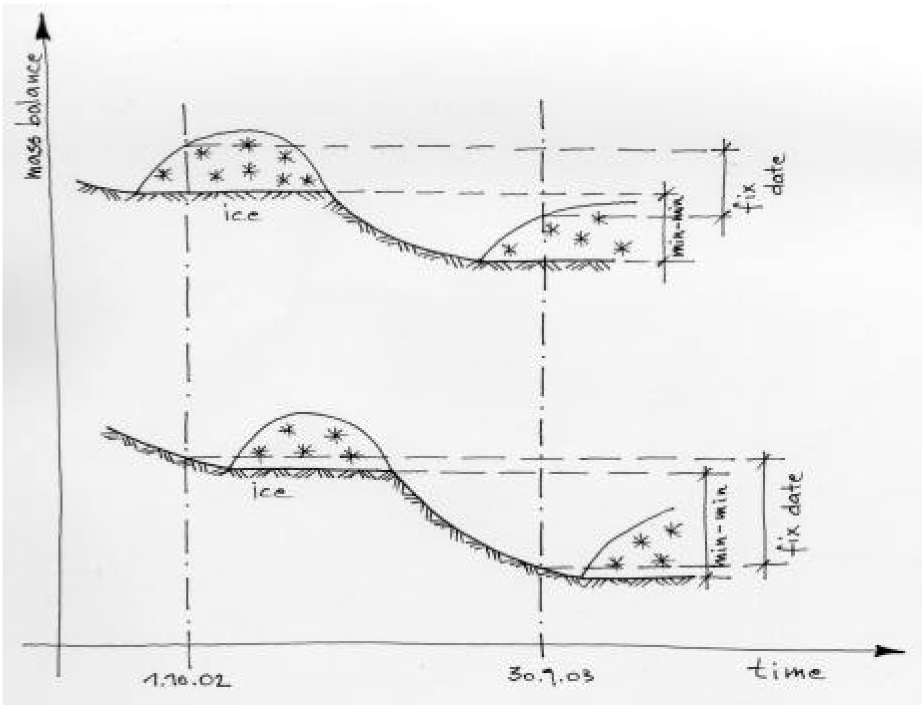


Figure 24: The seasonal development of the surface in the ablation zone.

If snow covers the last visit and remains snow covered for the rest of the season, presumably, the time of maximum ablation (minimum mass balance) took place at some point earlier (fig. 24, top). Weather records from a nearby station help with determining more accurately the date of snowfall and therefore the date of minimum glacier balance.

If ablation continues after t_2, the magnitude of the ablation can only be measured at the next years visit (t_3) (fig. 24, bottom). The date of the end of ablation must again be approximated from weather records.

6.5. Mapping the ablation area

The knowledge of the pattern of bare ice appearing at the end of the observation period (particularly at the end of the ablation season) is of great use when drawing the mass balance features into a topographic map (see chapter 9). It would be best to measure the extent of bare ice by geodetic methods but a field mapping supported by photographs taken from different points is sufficient.

6.6. The steam drill (by Erich Heucke)

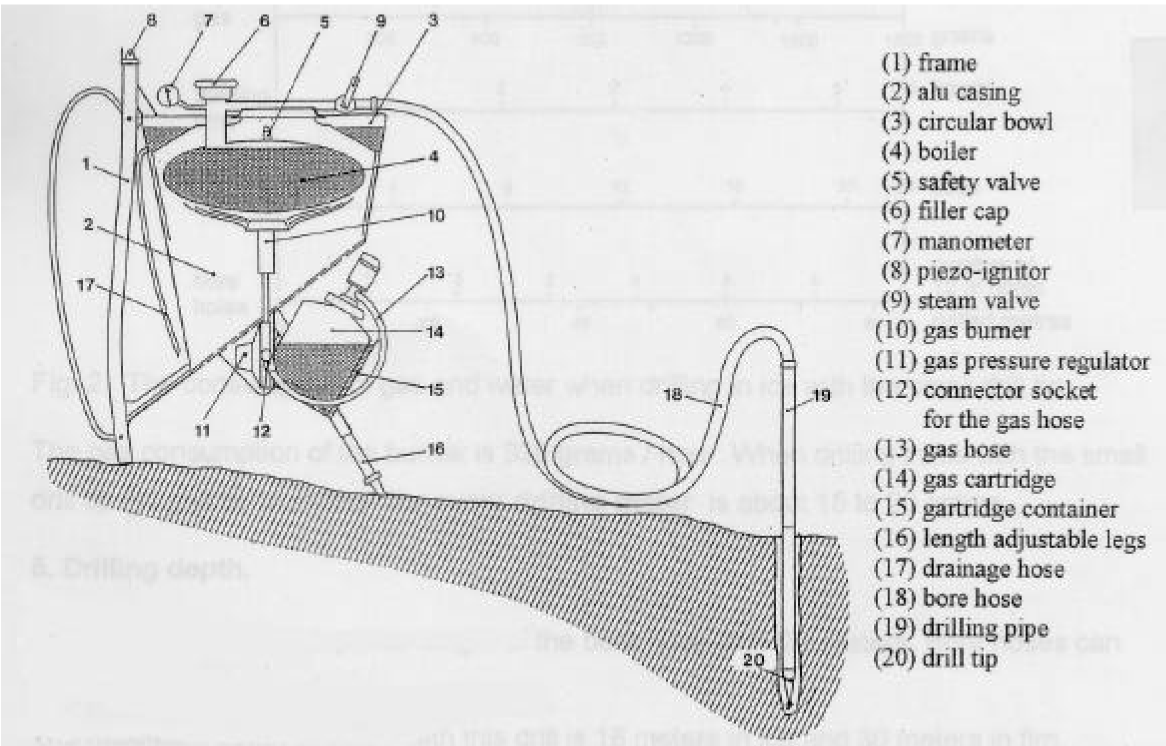


Figure 25: The steam-driven HEUCKE ICE DRILL.

A butane (or propane) burner heats water in a boiler and generates steam. When the valve is opened the steam escapes through the nozzle of a drilling pipe at the end of an insulated hose. The condensing steam transfers energy to the ice causing it to melt. The high degree of latent heat contained in the steam guaranties a very efficient energy flow from the boiler to the ice. The entire drilling device consists of the steam generator, the rubber hose, and the drilling pipe with interchangeable tips. It can be carried on the back like a rucksack and can be operated by one person. **A** small drill tip (21 mm in diameter) creates hole diameters of 30 to 35 mm and a large drill tip (30 mm in diameter) creates hole diameters of 35 to 45 mm in ice.

Chhota Shigri, October 2002

7. Accumulation measurements

The net accumulation is measured by digging pits at each of the stakes in that area of a glacier where snow has accumulated during the immediate past period (t_1 to t_2) of investigation (i.e. season or mass balance year). Like in the ablation zone, the amount of accumulated snow is measured in water equivalent length units [m we] or water mass per area units [kg m^{-2}]. This is calculated from measured snow depths and the respective snow density. For the necessary measurements the snow cover has to be penetrated to the last observation dates (t_1) horizon either by digging snow pits or by taking cores with a respective drill.

7.1. Selecting the sites

The accumulated snow cover has usually a rather complex distribution of depths but comparable uniform density profiles. Because of the logistical limitations, the number of measurement sites is limited and depend on the extent and the complexity of the respective accumulation area. Typically, 3 – 5 measuring points are suggested. These points with depth and density measurements are complemented by spatially extensive depth information from probing. Successful probing depends on a reference layer of clearly greater density (usually the previous summer surface), which can be identified. If no reference layer can be found when probing, which is rather probable under low latitude climates (see chapter 7.2), the number of measuring points must be increased.

The location of accumulation measurements must represent a possibly large surrounding area. To a certain extent, the field experience of the investigator can help to find most representative sites.

7.2. The identification of previous year layers

Net accumulation is, as the net ablation too, determined in respect to a previous surface position. Whereas this can be easily determined in the ablation zone because of the ice surface, any natural or artificial marking in the accumulation zone made at t_1 will be buried by snow by t_2. Under mid-latitude conditions, a well definable layer usually develops at the end of the ablation season. This is because the surface had experienced melting, collected dust during the ablation season, and re-froze before the arrival of winter snow. This reference layer is characteristically dusty and hard. Thus, all snow superimposed on this hard dusty layer is considered to be new accumulation.

Under low latitude conditions measurements of net accumulation are more complicated. Neither in the monsoon type regime (Ageta and Fujita, 1996), where accumulation appears during the warm season, nor in tropical regimes, where melting occurs all the year round, does a hard dusty layer develop. Sometimes a dust layer will be found on low latitude glaciers, but they are seldom regularly developed and are often linked to individual events such as storms rather than to the end of the ablation season. In this case, artificial markers are needed. Dust or soot are not suitable because it will tend to wash out and will alter the surface energy balance leading to increased local ablation.

Accumulation stakes can be installed with a piece of tape marking the level of the surface prior to the accumulation season. These stakes have to be quite stable since they have to erect substantially for not being buried entirely by subsequent snow. Markers fixed on stakes and buried by the accumulated snow can only be found by digging a snow pit. Still, the pit can also be used for the necessary density measurements.

In the accumulation area it will be very important to establish the net addition of mass. Sometimes the previous years surface may be difficult or impossible to distinguish. In such cases we recommend to sprinkle saw dust, preferably dyed dark with a water insoluble dye. Saw dust is very useful since it is lightweight when dry but becomes more immobile on a snow surface since it soaks up water and becomes heavier. Dusting should be made so that the surface is not completely covered with sawdust but is neither so lightly dusted so that identification of the dust in a snow pit may be impossible. When digging a snow pit at the stake the following year, the sawdust can be distinguished and the previous surface positively identified. It is also possible to cycle through a series of colours so that deep pits can verify several years of accumulation. This is however not necessary for the standard mass balance programme.

If sawdust is sprinkled around a stake it is advisable to spread dust over a relatively large area and make notes on the size of the area. This becomes useful if the stake is lost during the year, e.g. snowed over. The likelihood of hitting the dust when digging in the assumed area of the lost stake is higher the larger the area that is sprinkled with saw dust.

7.3. Internal accumulation

On the glaciers of the rather cold and dry regions on the continental sides of the Himalayans a major problem may appear from **internal accumulation** when melt water penetrates into cold subsurface layers and refreezes. This mass redistribution appears to be lost from the glacier. Internal accumulation can only be measured by penetrating abundantly deep into the firn body.

7.4. Snow density

The best way to measure the density of a snow pack is by digging a snow pit and making careful measurements of the snow density down the pit wall. Coring may be easier and faster, but the action of coring compresses the snow somewhat leading to over estimating the actual snow density.

The **size of a snow pit** and its shape depends on the expected depth. The deepest point of the pit should be a square approximately 0.5 x 0.5 m to provide sufficient room for making density measurements. Also, for density measurements and stratigraphy observations, one continuous wall from the top to the bottom of the pit must be planned. This measuring-wall is oriented to avoid direct sunlight.

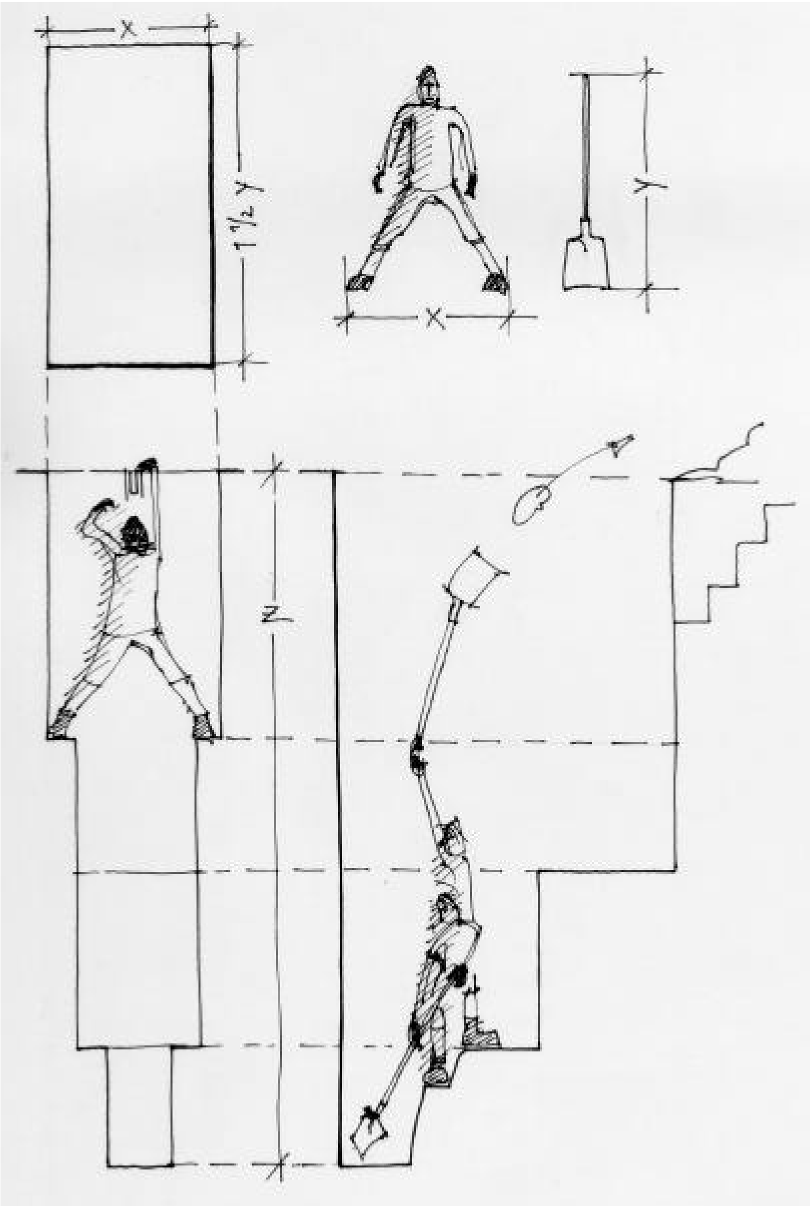


Figure 26: Shape and size of a 5 – 6 m deep snow pit.

Each experienced investigator has their own technique and philosophy for planning a pit dig to achieve the proper depth, size, and measuring wall. Figure 26 is one such suggestion. Note that measures are not in usual length units but in relation to the human body and, to some extent, related to the length of the shovel. It is generally advised that all walls should be kept perpendicular while digging and all angles as right angles. This is the most effective way to reach the required depth with a minimum of volume to be removed. A well made six meters deep pit is shown in Figure 27.

Figure 27: A 6 m deep snow pit.

The **snow density**, ρ_*, is determined by measuring the weight (mass), m_*, of a snow sample of sample volume, V_*.

$$\rho_* = m_* / V_* \quad (8)$$

For this purpose, tubes with a volume capacity of 500 cm^3 (usually with a length of 20 cm with the respective diameter) are very practical. They can easily be made from stainless metal. Note, however, that the sharp side must not affect the sampling of the volume (figure 28). Since the aim in context of mass balance investigations is not primarily the variation of density with depth but the determination of the water column stored in the accumulated snow pack, samples must not be taken horizontally but as vertical cores each one beneath the other (figure 29). If dear changes in snow properties are met, which indicate a certain event or change in the accumulation processes, this can be considered by accordingly separating the density measurements. Necessary tools and their use are shown in figure 30.

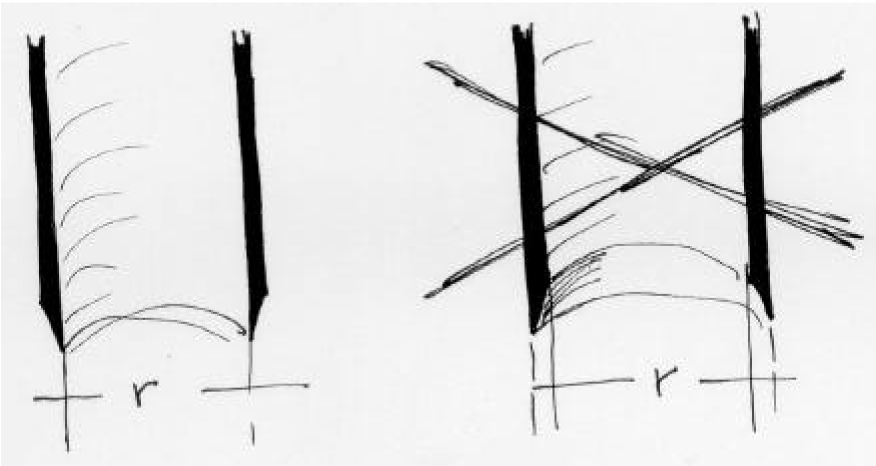


Figure 28: The sharp edge of a density tube must not affect the sample.

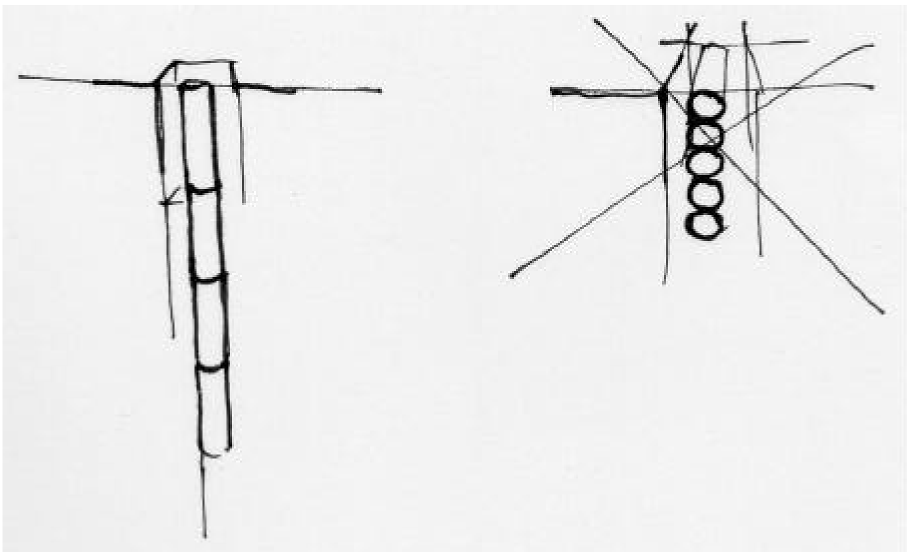
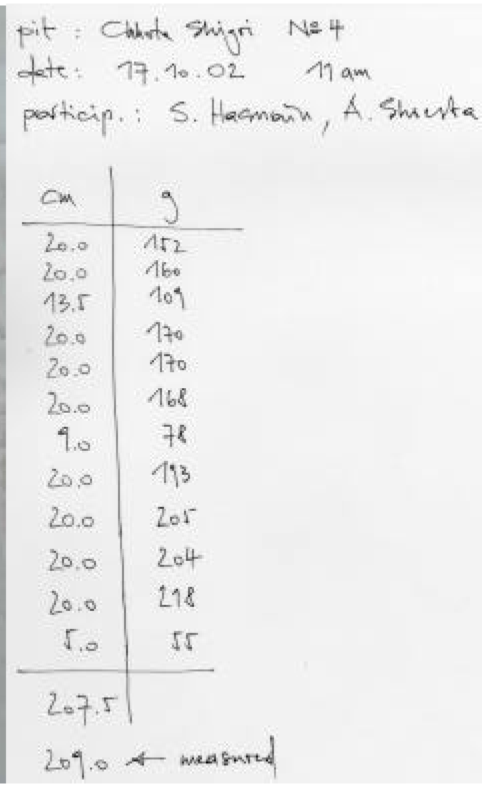


Figure 29: For mass balance purposes sampling is better made vertically.

Each measurement is recorded in a field book filing up the lengths of the samples in one column, the density in the next column, the length-weighted mass in the third. For a final check the sum of taken sample lengths is compared with the separately measured total depth of the pit from the surface to the reference layer. An example of a field book note is shown in figure 31.

In many cases, a stratigraphic description of the snow layers can be very helpful when analysing the data and when comparing the results from different snow pits. This has not to be as sophisticated as for avalanche studies, but should consider major changes in the snow pack (change from crystals to grains, dust layers, descriptive free water content, ice layers etc.), which can be related to certain weather conditions throughout the accumulation season.



pit : Chhota Shigri № 4
date : 17.10.02 11 am
particip. :

cm	g
20.0	152
20.0	160
13.5	109
20.0	170
20.0	170
20.0	168
9.0	78
20.0	193
20.0	205
20.0	204
20.0	218
5.0	55
207.5	

209.0 ← measured

Figure 30: Tools for measuring snow density

Figure 31: Field book notes on snow density measurements

8. The locating of the measuring points.

The position of the measuring points must be known. In mass balance analysis, a best guess estimate of the location of the points on a good map may be sufficiently accurate to obtain a reasonable mass balance. This caused by the extrapolation from points to surface area values, and as long as the point is within the area it represents, then the exact position is not required. Importantly, the input data must be more accurate than the method of analysis by an order of magnitude to obtain the best results possible. In many cases, at least the ablation stakes are located each year geodetically, which provides data for analysing the ice velocity (see chapter 11.3).

The snow pits are usually dug relative to topographic features on the glacier, which are rather constant over long periods. Thus, their position is relatively easy to determine from a map and rather constant in time. In this respect, useful hints are given in chapter 6.2.

9. Analysing the field data

Once the point measurements are determined for a comparable time period and their position is known, the data can be located on a topographic map. Further analysis is conducted by creating lines of constant mass balance and summing the areas of equal mass balance.

Alternatively, the mass balance versus elevation can be plotted and a regression curve can be calculated. In particularly variable mass balance data, the curve might have to be fit by hand. The mass balance curve is multiplied by the area-elevation curve and summed over altitude intervals to produce the total mass change of the glacier.

9.1. Maps

The basic tool for carrying out mass balance analysis is the availability of an accurate map on which measured point data are entered, lines of equal mass balance are created, and, finally, mass balance volumes are calculated for different altitude intervals. The area of the glacier and the distribution of the area with altitude must be known with some degree of certainty. For the glaciers sizes discussed above, map scales between 1:25,000 and 1:10,000 are suitable. The map must be remade from time to time when the glacier changes its surface area. In many cases the mapping of the portions of the glacier (e.g. terminus position, rock islands) with traditional geodetic or modern GPS (geo positioning system) methods is sufficient. If the glacier changes its surface geometry to a considerable extent a new map must be produced. For long term monitoring, glacier programs have found it beneficial to have a net of geodetically fixed points. The surface of the glacier can be surveyed from these locations. With availability of GPS equipment these fixed locations can be tied into the global network of elevations.

9.2. Contour method

This procedure is well known from other fields where spatial values have to be derived from scattered point values. The first important step is already made when the points for accumulation and ablation measurements are chosen in the field. In our recommendations we suggest an even spacing in elevation covering the whole altitude interval of the glacier. Once the values of mass balance and their position on the glacier are known, they are incorporated into the topographic map of the glacier. The lines of equal specific net mass balance are interpolated from the point data. Since we are supposed to calculate the mass balance in discrete interval and we may have 10-16 stakes along a longitudinal profile on the glacier, we may as well choose to calculate the mass balance in 10-15 contour intervals. This means that the contour intervals may be 10, 20, 25, 50, 100 or some other even interval so that we have at least one stake in each interval. There is absolutely no use to have a denser contour interval than the number of stakes allow. Contour intervals with no stakes will simply contain interpolated data from neighboring intervals and, hence not contribute new information to the mass balance calculation. We therefore suggest to make sure you chose a contour interval that ensures at least 1 stake in any interval. To a large extent, the drawing an isoline map of mass balance depends on the practical experience and knowledge of the field site. Additional information, such as the extent of bare ice, or avalanche deposits is of great help. Subjective differences by individual investigators can be substantial. However, a comparison of maps made by different mass balance investigators were quite similar yielding confidence to the procedure (Kaser and others, 1995). For a team of investigators such as those in the different institutions carrying out the mass balance measurements in the HKH-FRIEND region it is suggested that several members should make the interpolations independently. Open and unbiased discussion of differences in opinion between independent evaluations made by members can be a very productive way of gaining appreciation of the glacier and its peculiarities in terms of mass balance distribution. At least in the beginning, this can help achieve the best result and develop a common approach.

Once the contours of equal mass balance are drawn **areas of equal specific net mass balance** are determined (fig. 32). By multiplying each surface area with the corresponding value of specific mass balance, the mass change is obtained. All the areas are summed to determine the total mass balance.

In practice, the position of the contour lines of equal mass balance is chosen on basis of the location of measured values, which might differ from year to year. Also the contour interval may change as well for similar reasons. Changing the contour interval can change the result to some degree. When the pattern of mass balance pattern is complex or when extreme gradients occur, it might be more suitable to assign values of mean mass balances directly to respective areas rather than via the contours.

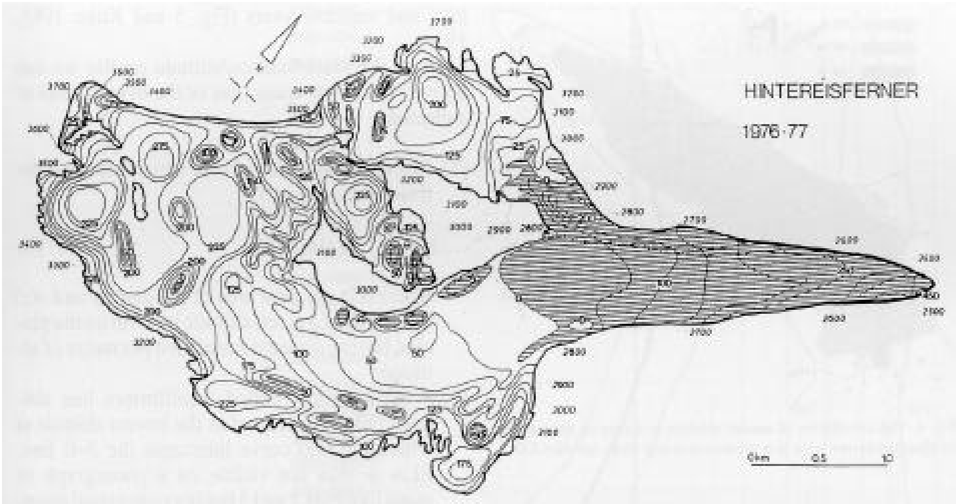


Figure 32: Analysis of specific mass balance, Hintereisferner, Austrian Alps (Kuhn and others, 1999)

9.3. Digital methods

Geographical Information Systems (GIS) can also be used for deriving spatial information from point values. Tests showed that the outcome was poor in comparison with hand-drawn results (figure 33). This is in part due to the paucity of data and uncertainty in digital routines to handle open boundaries. In addition, the human has intuitive knowledge of the glacier that is expressed in the contouring.

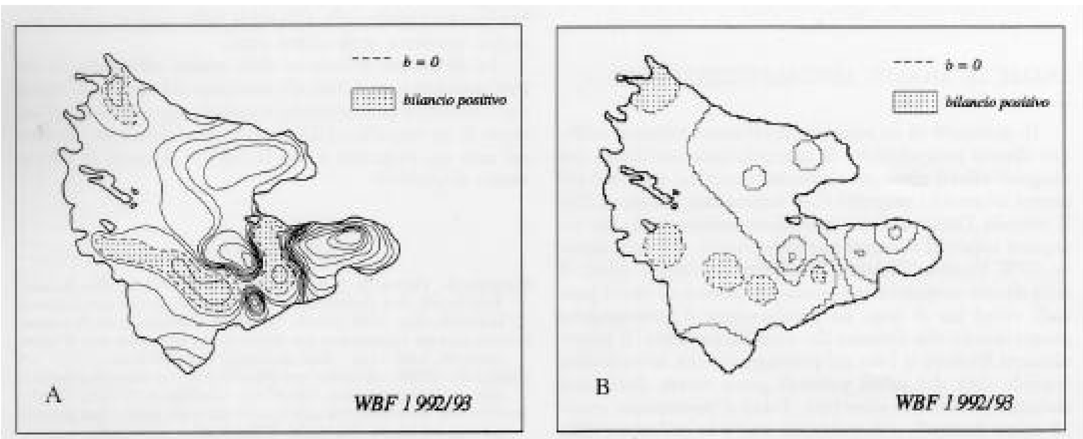


Figure 33: Analogous (left) and automated mass balance analysis, Weissbrunnferner, Italian Alps (Kaser and others, 1995)

A best combination might be to draw the contour lines of equal mass balances by hand, but after digitising them, to make use of GIS for the further analysis and calculations to reach the aimed glaciological key values.

We do not recommend the use of GIS software in calculating mass balance.

10. Data presentation and reporting

10.1 Reporting data

Mass balance data is of little value unless it is made available to the scientific community. Contributing data to the community also ensures free access and exchange of other data. There are several ways to accomplish this. In the past written reports have been the norm but today mass balance data alone is difficult to publish in scientific journals with wide spread distribution. Reports published in smaller numbers by individual institutes have the disadvantage that they are not circulated widely. Emerging as probably the best means to make available mass balance data in the Internet. However, before making recommendations, we should scrutinize these ways in more detail. Although the Internet makes data available on a global scale web sites are easily removed and hence lost from the view of the international community. Web pages can therefore not be the only means of storing and displaying data. Internal reports, whether actually printed or simply xeroxed, should therefore accompany any display of data on the Internet. If at all possible, one good solution to spread the written report would be to prepare it as a PDF (Portable Document Format) file and posted on the web site.

How then should data be reported? There are obvious results that should be displayed. Most important is of course the mass balance value itself, but perhaps of equal importance is the mass balance gradient, the elevation dependent mass balance. These values should be reported both as volumes (m^3 water) and specific values (m water equivalent). In addition to these basic numbers, a map of the glacier with stake locations and preferably mass balance values at the individual stakes should be given. This information becomes invaluable as documentation when comparing results from different years.

Apart from the results of the measurements, any report should also contain a brief description of the mass balance work itself and the persons involved in the work. Knowledge of who did what during a specific mass balance season makes it much easier to check on older data. The mass balance year should also be described briefly. Information such as monthly averages of temperature and precipitation, if available from nearby stations, should be given in table form. It is also of much value to include general descriptions of conditions from the mass balance year such as frequency of snowfall, perspective of the meteorological year (i.e. whether the year has been average or extreme in any way).

For each glacier, there should be a brief description of its climatic setting and physical data such as elevation span, area, etc.

The report can be made according to a predetermined format so that updating can be done with ease by simply entering new data and updating the descriptions specific for the new mass balance year.

In addition to the annual mass balance map (fig. 32), maps of seasonal balances, if measured, should also be made. A graph of the altitudinal distribution of the specific mass balance (VBP) and of surface area as well as the values of the individual measuring points in each year (season) should be included as well (fig. 34). Finally, several tables should be constructed, including the data set used to make the maps, a table of mass balance with altitude, and one with final values of seasonal and net yearly mass balance values.

10.2 Data depositories

The data should also be reported to the international centre for glacier data: the **World Glacier Monitoring Service (WGMS).** It started in 1986 to maintain and continue the collection of information on ongoing glacier changes. This effort is the result of combining two former International Commission on Snow and Ice (ICSI) services, the Permanent Service on Fluctuations of Glaciers (PSFG) and Temporal Technical Secretary / World Glacier Inventory (TTS / WGI). As a contribution to the Global Environment Monitoring System (GEMS / GTOS) of the United Nations Environment Program (UNEP) and to the International Hydrological Program (IHP) of the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the WGMS of the International Commission on Snow and Ice (ICSI / IAHS) and the Federation of Astronomical and Geophysical Data Analysis Services (FAGS / ICSU) today collects and publishes worldwide standardized glacier data.

Among different investigators and investigating agencies there exist slightly different manners of presentation of the resulting mass balance data. This depends, to a certain extent, on the purposes aimed. The structure of data submission requested by the **World Glacier Monitoring Service (WGMS)** (http://www.geo.unizh.ch/wgms/) is a starting point and forms are provided as appendices I – VI. For the HKH glaciers, the requested seasonal mass balance data (mid latitude "winter" and "summer" bias) must be treated differently from the WGMS forms.

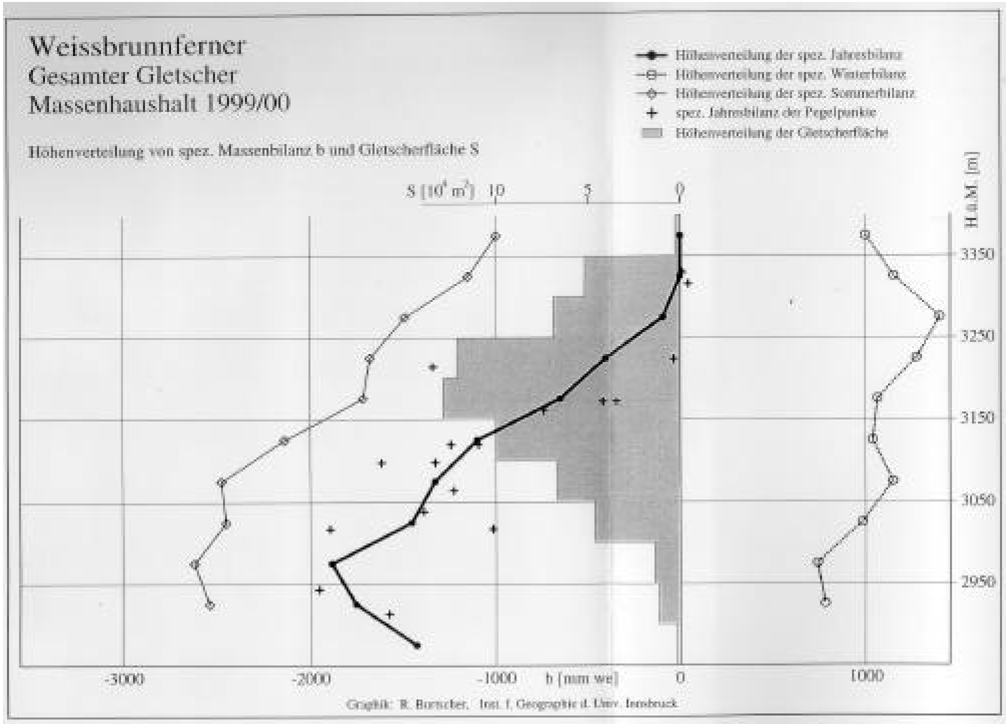


Figure 34: Seasonal (thin lines) and annual (bold line) profiles of specific mass balance, area altitude distribution (shaded area) and values of annual mass balance measurements at selected points (crosses). Weissbrunnferner, Italian Alps.

IV. A BRIEF OVERVIEW OF POSSIBLE ADDITIONAL MEASUREMENTS

The extrapolation of the knowledge gained on benchmark glaciers is one of the most important issues of a mass balance network. For this, the availability of additional information is of great use. Thus, if logistics and budgets allow, such measurements should be carried out.

11. Geodetic measurements

11.1. Changes in surface area

The geodetic determination of the glacier topography is not only fundamental for mass balance analysis and for the calculation of the mean specific mass balance, $\bar{b}$, but provides a basis for an independent check on the glaciological method as outlined in 3.1. In addition, frequent determination of the surface area documents changes of the horizontal extent of the glacier helping to understand the response time of glacier length to changes in mass balance. This information is valuable for interpreting past glacial changes derived from old maps, photographs, and moraines.

11.2. Terminus variations

In many mountain areas of the world terminus variations provide the most frequent and longest glaciological data series. These series are often enlarged by information reconstructed from moraines. Even though the fluctuation of a glacier terminus is a complex response between climate change and glacier dynamics, the long-term average provides a good index for the climate trend in this area. If the terminus area is accessible, the distance of the ice from a defined point (rock) in the fore-field is easy to measure.

11.3. The ice velocity

If geodetic instruments are available, the stakes can be used for measurements of the surface velocity. The number of stakes may not satisfy the requirements of an investigation on ice dynamics but it will give a good indication of its dynamic response to changes in mass balance. The measuring of the bottom instead of the top of the emerging part of the stake is more precise. Both traditional theodolites and laser ranging as well as differential Global Positioning System (GPS) instruments are suitable. The repositioning of the stakes is easier with the old systems and, if a good fixed point net is available, they are also faster than comparably precise GPS measurements. In remote and largely extended areas, however, GPS instruments may be the best to use.

11.4 Land-based photography

Establishing well-defined points (maybe even fixed points) for repeated photo-documentation of the glacier can be of vast importance for future generations. In many parts of the world early explorers used cameras to document their explorations. Such photographs now have tremendous value to establish long-term changes in glacier extent. Photo-documentation should therefore be an integral part in any field program

Digital cameras have become increasingly popular and provide very quick ways of documenting ongoing work. As such they are very useful. However, for long-term storage of photo-documentation, digital cameras are a menace since a digital image can easily be destroyed by the touch of a button. Black and white traditional photography is currently the most stable form of photo-documentation. We strongly recommend that you augment your field measurements by documentation in black and white regular film. However, it is important that care is used when developing film etc. so that it becomes free from chemicals that deteriorate the film with time (such as fixer salts etc.). Films should also be catalogued and stored with care to ensure long-life. Preferably paper copies should be made. This kind of photo-documentation does not have to comprise hundreds of photos per year but maybe 5-10 pictures from carefully selected locations showing different parts of the glacier. Obviously the terminus area and the lower part of the ablation area is where changes may be most dramatic and hence more effort should be spent in these areas. It is not necessary to make the documentation every year since year-to-year changes may be small. It is also useful to make sure that the camera views are the same from any one point so that comparisons between years can be made with ease.

12. Geophysical measurements

(Radar measurements to determine the bedrock topography)

For investigations related to the dynamics of a glacier, the knowledge of the bedrock topography is essential. It is also necessary for the determination of the entire ice volume stored in a glacier. The bedrock topography is obtained by the application of lightweight radar instruments, which are adapted for glacier measurements. The measurements are only made once, thus the acquisition of such an instrument is not advisable if measurements can be carried out within a cooperation program with institutions or scientists, which can supply field radar instruments. This is also advised since well trained staff is necessary to carry out the measurements but also for the data analysis. Fieldwork can be limited to selected cross sections if only the application of the flux divergence method to obtain mass fluxes through these cross sections is aimed.

13. Climate and hydrological records

As stated before, the mass balance of a glacier is the immediate result of climate and is, in turn, a crucial component of the hydrology. To understand and model these processes the recording of climatological and hydrological variables are important. Here, only the most common parameters are presented. In addition to contributing to a knowledge of glacial processes, stations in mountainous environments are relatively rare and new stations would make a contribution to our knowledge of climatic processes in these regions.

Climate measurements can either be taken directly on the glacier or somewhere in the surrounding such as on a moraine ridge or in the fore field of the glacier. Beside logistic considerations and accessibility, the location of weather stations must be well thought out from the scientific point of view. Stations on the glacier are important for detailed studies of the interaction between glacier surface and the atmospheric boundary layer. These stations and their instruments have to be maintained continuously because of either snow accumulation or ice melting disrupts the station. For the parameterisation of the local glacier climate, stations outside the influence of the glacier wind are recommended. The glacier wind cools the summer air reducing its variability and extrapolations to the climate outside of the glacier are more difficult. Stations near the glacier, but not within the influence of the wind, better represent the atmosphere, which influences the glacier. Ideally, they are positioned on a well ventilated moraine or rock ridge close to the present time mean equilibrium line altitude (ELA) of a glacier.

The parameter which is most correlated with ablation is **air temperature**. It has an impact on the sensible heat flux from and to the glacier surfaces, the incoming long wave radiation, and, to a certain extent, to the origin of clouds, which protect the glacier from the solar radiation. In turn, the air temperature, which is measured 2 m above the ground according to standard convention, depends among others from the incident short wave radiation absorbed. Even the latent heat flux, which too controls the surface temperature of the ground, is slightly represented by the air temperature. Still, although air temperature is the most common variable measured, it must be treat with particular care. Good air temperature data can only be obtained if the thermometer is well ventilated which needs a reliable energy supply. This is particularly problematic above highly reflecting surfaces such as snow covers. Unventilated temperatures may represent the heat budget of the surrounding ground better than the air temperature, but they cannot at all be defined and they are not comparable to other temperature measurements.

Air humidity is usually measured as a value relative to saturation. Absolute values can then be derived with the help of the air temperature. Note that sensors measuring the relative humidity have to be ventilated too. The absolute air humidity is, together with the turbulent exchange of air masses, represented by the wind speed, the crucial variable driving the latent heat flux. This, in turn, is mostly neglected for mid latitude glaciers but plays a crucial role on glaciers of low latitude dry environments. This is obvious when looking at the energy used for sublimation is eight times higher than for melting. Changes in air humidity can have a great impact on the fluctuations of meltwater production.

The **wind speed** controls the intensity and efficiency of the turbulent energy fluxes. The **wind direction** allows further interpretation of regional and local air movements. Wind measurements also indicate the displacement of snow due to drift.

The **incident short wave radiation** is a measure of the short-wave (mostly visible) energy flux from the sun. Incoming short wave radiation measurements taken at one point can then be calculated for any point of the glacier with the help of terrain models. Beside cloudiness, the ability of the surface to reflect the short wave (**albedo**) is crucial for estimating the magnitude of solar energy absorbing into the surface. Although albedo measurements at a point are relatively easy to record, spatially distributed measurements are impractical. An automatic camera, which takes an image of the glacier each day, can be of great help. Approximate albedo values can then be assigned to certain surface characteristics shown on the images. Besides, such regularly taken images provide information about position of the **snow line** on a glacier. This can be useful information for the mass balance analysis. In many cases, the position recommended for a weather station near the equilibrium line provides a good view to wide portions of the glacier.

Precipitation is the key variable for accumulation. It is highly heterogeneous in space and rather difficult to measure. Knowing these problems and after a calibration of precipitation and accumulation values, collecting gauges are of considerable use in remote high mountain areas. Best experiences are made with simple collectors of shape and size as indicated in figure 35. The altitude of the collector must be adapted to the expected precipitation amounts in order that the water not reaches the conic part. These collectors can be made cheaply. On glaciers, the distribution of solid precipitation with altitude is of particular interest. Thus, a chain of several well distributed collectors is recommended. The World Meteorological Organization has published studies and recommendations for precipitation measurement in mountainous terrain.

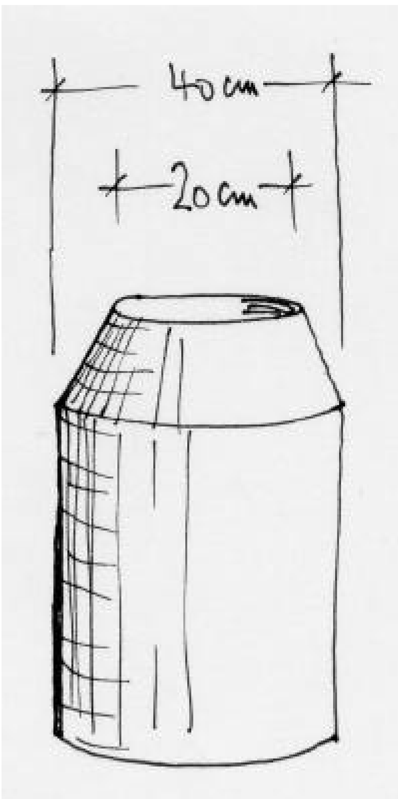


Figure 35: practical shape and size for a high mountain precipitation gauge.

The **runoff** from a glacier is not only its contribution to the regional water supply but it is also the integrated and smoothed result of melting processes which take place on a glacier. Runoff measurements can be used with the meteorological and glaciological measurements to develop and test runoff models in high alpine areas. From this effects of global climate change can be inferred for the high altitude streams.

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Safety – Rescue – High Altitude

Chhota Shigri, October 2002

V. HOW TO BEHAVE ON A GLACIER

Extracted from: **"Glaciers & Ridges"**
Authors: Florian PIPER and Michael LARCHER
Proof-reader: Jo LIGHT
Drawings: Angelika ZAK
Editor: Michael LARCHER

With the permission of the owner and publisher:
Österreichischer Alpenverein
Wilhelm Greil Straße 15
6020 Innsbruck
AUSTRIA
michael.larcher@alpenverein.at

14. Skill

No matter on which level of experience you are, whether a good climber or a good hill walker, one aspect in mountaineering is vitally important: before you plan a trip to the mountains you should constantly ask yourself the question about your personal skill and you should be honest with yourself to avoid any kind of complications during your trip. Find out more about your own abilities, responsibilities, your personal strengths and weaknesses and decide what is good for you and what is not!

- Are you *physically prepared* to tackle a certain tour safely with respect of your physical fitness? You don´t need to be an athlete to go on a mountain trip but you have to be involved in previous training, especially in endurance activities, or stamina training.

- Are you *technically prepared* to cope with glaciers, ridges and ice faces and to be able to meet the right decision at any given moment? If you think you can´t cope, seek for expert advice from mountain guides and decide for a guided tour. Moreover you have to be technically prepared in terms of additional and appropriate equipment (spare clothing, food, first aid kit etc.).

- Are you *mentally prepared* to deal with an emergency situation, for example having your first aid knowledge permanently at the back of your mind? Are your objectives clear and distinct (goal setting?)?

- Are you *morally prepared* to put safety first and your inner motivation secondl ? For example, safety in terms of a retreat from a climb when bad weather approaches and inner motivation in terms of your ambition to reach the summit at any price = conflict.

15. Equipment

Appropriate clothing, footwear, technical equipment and additional items are the most vital components for the mountain sport.

Clothing

In mountaineering the body evaporates moisture, causing a reduction in temperature. If the strength of the wind is increasing the rate of evaporation and the cooling effect rise. The same effect occurs with damp or wet unappropriate clothing and you are at risk to reduce the body temperature to a point where it becomes a health or even a life threatening problem. Thus, clothing should be windproof, waterproof, insulating and 'breathable' material to allow protection from the cold and the passage of water vapour but not liquid water. The best method is to wear multi-layers of clothing, which can be taken off or put on as circumstances require. Inner clothing, say fleece materials provide insulation and conduct water vapour to the waterproof and breathable outer shell. A further advantage of fleece materials is the short period of time they need to dry.

Boots

Walking boots cover a wide spectrum of products: climbing footwear, specialized Trekking boots and those for winter use. Alpine terrain and winter mountaineering require stiff boots with fairly rigid soles and edges. The Vibram sole is suitable for wet rock, muddy ground and glacier walking . The boot should be high enough to provide a degree of ankle support. Two types of boots are recommended:

- the traditional *leather mountaineering boot*: stiff boot with a deep welt for crampon use! These boots require basic maintenance to prolong their life (eg. oil treatment). It is necessary to clean them after use and dry them in a moderately warm room without heating. The maintenance procedure is probably the main disadvantage of this product. Leather boots require adjustable crampons fitted with straps.

- the modern *plastic mountaineering boot*: stiff boot, nearly waterproof, light in weight and comfortable to wear. The inner boot is removable and dried separately. Plastic boots require step-in crampons with one strap around the ankle used as a safety binding only. This model is probably the best choice, because of ist perfect foothold on ice.

Equipment list

Clothing, boots and other items

- Trousers, overtrousers, underclothes, shirts, sweater, socks, anorak (don´t forget spare clothing!)
- Hat, balaclava, gloves, overmitts, gaiters, light scarf
- Leather or plastic boots for crampon use
- Pair of trainers

- Day pack rucksack (30-40 l)
- Goggles or sunglasses
- Thermos flask with mug, 1 l bottle with screw cap, day rations
- Sunscreen lip salve, suncream (sun blocker)
- Toilet requisites

Equipment for mountain navigation and emergency

- Map, guide book, compass, altimeter, watch
- Whistle and/or flares for distress signal, head torch
- First aid kit in waterproof bag, thin emergency cover with aluminium layer
- 2-man bivi or survival bag (breathable membrane) or large polythene bag
- In general: mobile phone, radio for communication and GPS are certainly useful materials in case of a casualty to get quickly in contact with rescue services. These items are not compulsory equipment and the application of phones and radios rely on the given circumstances in a foreign country,e.g. check official requirements for the use of radios!

Technical equipment for glaciers, ridges and ice faces

All of you need the following items:

- 1 × ice axe (70 cm shaft, alloy material), 1 × short ice axe.
- 3× accessory cords: 1×1.5 m, 1× 3 m, 1× 5 m (Ø 6 mm)
- 1× figure-of-eight descender
- 2× gate karabiners
- 1× pear-shaped screw-gate karabiner (‘HMS’ karabiner)
- 1× screw-gate karabiner
- 1× ice screw (tubular shaft, 17 cm)
- 1× tape sling (sewn-slings, 240 cm)
- 1× helmet (UIAA or CE tested!)
- 1× pair of appropriate crampons
- 1× combination: either chest and sit harness, chest and waist harness or full body harness. The chest and waist harness is the recommended combination!

Select:

- For the tie in point of chest and waist harness combination: either 1× open tape sling (120 cm)or 1× accessory cord (120 cm, Ø 6mm) combined with 1× open tape sling (from express sling/quick-draws)
- For the tie in point of chest and sit harness combination: 1× accessory cord (120 cm, Ø 6mm)
- For the tie in point of the full body harness: 1 × accessory cord (100 cm, Ø 6 mm)

The leader needs additional items:

- 1× single rope or 2 × half ropes (50 m)
- 1× tape sling (sewn-slings, 240 cm)
- 2× tape slings (sewn-slings, 120 cm)

- 2× accessory cords (5m)
- 2× screw - gate karabiners
- 2× gate karabiners
- 3× express slings with 2 gate karabiners each
- 3× ice screws (tubular shaft, 17 cm)
- a <u>critical</u> selection of mobile rock belays, which depends on the grade of rock climb you plan to do: chockstones (rocks, nuts) with wire, tape or rope slings attached; 1× nut key (extractor); hexentrics on tape or rope; friends and friend extractor; pitons, 1× peg hammer

16. Movement techniques

This chapter will introduce you to the different application of techniques on moderately steep snow/firn slopes and techniques on moderately hard and steep snow and ice slopes. Furthermore the trainee will acquire skill in cramponwork, the use of an ice axe, self-rescue and the general movement techniques. The topic of this chapter is logically structured into progressive steps from easier techniques without the use of crampons to more demanding techniques on steep ice slopes with the use of crampons.

16.1. Use of ice axe

Carrying the axe

When the axe is not needed you are advised to carry it with appropriate protection (plastic cover for spike, pick and adze) on the outside of your rucksack in the loops provided. On slopes where the ice axe is required, the tool should be carried with the pick pointing backwards and the adze facing forewards. This is the best position from which to move directly into the self-arrest position without further adjustment. Make sure that you insert your hand through the wrist loop and over the head of the shaft to be fully prepared for a slip. With the wrist loop tightened, the axe will not be lost if dropped.

When ascending, descending or traversing on moderately steep snow slopes you should use the ice axe on the uphill side for support. Just imagine using the axe as a third leg and you will quickly adopt the right sequence of movement: plant the axe one arm length from your body in the snow and then step towards it, so that always two points are in contact with the snow surface.

For techniques on steep snow and ice the axe is used for extra security and as a climbing aid. Steep ice techniques in terms of vertical ice climbing normally require two short ice tools, one in each hand, which are hooked into the ice above the mountaineer´s head (anchor technique). Other techniques such as the dagger technique are described later in this chapter.

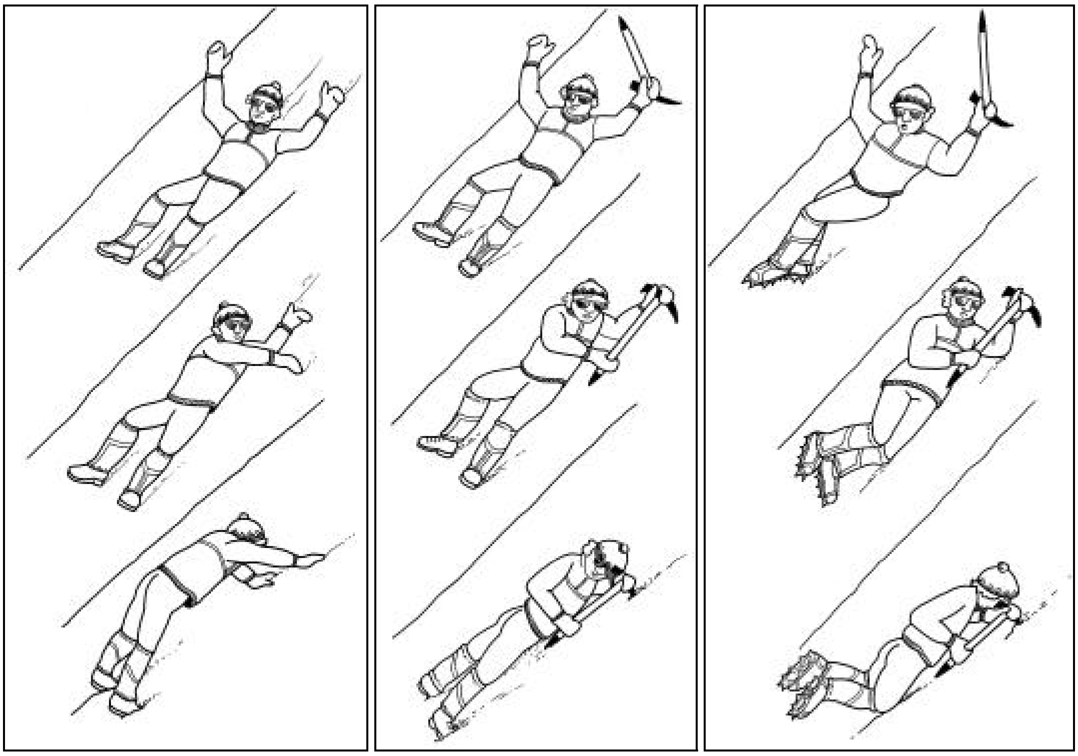
16.2. Self - rescue techniques

Press-up technique

If you fall on a slope certain methods of stopping must be quickly adopted. The press-up technique is reasonably successful when you slip on a slope and you want to bring your fall to a halt without the use of the ice axe and crampons. In the event of a slip all you do is try to get into a sliding position with your back on the slope. Then try to turn your upper body and your hip towards the slope to adopt the face down position. Finally, all your extremities should be spread out to maintain your body weight on your toes (front pointing in the snow)and your hands. The final braking position is perfectly achieved when you lift up your body from the slope on your hands and toes.

All self-arrest exercises require the following safety measures:

- at first : train on the lower part of a concave slope with a long run out in the event a fall can not be stopped.
- the practice progresses with steeper slopes and faster slides attempted.
- make sure the slope is free of protruding rocks.
- never train with rucksack or crampons on, because of the risk of injury.
- never attach the ice axe to your body (remove the wrist loop from your hand), because of the risk of losing control over it during the fall, which could cause fatal injuries.
- always wear full waterproofs, gloves and (a helmet).
- be aware that you are carrying a dangerous tool and that adze, pick and spike can cause puncture injuries.



Left:
Press-up technique after a slip without using the ice axe and crampons: a) sliding on the back, feet first
b) turn your upper body and your hip towards the slope c) the final braking position: put your weight on toes and hands and lift your body from the slope

Middle:
Ice axe braking without crampons: In reality a slip comes suddenly and you may fall as demonstrated in the illustration.

a) sliding on the back, feet first with the axe in one hand
b) turn your upper body and your hip towards the slope and the ice axe. Grab the ferrule of the ice axe with your free hand and plant the pick into the snow

c) the final braking position: put your weight on your toes and press hard against the ice axe shaft until you come to a halt.

Right:
In reality ice axe braking with crampons should be done as follows :
a) sliding on the back, feet first with the axe in one hand and crampons on.
b) turn your upper body towards the slope and the ice axe. Grab the ferrule of the ice axe with your free hand and plant the pick into the snow.
c) the final braking position: put your weight on your knees and press hard against the ice axe shaft until you come to a halt.

Ice Axe Braking

The technique of ice axe braking or self-arrest plays an important role in the course programme even if you won´t have the opportunity to practice all of them. But it is an essential skill, which has to be adopted by the novice mountaineer. Those who have already acquired this skill may think about their technique and evaluate whether there is room for improvement or not.

a) without crampons:

Instruction guideline for practising on a training slope.

- Grab the head of the ice axe with your left hand with the pick pointing backwards.
- Grab the ferrule with your right hand covering the spike for safety reasons.
- The ice axe should be held across the trunk whenever possible with the upper hand (right hand) on the head of the ice axe and the lower hand on the ferrule. In this position the pick is pointing towards your feet. The upper hand is at shoulder level (adze under the right shoulder) and the lower hand is at waist level.
- Before rolling over into the basic braking position: slide on your back with the axe held across the chest.
- From this position rotate towards the side on which you are holding the ice axe pick (towards the upper right hand). Don´t roll towards the lower left hand side, because you would be at risk of digging the spike into the snow first, which could result in loss or injury.
- Roll over to the side where the shaft´s head is held by moving the trunk first and the opposite leg second.
- Once you are facing the slope, sliding on your stomach, you plant the pick into the snow.
- In this position try to press hard against the axe shaft. Your legs and feet are apart. Try to put some body weight on your toes until you come to a halt; the full braking position.

b) with crampons

Attention: This exercise will only be practised without crampons!

Instruction guideline for practising on a training slope.

- The exercise is to control the downhill slide on the back pretending that crampons are being worn and adopt the final full braking position.
- The sequence of movements is exactly like in the previous example, except the position of your legs and feet!
- Your legs are apart and your feet as well, but when sliding on the stomach you raise the feet off the ground and put some body weight on your knees to achieve friction on the snow surface.
- When the full braking position is adopted your slide will finally be arrested.

Important: Raise your feet off the ground!

The progressive steps - 'digestible bits':

As you can see, all self-rescue techniques result in the final full braking position.
It is better to subdivide the self-arrest exercises into three simple progressive steps rather than discussing the different falling possibilities such as `head first, on the back`, `head first, on the stomach` or `the tumbling fall`. A slide is something unexpected and in the event of a fall you have to react immediately and instinctively and you won´t have time to think about techniques you learned in theory. Therefore keep the brief summary of self-arrest exercises in your head:

1. *Press-up technique*: braking without crampons and without axe using your feet and hands to adopt the arching position.

2. *On the back, feet first without crampons*: braking with axe instead of using the hands. Without crampons you have to use the feet like in 1. but without arching the back.

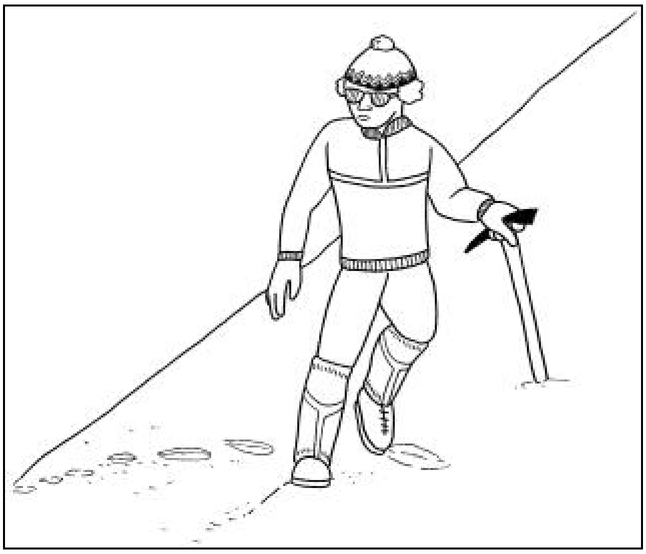
3. *On the back, feet first with crampons*: braking with axe and pretending to wear crampons. That means, pull up the feet to your bottom.

16.3. Techniques without crampons

The basic movement techniques without crampons on moderately steep snow and firn slopes require a good economy of effort, because you often have to step your way up through deep snow. Find the right rhythm of walking and approach the summit slowly by breathing regularly. *The ascent* could be either a straight up the fall line or the traversing diagonally in a series of zig-zags. Which technique you chose is up to you, but the zig-zag ascent seems to be the less tiring approach. It is therefore the recommended technique even if it takes longer.

The diagonal ascent

With your axe in the uphill side hand for support and balance you zig-zag your way up the slope trying to maintain a good foothold for your fellow climbers. Zig-zagging becomes easier and less tiring when the snow is harder and you can kick slices into the surface using the edge of the boot. The steps created with the side of your boot should be horizontal and as long as the boot and as wide as is required for safety.



Diagonal ascent on moderately steep snow and firn slopes - the method of kicking slices into the snow. The picture also shows the correct body posture with the hips slightly turned to the slope and the upper body above the feet - just like in skiing!

The direct ascent

With your axe for support you walk straight up the fall line using steps simply kicked into the snow with the front of your boot: try to save energy resources by kicking steps, which are not too far apart and it is useful to know that only swinging the lower leg from the knee is enough work to produce an adequate step. Trained calf muscles are required for this technique. Ascending in the fall line is recommended when the snow is too deep for the zig-zag ascent but especially when the slope angle steepens (short passage) to a degree where zig-zagging is uncomfortable.

The descent

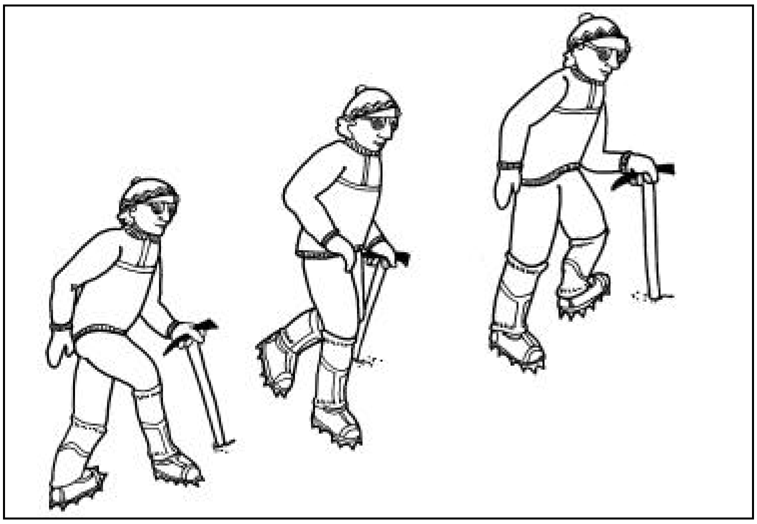
Sequence of descending on moderately steep snow and firn slopes is an easy undertaking by walking straight down with your weight on the heels sliding down from step to step. The movement is almost a vertical drop on to the heel and the front of the boot is kept in the air. Don´t forget to hold the axe in the right position as described before to be fully prepared for a slip. When the slope steepens and you are still walking without crampons it is good to know how to maintain the right body posture: Bend your knees but never lean backwards into the slope, because the centre of gravity has to be vertically over your feet. If you don´t adopt this walking position you will make a slip more probable!

16.4. Techniques with crampons

The basic movement techniques with crampons on moderately steep snow and firn slopes (icy slopes or hard snow with a maximum angle of 40%) are subdivided into the so-called Eckenstein technique for the ascent and the simple flat footing for the descent.

Eckenstein technique

Using the *Eckenstein technique* on hard snow and ice you zig-zag your way up the slope by placing the crampons onto the snow using all points, except of the front points. This zig-zag technique with full 10-point contact is (again) less tiring than using only the front points of your crampons when walking straight uphill.

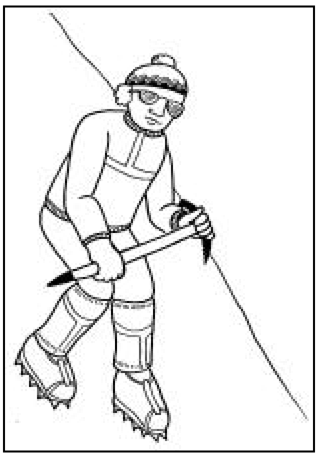


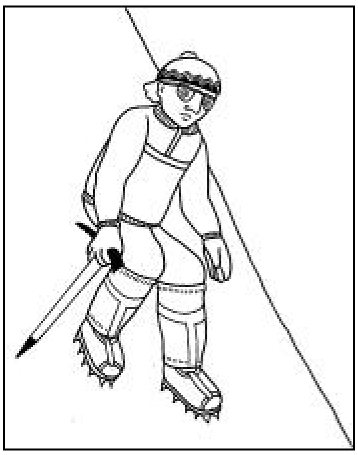
The Eckenstein technique: The axe is in the uphill side hand for support and balance. While your toes in the uphill side boot are pointing slightly upwards your toes in the downhill side boot are turning more downwards. In other words you spread your feet slightly apart (Charly Chaplin)and your hip is moving towards the slope, but you still keep the weight of your upper body over your feet to avoid a slip by maintaining the right centre of gravity. Try to adopt a body posture that seems to be very natural for you and avoid any uncomfortable movements in your joints.

Using the crampons means you have to be careful and to concentrate fully to avoid any risk of injury or damage caused by puncturing gaiters or even your calves with the front points. Thus you have to get into the habit walking more consciously by placing your feet deliberately apart from each other at a secure distance: moving with a wide gait is the right answer (John Wayne).

The descent: flat footing

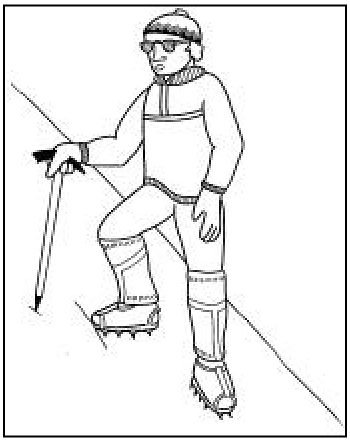
The right technique for the descent on moderately steep snow and ice slopes is the *flat footing*: you walk down the fall line with your back facing the slope and the axe is used for support and balance; all points of your crampons,except the front ones, bite into the snow. Keep your feet one shoulder width apart while your boots are kept in a parallel position. The most important thing to remember is the maintenance of the body posture: Don´t lean backwards into the slope but slightly bend your knees and keep the upper body over your feet.





The combined technique: Eckenstein and front pointing

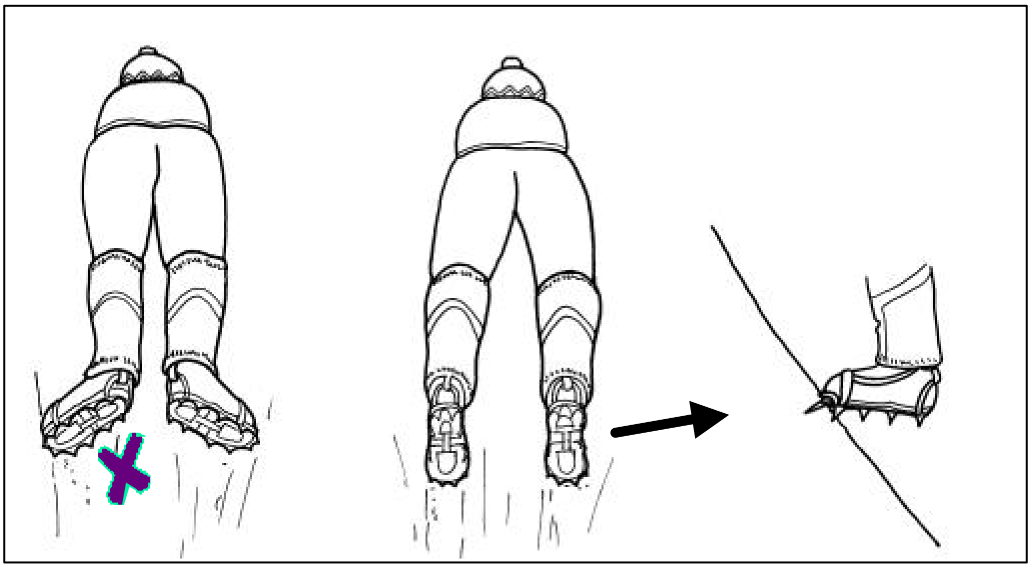
As the terrain grows steeper and you feel more and more uncomfortable using the Eckenstein technique only, it is necessary to combine both techniques, *Eckenstein and front pointing.* This combination allows you to crampon up a long and uniform slope without the feeling of exhaustion and fatigue in the calves.



When moving in a diagonal zig-zag ascent you place the lower boot with the toes pointing slightly downwards in a flat, 10 point contact position (Eckenstein) and the uphill side boot with its front points inserted in the right angle to the slope. The lower foot is in this case in a resting position.

Front pointing techniques

The next stage of basic movement techniques on steep snow and ice slopes is subdivided into the so-called anchor and dagger technique for the ascent and the front pointing technique for the descent. It doesn´t matter which of these techniques you apply but the *front pointing technique* has to be learned beforehand. This technique is physically more demanding, particularly in the lower leg muscles but it is certainly the most effective method on steep hard snow or ice.



Front pointing - your feet should be one shoulder width apart to ensure a reasonably secure standing position on hard snow and ice. Note that the inner side of the boots are at right angles with the slope.
Left: wrong, because the heels are too close together
Right: correct, because the right angle ensures a good stance.

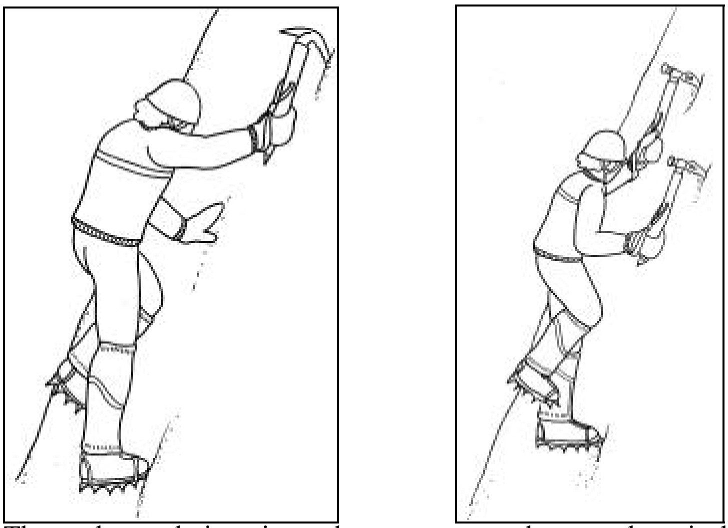
Front pointing - you swing the lower leg from the knee and allow its momentum to work for you. Make sure that the front points of the crampons are inserted at the correct angle to the slope: the heels are slightly dropped downwards.

The dagger technique

When descending a steep slope you probably feel uneasy about walking down with flat footing like you would do on a moderately steep slope. The right technique is then to face the slope and lower yourself down using the front pointing technique in combination with one or two ice axes. This method is nothing else than a daggering technique for the descent.

The dagger technique works well on steep hard snow and ice conditions: you can either use one or two ice tools for this method. But if you have only one ice axe, you will need your hand placed on the slope for support. Facing the slope, the daggering pick is then planted into the snow or ice about waist level with the hand placed on the head of the ice axe. Once the ice axe is planted into the surface you pull your body upwards while using the front pointing method to gain height.

The anchor technique



The anchor technique is used on very steep slopes and vertical ice pitches. When the terrain becomes steeper it is necessary to climb with two short ice tools to maintain always three points of contact with the ice (one pick, two crampons bite into the ice while the other axe is in use; <u>or</u> one crampon, two axes bite into the ice while the other crampon is in use = sequence of movements in ice dimbing). You use front pointing and the axes inserted into the ice above your head with the hands on either shaft.

16.5. Cramponwork exercises

If a good and safe training site is chosen , it is possible to practise and experiment with the different techniques as described before with your crampons. The main skills to be acquired are the confidence of walking on ice with crampons; balance; and the adequate economy of effort. To avoid the risk of injury after tumbling, even on easy terrain, always respect that...

Crampons are dangerous tools!

<u>Introduction guideline for practising:</u>

- *warm-up session* before performance: fexibility and mobility training.
- *basic exercises with crampons on easy terrain*: moving with a wide gait, games: walking like an elephant, a tiger or an heron, walking while rotating arms or touching the sides of the boots, walking like the shadow of your partner (imitate what he or she is doing), walking in a `figure of eight` with partner or group.
- *basic exercises with crampons on easy angled slopes without ice axe:* ascending (Eckstein technique, front pointing), descending (flat footing).

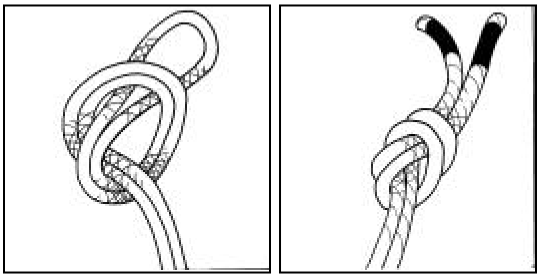
- *flat footing games on easy slopes without ice axe:* descending with the group like a snake (with a tape sling tied around the waist to maintain the right distance from the partner and to reinforce the right body posture), descending with a partner like a snake, descending alone in progressive steps as the steepness of ground increases.
- *Eckstein and front pointing games on moderately steep slopes without ice axe:* ascending alone following a marked zig-zag route (Eckstein) and finally descending (flat footing). Front pointing left/right traversing, front pointing up/down ascending and descending.
- *basic techniques on steeper slopes with ice axe:* ascending (Eckstein, Eckstein/front pointing combination, dagger technique, anchor technique), descending (flat footing, dagger technique).
- *cool-down session:* recovery exercises.

17. Rope techniques

17.1. The knots

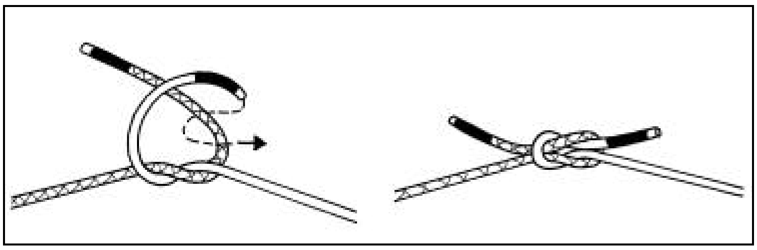
Every mountaineer should be able to tie the following knots and to master them in any sort of extreme situation, such as thunderstorms, emergencies and at night. Knots can have several applications and when tying them make sure that they are all tightened. The free ends of the knot must be pulled tight and should have at least 10 cm security distance from the knot itself (tape slings: 7 cm). In other words ensure that a sufficient length of the tail is left after tying. Before using the knots always inspect them carefully, which means you have to check if they are neat, small and lie correctly. Knots are just temporary connections and one of their attributes is that they work loose on their own after a certain time. Therefore check them regularly and tie so-called ‘stopper knots’ (overhand knot) in whenever possible. Regard the following list as the most important manual for the mountaineer, which is updated and kept lucid. Old knots such as the ‘Bowline’ will deliberately not be introduced in this chapter, because it is a dangerous knot, which could do you harm.

Overhand Loop or Girth hitch



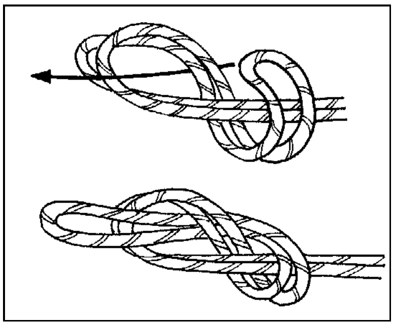
This knot is used for tying a sling, which could be used for different purposes. It is not a harness knot, because it is difficult to undo it after it has been loaded.
Good knot for connecting two ropes of nearly the same size and for tying a sling.

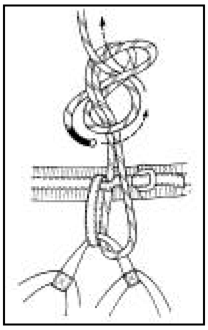
Overhand Knot 2



Suitable knot for tying the two ends of accessory cords together (e.g. bracing an anchor point). The first essential of this knot is to keep it in permanent tension, because otherwise the knot would easily open.

Figure-of-eight knot

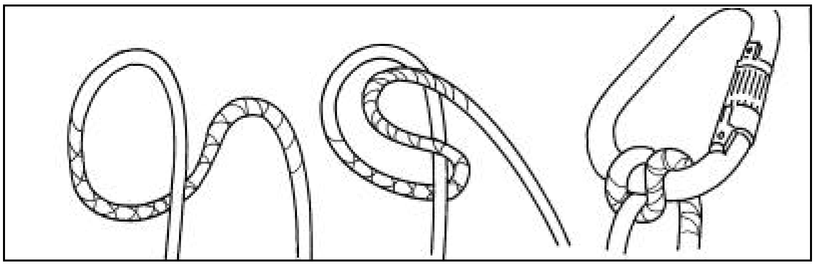




Left: This knot is fairly easy to untie after it has been loaded. It is recommended to tie a stopper knot in the free end, which supports the strength of the knot itself. The stopper knot doesn´t make it any stronger but gives you the security, that enough rope in the tail end has been left.

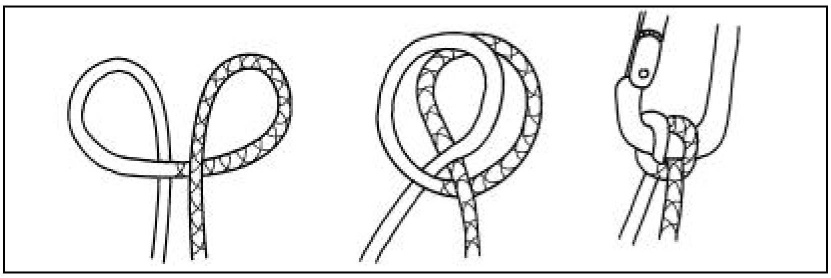
Right: Re-threaded Figure-of-eight (p. 8 oben mitte und rechts): This knot is the most appropriate and secure tie in knot for mountaineering. The Figure-of-eight is simply tied in the single rope and the end (make sure it has enough tail!) follows the original knot in reverse order. It is used for tying into a harness.

Italian Hitch or Reef Knot (HMS)



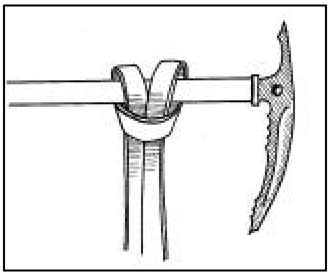
In combination with a so-called HMS karabiner (pear-shaped screw-gate karabiner) it is a quick method of belaying a partner.

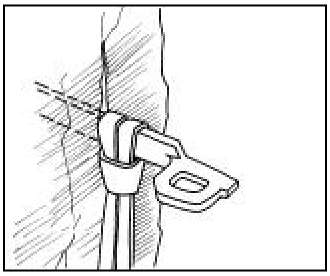
Clove Hitch



The ideal knot for self belay in combination with a screw-gate karabiner when setting up a belay stance. It is easy to untie after it has been loaded.

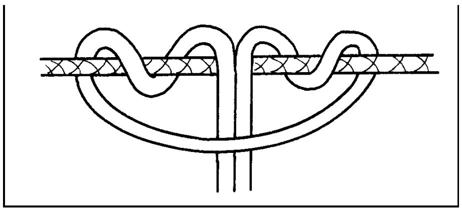
Lark´s Head

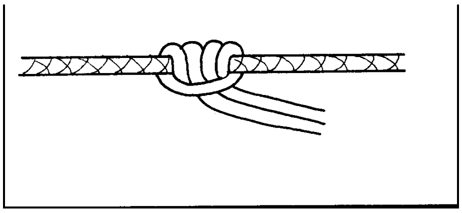




The basic knot used for tying off pegs and the shaft of ice axes with tape slings and accessory cords.

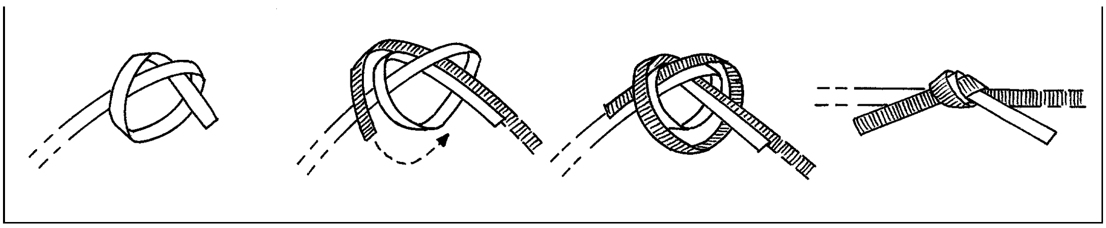
Prusik Knot:





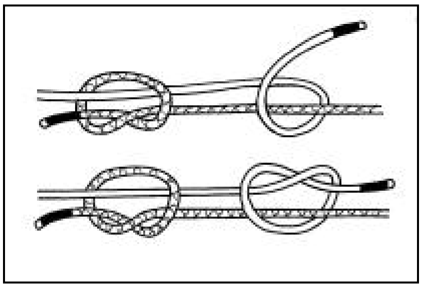
This knot is used in many self-rescue techniques, especially in crevasse rescue and Prusiking (ascending and descending a rope). When loaded, the Prusik locks onto the main rope, but when released it slides easily. In crevasse rescue it is used to transfer the load of the crevasse victim from the main rope to a dead man belay. The Prusik is easily tied onto the rope: putting the loop of a sling behind the rope and then threading through itself twice. The effect of jamming is best achieved with a 6mm diameter accessory cord. The larger the main rope, relative to the sling of the accessory cord, the easier it is for the Prusik to bite. If the 6 mm Prusik sling doesn´t bite effectively you have to add a third loop around the main rope.

Tape Knot



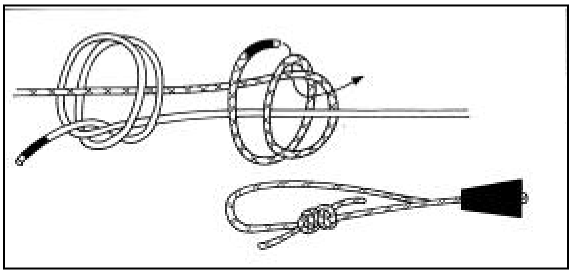
This knot is the most suitable for tying tape ends together to form a sling. An Overhand knot is tied in one end of the tape and the other end then follows it through.

Single Fisherman´s Knot



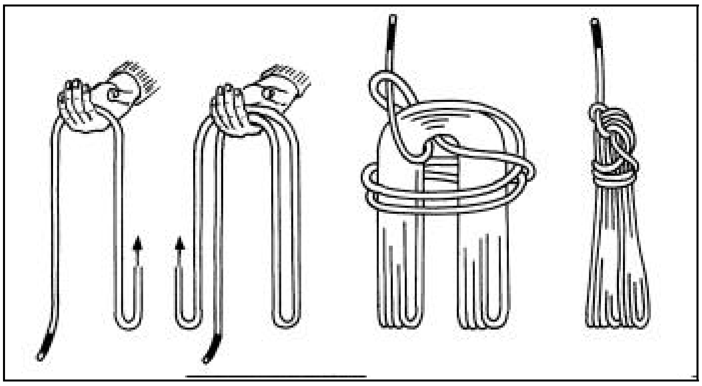
The simplest knot for joining two ends of accessory cords to form a sling. This knot is not used to tie two rope ends together anymore. Two Overhand knots are tied round the other rope and pulled tight.

Double Fisherman´s Knot



This is a secure knot for joining two ends of accessory cords to form a permanent sling, e.g. for nuts. Two double Overhand knots are tied round the other rope and pulled tight.

Coiling the rope

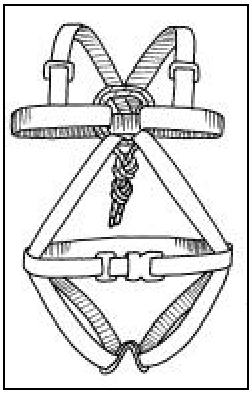


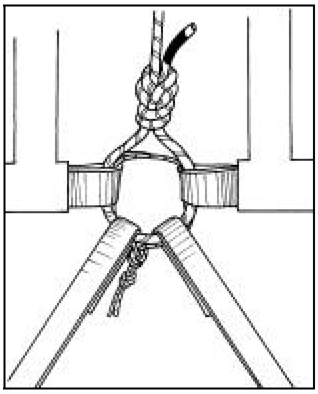
If the rope is coiled correctly it can be transported tangle-free.

17.2. Methods of tying onto the rope

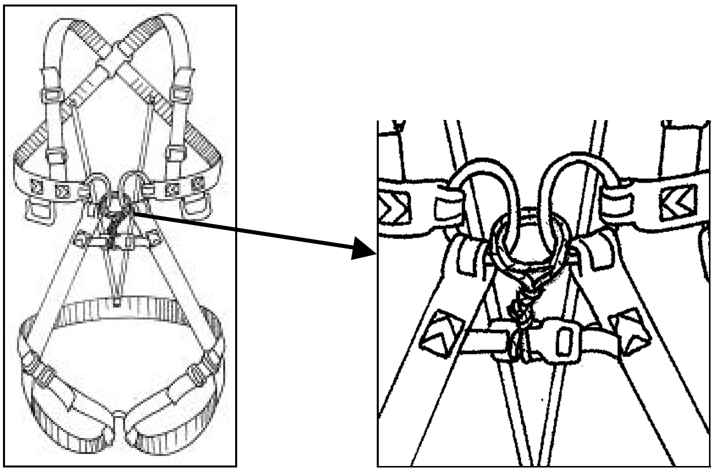
In general the tie in point for mountaineering activities where long falls are possible has to be at chest level; exactly at the end of the sternum to ensure the correct centre of gravity. When it comes to an uncontrolled fall the following combinations of harnesses will give the climber the most security. Safety aspects don´t allow to wear only a sit- or an adjustable waist harness, because the attachment point is below the body´s centre of gravity, which could result in serious spinal injuries in the event of a fall.

Chest and sit harness combination





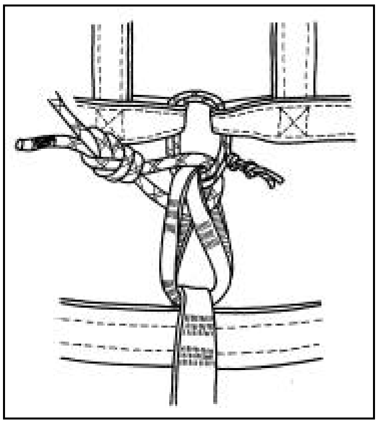
The sit harness should be attached to the chest harness with an accessory cord (120 cm, Ø 6mm) before tying onto the rope. The accessory cord is threaded twice through the attachment points of the chest and sit harness and finally tied off with two Overhand knots. The second Overhand knot ensures that you have left a sufficient length of the tail ends and prevents the other Overhand knot from becoming undone.The rope will then be tied with a re-threaded figure-of-eight in the chest and sit harness combination.

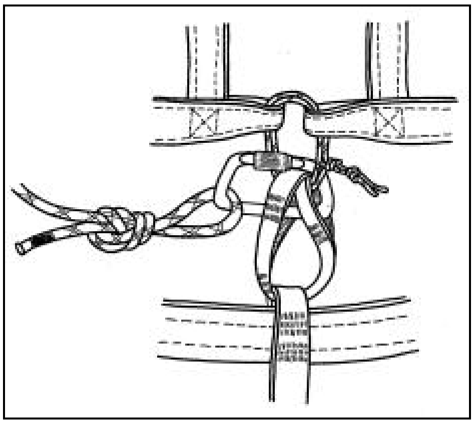


Full body harness (p. 11 unten rechts): the method of tying onto the rope is exactly the same as described for the chest and sit harness combination, namely using an accessory cord (this time: 100 cm, Ø 6mm) to connect the full body harness properly before tying the main rope into it.

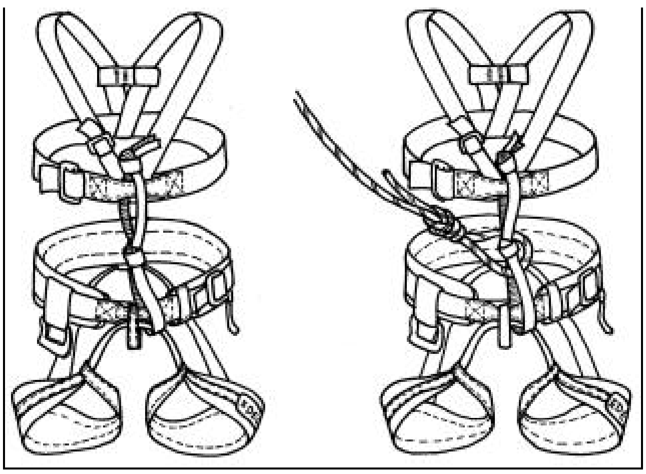
Chest and waist harness combination

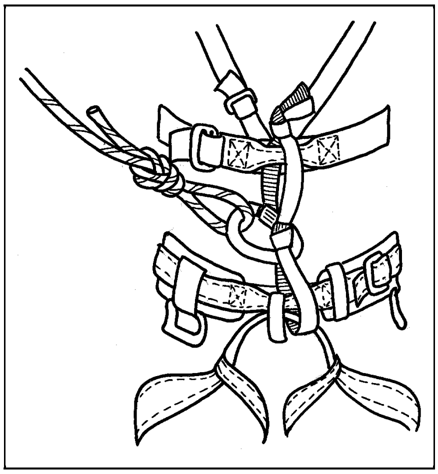
There are two recommended methods of tying the chest and waist harness together to create the correct and safe attachment point for the main rope.





The first method is done with one accessory cord (120 cm, Ø 6mm) and one open express sling. The express sling in the waist harness is connected with the accessory cord in the chest harness, whereas the accessory cord is tied into the chest harness and express sling as described in the first example: the accessory cord is tied twice round the tie in points of the chest harness and the express sling and finally tied off with two Overhand knots. The express sling could also be tied into the attachment point of the waist harness using a Lark´s head.





The second method is done with one open tape sling (120 cm), which is properly tied through the waist harness first (not only through the waist harness loop!) and secondly tied off with an overhand knot at sternum level. Finally, the two free ends are threaded through the chest harness and tied off with an Overhand knot instead of a tape knot. The attachment point for the main rope is the Overhand knot at sternum level. The rope could either be tied directly into it with a re-threaded figure-of-eight or indirectly with a screw-gate karabiner.!!! illustration p. 12 bottom and p.14 top right. Using a waist harness means you have to re-ensure, that you re-thread the harness belt, because of safety measures.!!!illustration p 13 bottom.

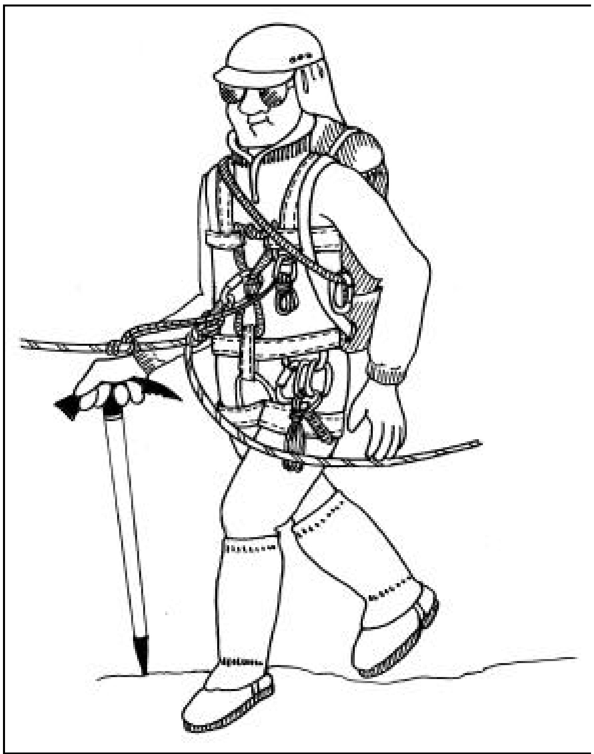
17.3. Independent rope party on a glacier

The danger of falling into a crevasse on a glacier is an obvious danger and has to be taken into account by the mountaineer. Thus the climbers have to meet this danger by using the rope on glaciers. If all crevasses are completely visible it is normally not necessary to rope up.

> *However, it is recommended to decide for the security of a rope whenever you move on a glacier, especially when the surface is covered with snow !*

What are the most important factors, which have to be considered when moving on a glacier ?

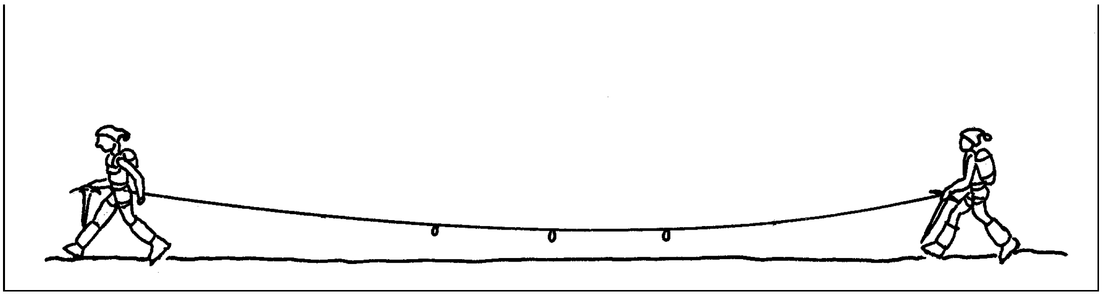
- The bigger the *size of a roped party* the less dangerous is the movement on the glacier, because the risk of being dragged down with a partner into a crevasse is nearly impossible.
- The right *intervals* between the climbers in a roped party and so-called *friction knots* contribute to more safety and better friction of the rope in the snow, when someone has fallen into a crevasse.
- The *correct use of the rope* is important for more safety on the glacier, e.g. don´t allow slack in the rope. Rope discipline!
- The better the knowledge about *rescue techniques* and the communication within the group the more effective is the management in an emergency.
- With the right knowledge about *belay techniques* (ice screw, dead man) on difficult sections such as Bergschrunds and snow bridges the team members could be safeguarded more effectively.
- The right *choice of equipment* and equipment organisation could save time in an emergency.


The well equipped mountaineer travelling on a glacier.

Preparation

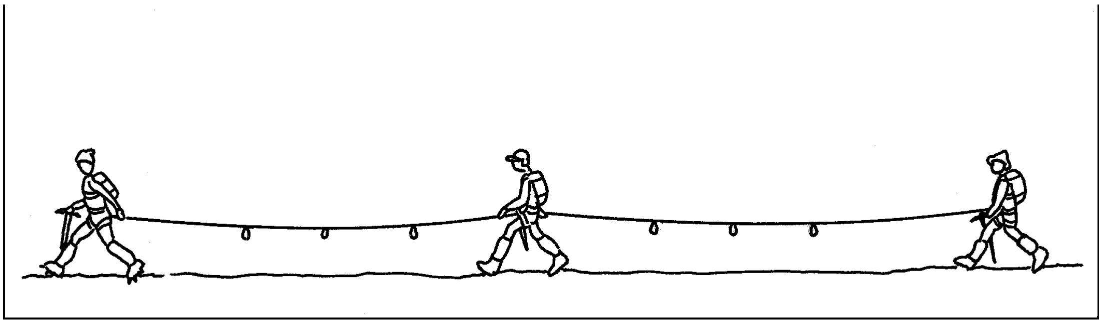
- Tying onto the rope with chest-sit-, chest-waist- or full body harness using a short figure-of-eight sling, which is attached with a screw-gate karabiner in the accessory cord (sling that connects the harness combinations).
- Minimum interval between the climbers in a roped party is 8 m. Any rope left is either wound as coils around the body or put in the rucksack.
- The leader: before travelling on a glacier make sure that everyone has understood the basic rules of behaviour in case one climber falls into a crevasse. For example: the leader has to tell the others beforehand, that he/she is responsible for his/her own rescue out of the crevasse by applying the technique of Prusiking. Any ‘on the spot decisions’ by the group deciding for a not properly organised rescue haul, because of the lack of experience, could result in harmful consequences for the victim, because the group may not realise, that screams out of the crevasse cannot be heard on the glacier. The right method of rescueing a team member is introduced later on.

Rope management for a group of two:



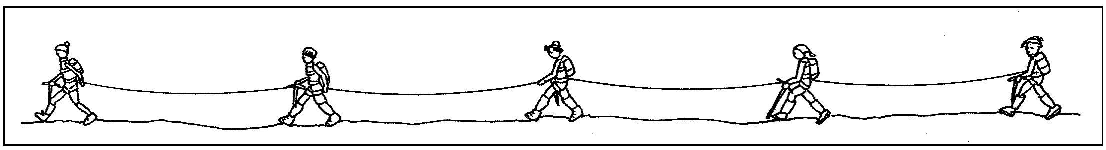
Groups of two have many weaknesses, because the risk of being pulled into the crevasse with the partner is greater than compared with a larger rope party, who can stop a fall easily. Therefore it is recommended to join another rope party whenever possible. However, if a rope party of two cannot be avoided, the distance between the two climbers is in total **12 metres**. In addition, 3 to 5 friction knots (Overhand loops) tied into the rope are necessary to allow more friction in the snow in the event of a fall. The friction knots function as an anchor, when the rope cuts into the edge of the crevasse when loaded.

Rope management for a group of three:



In groups of three the risk of being pulled into a crevasse is markedly reduced, but could also occur especially on steeper angled ice slopes. The party always has to respect that the rope has to be kept tight (rope discipline). Anyway, the climbers tie onto the rope at a distance of **10 metres**. Finally, 3 friction knots are added between the climbers (each braking knot requires about 0,5 metres of rope).

Rope management for more than three climbers:

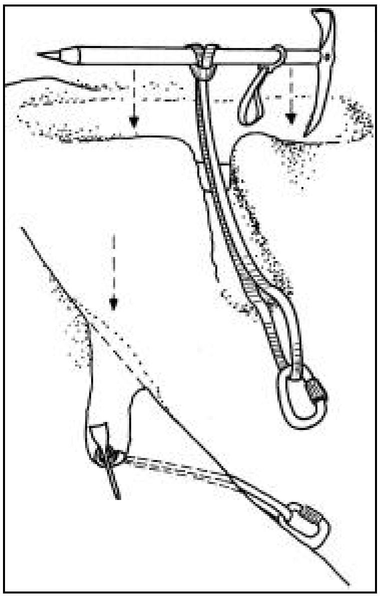


Rope parties with more than three climbers are certainly the most secure organisation on glaciers. The distance between the climbers is in total **8 metres** and friction knots are not required. The maximum size of a rope party depends on the length of the rope (a 50 metre rope allows only for a team of 7 mountaineers).

18. Belay techniques

Basic belay technique on snow and firn slopes

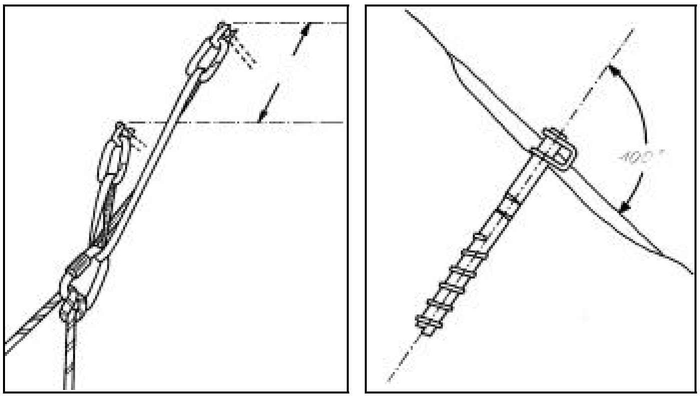
On snow and firn slopes the so-called dead man gives good support for a belay stance. In most cases the dead man ice axe anchor is applied in connection with crevasse rescue but could also be used as a normal belay point on steeper snow and firn slopes.



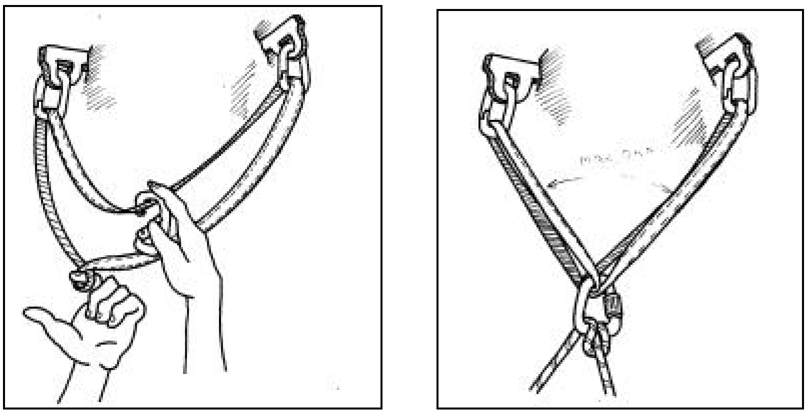
The dead man: the ice axe is buried horizontally in the snow with a vertical slot to prevent the axe of being pulled out of the snow when the rope is loaded. A sewn tape sling or an accessory cord is attached to the centre of the ice axe shaft using a lark´s head. Finally the main rope is then put into the karabiner for whatever purpose.

Basic belay technique on ice

To set up an ice belay you have to place two ice screws with the correct angle into the ice and connect both with a tape sling using two karabiners for the attachment. The vertical distance between the ice screws should be at least 0,5 metres.

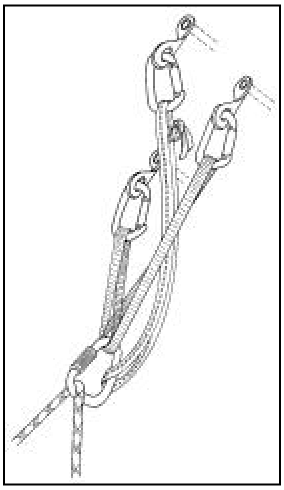


Right: placing an ice screw with the correct angle after removing the rotten ice with the axe.
Left: Two ice screws connected with a tape sling. The illustration perfectly demonstrates how to set up a belay for safeguarding a partner using an Italian hitch knot in combination with a pear-shaped screw-gate karabiner. The belayer himself is attached to the tape sling using a clove hitch knot in combination with a screw-gate karabiner.



Correct method of attaching the screw-gate karabiner into the tape sling.

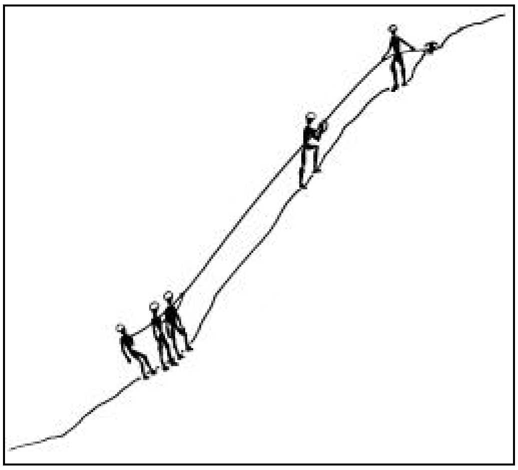
The top rope stance on ice



A top rope stance is used for vertical ice climbing and is set up just like in the previous example. The only difference is a third ice screw, which gives additional security for the anchor. The third ice screw is joined with the central screw-gate karabiner using another tape sling or accessory cord. The third ice screw should not be loaded with the weight of the ice climber.

The fixed rope

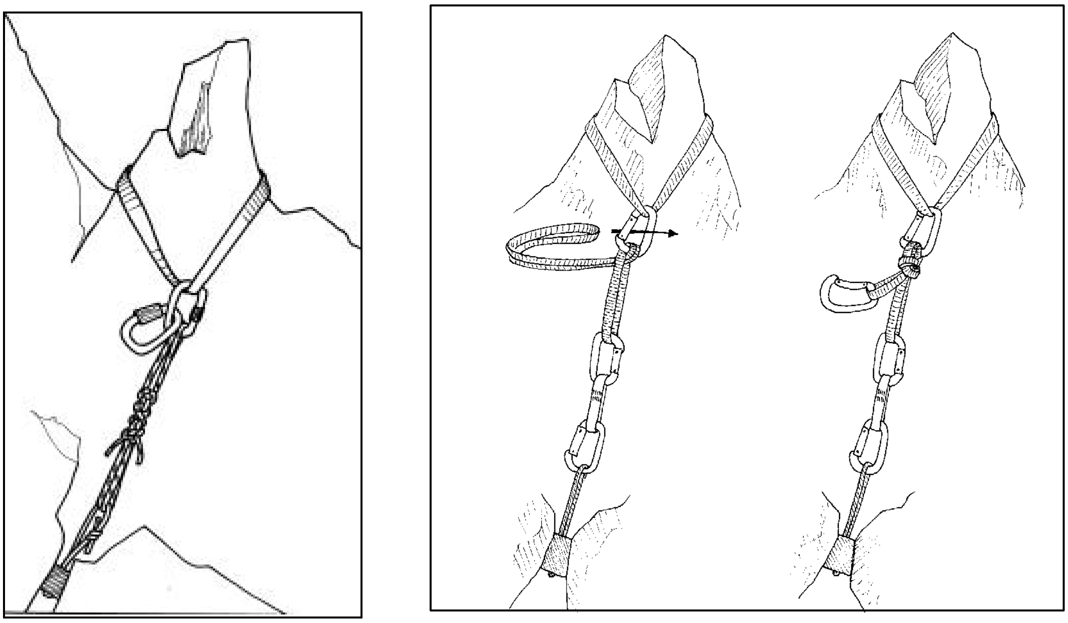
The fixed rope is the ideal method for a leader to safeguard a group up or down steeper passages on snow slopes and ice faces. The leader simply arranges an anchor point suited to the terrain with either a dead man or with ice screws. All group members, who must wait until the anchor is set, are attached to the main rope with a Prusik sling. The Prusik knot has the advantage of locking when loaded and of sliding easily when released. The last climber in the group (on the bottom) is tied onto the main rope and while the others are Prusiking their way up, he or she is responsible for keeping the rope tight enough for the other climbers, by leaning back. The last climber does not use the Prusik method, because he or she will be safeguarded by the leader, who uses the belay technique with an Italian hitch knot (friction knot) in combination with a pear-shaped screw-gate karabiner.



The fixed rope: ascending and descending by using the Prusik method

The belay stance on a ridge

There are many different methods of setting up a belay on rock faces, but with regard to the limited time of the course the easiest but very effective belay stance should be introduced.



Belay stance on a ridge: a sewn tape sling round a sound block. Bracing the tape sling with an accessory cord and a mobile rock belay (e.g. friend) from another direction will guarantee a better distribution of the load and it also permits a secure belay for the leading climber. If not braced, mobile rock belays used for stances are normally used for belaying only the last person on the rope!

19. Rescue techniques

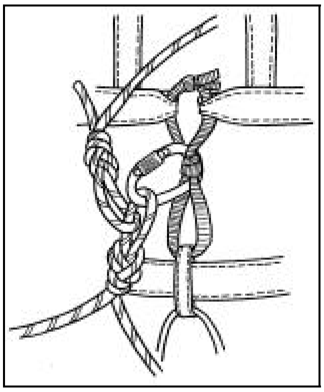
Fortunately falling into a crevasse is a relatively seldom event in mountaineering sports. However it is useful to know the techniques of crevasse rescue in order to be prepared for the extreme situation, because a fall into a crevasse can have very serious consequences. You may find yourself at the bottom of a crevasse and unable to make your way out on your own. This chapter introduces you to the main techniques, which have to be practised regularly.

The crevasse as a safe practice area

The equipment: 2 single ropes, recommended harness combination, 2 screw-gate karabiners, 1 pear-shaped screw-gate karabiner (HMS), 2 karabiner, 1 helmet, ice-axe, 2 tubular ice screws, 3 accessory cords(150 cm, 3 m, 5m, Ø 6mm), tape slings.

Important instructions regarding safety measures when practising at a crevassed training site:

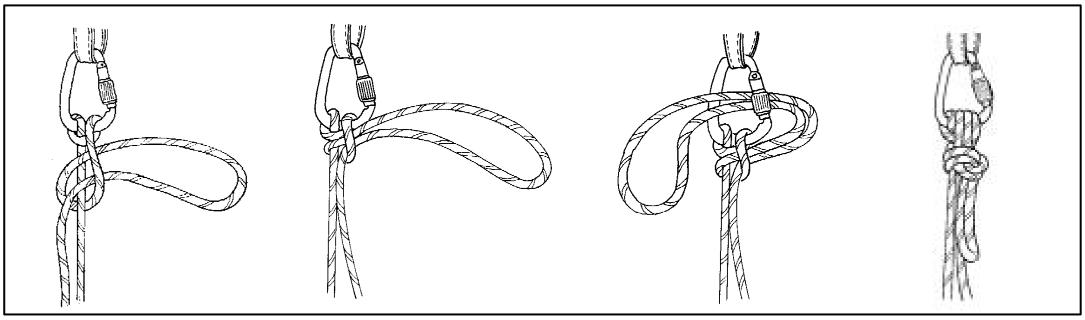
- at least *3 people in a team* are required for the crevasse rescue exercises (1 belayer, 2 people for the rope party).
- after approaching the training site with a roped party *mark the training field* and create a secure demarcation within which you are allowed to move without the rope.
- if the glacier is covered with snow it is important to *probe for hidden crevasses in the demarcation area carefully* before untying the rope.
- before the first team has moved towards the crevasse it is necessary to set up a *back belay stance* to give full security if the fall cannot be arrested by the fellow trainee.
- the back belay could either be a dead man ice axe anchor when the snow is soft or a stance with two ice screws and a tape sling when the surface is icy. Ice screws should always be covered with snow.
- *two ropes are used*: the first rope from the back belay stance is directly tied into the last person´s figure-of-eight sling (second rope) using a re-threaded figure-of-eight.



Method of tying the security rope onto the used rope

- *partner check*: necessary equipment carried? properly tied onto the rope? screw-gate karabiner locked correctly? helmet on?

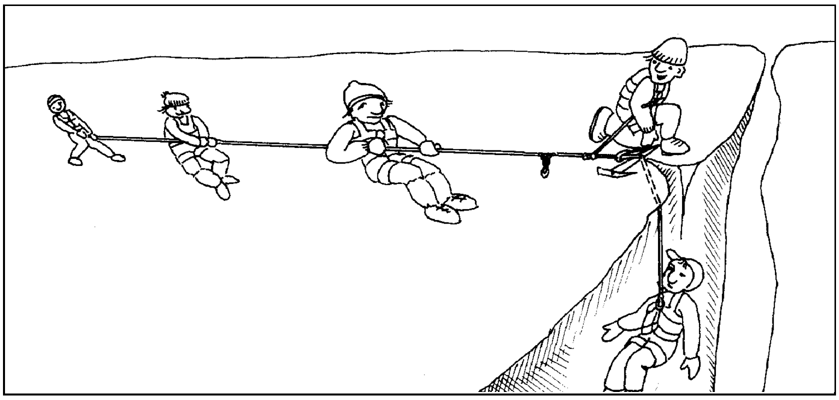
- once the back belay is set and the security rope is attached properly onto the used rope, a rope party of two can start to *approach the edge of the crevasse* until the first person has fallen into it.
- this *team of two is belayed* from behind by a third person with a pear-shaped screw-gate karabiner using an italian hitch knot for friction. Once the fall is arrested by the second climber, the rope from the back belay can be fixed by the belayer as demonstrated in the illustrations.
- during the exercise: *crampons are not worn and ice axes are not used* for arresting the fall, because of safety reasons!
- once the second climber has arrested the fall of the victim, the *ice axe for the anchor in the snow is provided by the belayer*.
- finally *another belay point is set up* by the one who arrested the fall to transfer the load from the victim onto a secure anchor.
- the *rescue* can start!



The illustration shows the method of fixing a rope securely in a pear-shaped screw-gate karabiner. Finally the braking knot is tied off with a fisherman´s knot.

The organised rescue haul

This technique is the easiest method of rescueing a climber in the event of a fall. For some people the rescue haul seems to be an obvious technique, which doesn´t have to be discussed in detail. But from the Austrian Alpine Club´s point of view it is an essential part of all Alpine Training Courses because there are several things, which could be disregarded by a rope party when pulling a fallen person back to the surface. This 'unorganised rescue haul' could lead to more harm and injury for the victim than originally caused by the fall itself.



A rescue haul could be a dangerous undertaking if not organised and applied properly. In any case the communication with the victim should be guaranteed.

The reasons why the group has to be careful when deciding for this technique:

- it is a matter of fact that the rope cuts into the edge of a crevasse when loaded, sometimes to a considerable depth, which is, without any doubt, a big obstacle for the victim because it is nearly impossible for the person to clear the rope of the snowlip. If the rescueing team ignores the *cutting effect* of the rope it could result in disastrous consequences for the victim, who might be stuck at the edge of the crevasse.
- the *enormous pulling force* produced by a team of 5 mountaineers should not be underestimated! If the rescueing team doesn´t apply the correct technique of pulling, the fallen person may then be injured seriously: overhanging edges of crevasses could set a deadly trap for the victim.
- the *crevasse is acoustically isolated* from the surface! A screaming person shouting for help is unlikely to be heard from the team standing outside, even f the distance to the victim is very short. A team is not able to decide whether the victim is conscious, uncoscious or injured unless it is checked by a team member.

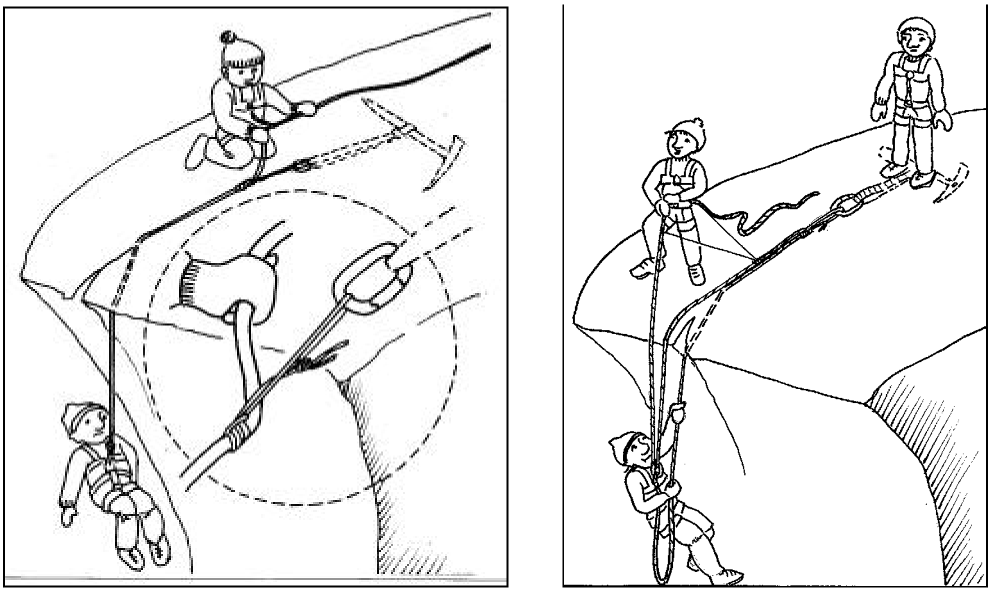
The recommended procedure:

- assuming it is a team of 5 who arrested the fall and who are holding the weight of the climber: the person who follows the victim on the rope is responsible for the organised rescue haul. This person is then safeguarding him-or herself with an accessory cord and a Prusik knot tied onto the rope before clipping off the main rope. With the attachment of the Prusik in front the climber approaches *the edge of the crevasse.*
- to protect the edge of the crevasse from the further cutting effect of the rope it is necessary to *place the ice axe* under the rope as far as possible towards the edge of the crevasse. To avoid the loss of the ice axe it is important to attach the axe onto the rope with a karabiner clipped into the wrist loop. The climber may need to sit down on the snow trying to push the ice axe with the feet forward. The ice axe allows the rope to run over the edge more smoothly.
- the climber at the edge steadily maintains the *communication* with the victim and the rest of the group. He or she tries to find out whether the victim is injured or not. According to the physical state of the victim the responsible person provides the rest of the team with appropriate instructions.

- when the rescue haul has been successfully completed the instructing climber goes back to the figure-of-eight loop in the main rope, safeguarded by the Prusik, until he or she is finally clipped onto the main rope again.

The rope pulley system

This technique is applied in situations when the rope party is too small or has been unsuccessful in doing a rescue haul. Moreover, it is applied by experienced mountaineers to bring up a fallen climber, who is not familiar with the necessary skills or equipment needed to climb or prusik out. The following description presupposes that the victim is conscious and able to follow instructions from the surface.



Left: Transferring the weight of the victim onto the anchor (dead man ice axe belay). The rescuer is attached to the free tail of the rope with an accessory cord using a Prusik knot and a figure-of-eight loop.
Right: The pulley system is set up and the victim can contribute to the pulling effort from above.

The recommended procedure:

- having arrested the fall, the first person who follows the victim on the rope is responsible for the organisation of the pulley system. This person, immediately after the arrest, sits down on the snow, leans back and tries to put all the weight onto the feet by kicking them into the surface.
- the prepared accessory cord on the rope (3 m, Ø 6mm) is needed to transfer the weight of the fallen climber onto a belay stance in the snow (dead man, ice screws, skis, inserted ice axe). Once the accessory cord is attached to the screw-gate karabiner of the anchor point, the load has to be transferred slowly onto the anchor. Another climber in the rope party should support the stability of the anchor by standing on it.
- everyone in the rope party has to untie the figure-of-eight loop, because the rest of the rope is needed for the pulley technique.

- the next step is to divide the long accessory cord (5 m, Ø 6 mm) into equal halves. The middle is tied with a Prusik knot onto the free tail of the rope, which is not loaded by the weight of the climber. One end of the accessory cord (about one arm length) is attached to screw-gate karabiner of the harness (normal tie in point) using a figure-of-eight knot. This method serves as a self belay and guarantees a secure approach towards the edge of the crevasse. The other free end of the accessory cord is used later on.
- the rescueing person then *approaches the edge of the crevasse* to find out whether the victim is conscious, unconscious and/or injured.
- assuming, that the victim is fully conscious and able to follow the instructions from above: a sling of *the free main rope is led down* to the victim with a screw-gate karabiner attached. The instruction is to clip the screw-gate karabiner into the tie in point of the harness and to lock it properly.
- once the victim is connected to the free rope, the person at the edge of the crevasse ties *a re-threaded Prusik knot with the left tail end of the accessory cord* onto the tail end of the main rope to complete the pulley: the re-threaded Prusik knot functions as a *recoil brake*; remember that the Prusik knot slides easily when unloaded and locks immediately when loaded.
- the *victim can contribute to the pulling effort* of the rescuer by lifting him- or herself up the loaded rope. Good instruction and coordination is required from above to pull and lift at the same time. Find a rhythm to do so. Good advice: the pulling effort and the forwarding of the re-threaded Prusik knot is eased by transferring the load onto the thigh.
- the pulley method works only when additional friction of the rope in the snow is avoided. This means that the rescuer has to choose his/her position as close to the edge of the crevasse as possible.

Attention!

A team of two in a roped party lives dangerously on a glacier, because the long distance between the climbers might be a factor why there is not enough free rope left to set up a pulley system. Crevasses are not always predictable and it is difficult to make an assumption who of the team members may be the victim. Therefore it is vitally important for both climbers to have enough free rope in the rucksack. One example:

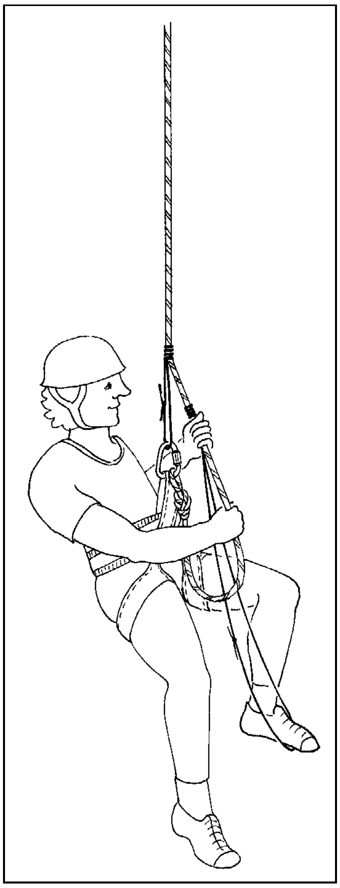
Rope lenght: 50 m ; 12 m dictance between the climbers; about 2,5 m are used for 5 friction knots (each 0,5 m). At the end there are 17 m left for each climber. Conclusion: 17 m may not be enough free rope to set up a pulley system!

Preventive measures:

- both climbers should know the rules of the self-rescue techniques (Prusik technique). Therefore the free rope and pulley systems are useless.
- the second climber on the rope takes all the remaining rope as it is more likely to be the first on the rope who falls into the crevasse.
- generally deciding for a longer rope. Never reduce the distance between you and your fellow climber, because it is more important to have enough rope to allow more friction in the snow to arrest the fall.

The Prusik technique

This technique is the most important method for self-rescue and has to be trained regularly. The method is good for those who are uninjured and physically conditioned to cope with an unassisted climb on the rope by using two accessory cords (1,5 m, 3 m, Ø 6mm) and Prusik knots. The 3 metre accessory cord is used as a step in aid tied onto the main rope and the short accessory cord is attached to the tie in point in the harness.



The Prusik technique with a foot loop and a short Prusik.

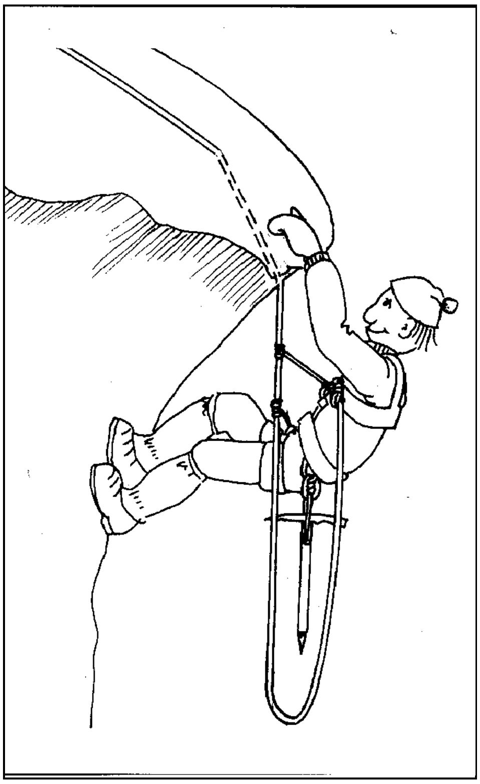
The recommended procedure:

- after the fall into the crevasse has been arrested by the fellow climbers, the self-rescue can start.
- the 3 metre accessory cord, which is already tied onto the rope with a Prusik knot serves as a step in aid or *foot loop*. The victim ties a sling with an Overhand knot; big and high enough to place one boot comfortably into it.
- the 1,5 metre accessory cord is then attached above the step-in sling onto the main rope using a Prusik knot again. The short accessory cord is connected clipped into the screw-gate karabiner in the correct tie in point of the harness. The maximum length of the *short Prusik* sling should not exceed 20 cm!

- the *ascending technique* requires a good physical condition, especially trained abdominal muscles for a demanding exercise. One boot is placed into the foot loop trying to maintain all the body weight onto it and to achieve a standing up-right body position. This method takes the weight off your harness. Doing so, the short Prusik will be unloaded for a moment until you push it as far up as possible on the rope. It immediately locks after you lean back transferring your body weight from the foot loop onto it. The next step is to slide up the long Prusik with your hand just below the short Prusik. By weighting the foot loop again, you unweight the short Prusik, which can be slid up the rope as before. The process is repeated until the surface of the glacier is reached.

The short Prusik technique

When the top of the crevasse is reached by the Prusik technique you may be welcomed by an overhanging lip, which requires another method to overcome it. Moreover, the fall into the crevasse may have caused the main rope to bite deep into the crevasse edge, which is another obstacle for the climber applying the normal Prusik technique. The short Prusik technique allows the climber to free the rope from the snow and to get over the edge. It is a demanding and strenuous exercise, which requires a good physical fitness.



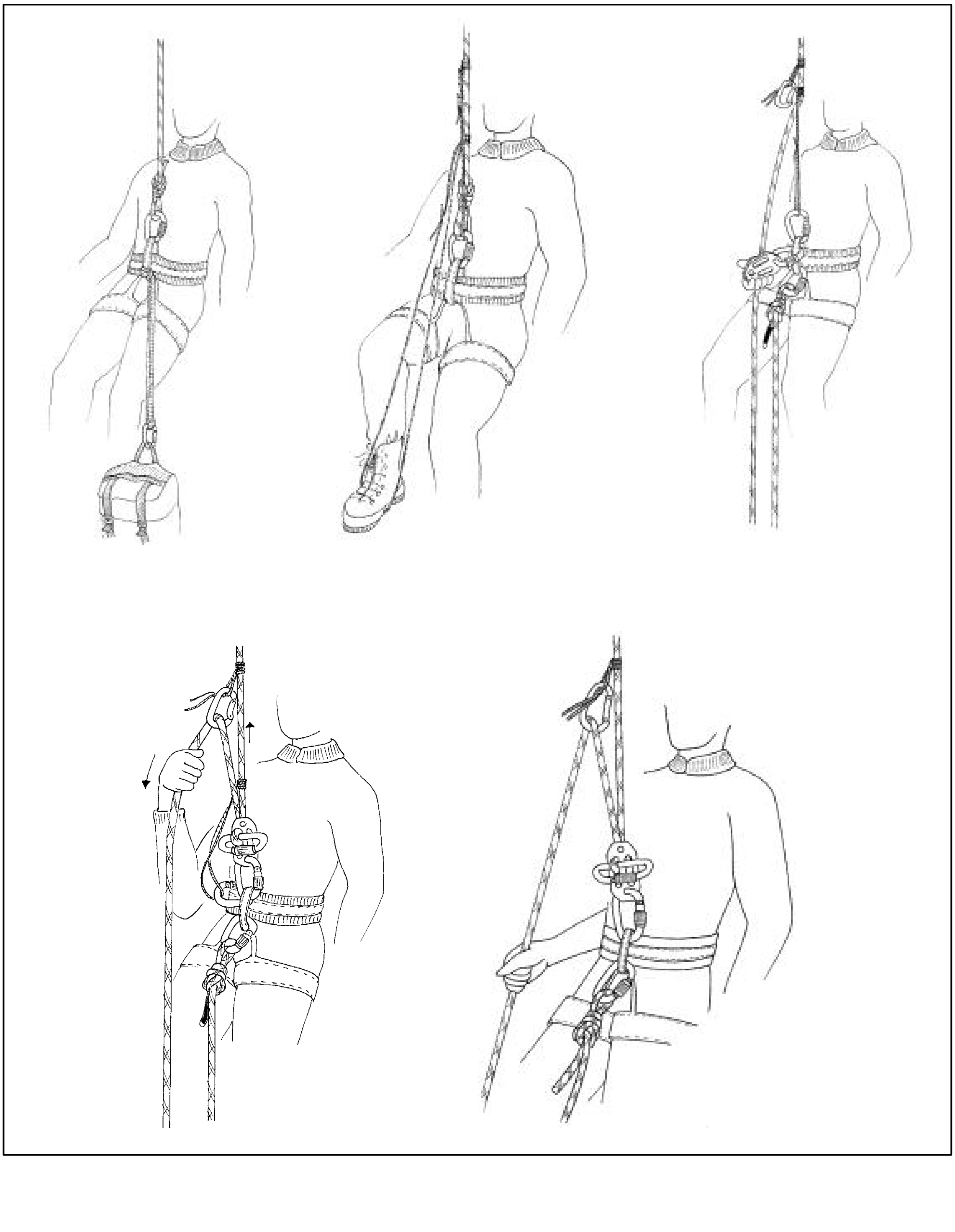
A climber is prusiking out a crevasse.

The recommended procedure:

- first of all the climber approaches the overhanging lip with the normal Prusik technique as described before.

- when the climber has reached the obstacle, the accessory cord for the foot loop needs to be shorter than before. The sling is shortened (maximum length 10 cm) with an Overhand knot again and pushed downwards to harness level. The sling is then clipped with two karabiners onto the leg loops of the sit- or waist harness.
- the accessory cord, which is attached to the tie in point in the harness probably needs to be shortened as well or a short, already prepared Prusik sling is attached to the main rope.
- ascending technique: prusiking up the edge of the crevasse means the climber has to push himself off the crevasse wall with the feet. This method frees the rope from the snow and permits a better starting position for the short Prusik technique. The climber attempts to raise the hips and to push the ‘leg loop Prusik’ as far up as possible, just below the ‘harness Prusik’. The next step is to forward the upper ‘harness Prusik’ by straightening up the upper body trying to maintain most of the body weight onto the ‘leg loop Prusik’ at the same time. The procedure is repeated until the surface of the glacier is reached.

The „Münchhausen"- technique



VI FUNDAMENTALS OF HIGH ALTITUDE MEDICINE

Mathias KNAUS

20. The human being at high altitudes

In addition to the factors of temperature, humidity and radiation, the level of oxygen, which decreases as altitude increases, especially limits the functioning of the human organism and its ability to perform. Functional limitation can already be measured at an altitude of 1,500 m, particularly when one ascends quickly at this altitude. The slower the ascent, the better the human organism reacts, i.e. the reaction is time-dependent.

The duration of the acclimation process varies among individuals and depends on the speed of the ascent, the absolute reached altitude, the relative difference in altitude achieved, and physical condition; it is not, however, dependent on one's endurance training condition. The following so-called acclimation times are therefore only approximate: to 4,000 m altitude approximately three to six days, to 5,000 m altitude approximately one to two weeks.

Once one is acclimated to a specific altitude and therefore continues to ascend, the acclimation process begins anew. Acclimation therefore always occurs level for level.

21. Altitude Levels

On the basis of typical differences in physiological reaction and in light of the typical occurrence of acute altitude sickness, one can define three levels of altitude:

1,500 – 2, 500	Medium altitude	immediate adaptation is sufficient
2,500 – 5,300 m	high altitude	immediate adaptation is insufficient, acclimation necessary
5,300 – 8,848 m	Extreme altitude	acclimation no longer possible, only possible for short stays

Note:
In the range between medium and high altitude, at approximately 2,500 m, that level begins as of which the human organism must be consciously acclimated in order to survive without damage. This area is referred to as threshold altitude.

22. The acute altitude sicknesses

"Every person can get altitude sickness, if he ascends fast enough."

The acute altitude sickness known as Acute Mountain Sickness (AMS) is understood to be several syndromes which are caused by a lack of oxygen at high sea levels. AMS occurs primarily at altitudes between 2,500 m and 6,000m. Over 50% of all mountain climbers suffer from AMS above 3,500 m.

Additional serious forms of acute altitude sicknesses are the altitude-related lung edema HAPE (High Altitude Pulmonary Edema) and the altitude-related brain edema HACE (High Altitude Cerebral Edema). AMS and HACE are neurological disturbances which have a negative effect on the blood flow and therefore on the oxygen supply to the brain. The consequence is brain swelling. In the case of HAPE, an abnormal level of fluid in the lungs occurs due to increasing lung pressure.

Symptoms
AMS is the most common form of altitude sickness. Common symptoms include headache, tiredness and sleeping disorders. AMS usually disappears within 24 to 48 hours; in some cases, however, AMS can become HACE with which HAPE often develops without any previous AMS symptoms.

A serious case of HACE is manifested in extreme headache, confusion and hallucinations. HACE can lead to coma and death within hours.

HAPE develops most often within 24 to 96 hours of reaching a height over 2,500 m. prominent symptoms are a sudden decrease in performance, coughing and foamy-bloody saliva production. HAPE can also lead to death within hours.

23. Altitude acclimation

One should remember the three most tactically important rules – the more one observes them, the greater the success of acclimation.

- Avoid ascending too quickly
- Avoid physical effort during the adaptation phase
- Sleep at the lowest possible altitude

The acclimation tactics in detail:

- The acclimation threshold, in other words that altitude at which a disciplined altitude tactic is necessary to avoid altitude problems, is approximately 2,500 m above sea level (so-called threshold altitude).
- The decisive criterion of every altitude adaptation is the time factor, namely the speed at which a difference in altitude is reached.
- As of 2,500 m sea level , every acclimation always proceeds in levels: After successful adaptation to an altitude, one is acclimated for this level and is therefore able to

perform and is largely free of risk of acute altitude sickness. At further increases in altitude the acclimation process and therewith the risk always begin anew.

- Decisive for acclimation up to 5,300 m is always the related sleeping altitude. This means concretely:
- Always sleep as low as possible
- Once the threshold altitude has been reached, sleep several nights at this altitude
- In the case of continuous ascent, ensure that the differences in sleeping altitudes are within 300 to maximum 600 meters
- For every 1,000 m of altitude, sleep at the same altitude two nights; day targets should be a maximum of 1,500 m higher
- Sleep with the upper body raised as much as possible.

These sleep altitude tactics are based on general experience, which can vary from individual to individual and therefore are not equally applicable to each altitude tourist or high altitude tour. One should orient oneself to one's individual reaction: How was I in the previous night, particularly concerning headache, the possible indicator of AMS? The actual next sleeping altitude should be based on the answer to this question.

The most important fundamental rule is: ascend in stages. Sleeping altitude should always be lower than the highest reached day altitude ("Climb high – sleep low").

In the acclimation phase, all physical activity should be avoided. Deliberately slow and energy-saving movements, short day stages, only light loads, frequent resting. Motto: "He who goes faster than an ox is the ox!" An inactive mountain climber acclimates much better than an ambitious, hasty one burning for action.

Level of performance should not exceed 50 – 60% during the acclimation process.
Pay attention to early indicators of acute altitude sickness immediately! In addition, it is necessary to mutually observe one another, particularly at night. But: shortness of breath, feelings of anxiety in the tent, sleep disturbances and periodic breathing at night with pauses in breath lasting several seconds are not yet signs of AMS, but rather normal altitude-typical phenomena.

Signs of Successful Acclimation:

- endurance performance in accordance with training levels
- Resting pulse returned to one's personal normal value
- Deep breathing at rest and under physical stress
- Continuance of periodic sleep breathing
- Increased urination, particularly at night

At extreme altitudes the following tactical rules apply:

- Prerequisite is always a solid acclimation at base camp. After arrival at base camp, several rest days absent of special physical activity are necessary.
- The ascent from the base camp should be executed in stages, i.e. ascents during the day of up to a maximum of 1,000 m above the sleeping altitude with immediate return descent after each one ("Jo-Jo tactic"), at the beginning to the base camp, and

- Only at the third ascent the first night camp at the next highest camp.
- At the latest after two such altitude stays, three days of rest at base camp
- If possible, bad weather phases should not be waited out at higher altitudes.
- Descend immediately in the case of common illnesses (e.g., infections, local infections, wounds, etc.) as these can be threatening at high altitudes.
- The peak ascent can only be done after reaching a sleeping altitude of a maximum of 1,500 m below the peak and should in general be done from base camp, in other words so quickly as possible and without avoidable camp stays.

Each peak ascent at this altitude is always a special risk. Therefore, after reaching the peak, immediately descend as far as possible, at least below the last sleeping altitude. This must be planned in at the point of departure for the peak. ("Speed is safety.")
The descent from a high peak is always more dangerous than the ascent. Therefore while descending one must tactically avoid an possible bivouac as well as resting in a lying position.

24. Additional health recommendations

Optimal energy supply can not be replaced by either insufficient training nor insufficient acclimation and also does not increase performance ability, but it is an essential factor for the maintenance of performance ability. A best-possible nourishment and liquid intake is an absolute priority for high-altitude mountain climbing.

Nutrition
Food should be high in carbohydrates, tasty and well-seasoned, easy to digest as well as correspond to one’s own daily eating habits. As altitude increases, fat intake should be reduced, replaced by carbohydrates. Due to the reduced oxygen supply, meals should be taken in smaller amounts more often.

Hydration Level
Drinking a lot before, during and especially after each day's activity is especially important. The feeling of thirst decreases as the level of fluid loss increases and even the intensity of sweating is not a reliable indicator for actual need of fluids because water is primarily lost through exhaling at high altitudes as a result of temperature, which can occur at a rate of 6 l / 24 h.

Questionable is the decrease of daily urine amounts to less than one liter in 24 hours (not however a change in urine color). An increase in resting pulse is a warning sign of dehydration.

Pacing and Breathing Rhythm
By pacing oneself using common sense and basing it on one’s own ability, one has an extremely effective, simple instrument at hand with which one can also overcome longer day ascents without threatening waste of energy. During the acclimation phase, a rational and deliberate pace is especially important.

The primary rule of thumb is: Everyone should go at his own speed.

Orient yourself under no circumstances to the pace of another, especially not that of a local guide, sherpa guide or porter! Those who go too quickly and unrhythmically, who ascend without adapting, risk early tiredness, a threatening exhaustion or, in the acclimation phase, acute altitude sickness.

Chhota Shigri, October 2002

WORLD GLACIER MONITORING SERVICE

GENERAL INFORMATION ON THE OBSERVED GLACIERS 1995–2000

NOTES ON THE COMPLETION OF THE DATA SHEET

This data sheet should be submitted for all glaciers on which data are submitted for inclusion in 'Fluctuations of Glaciers 1995–2000'; however, questions 5 to 14 should be answered only for glaciers not included in Volumes VI and VII, or for cases where new or improved information is now available.

1. Country or Territory
Name of country or territory where the glacier is located (for abbreviation, see Volume VII, p. 3).

2. Glacier Number (former PSFG number)
Numbering allows better identification of the glaciers and has proven to be especially helpful when dealing with glaciers having the same name, no name or names changing with time. National correspondents are therefore asked to give numbers to glaciers on which data are submitted for Volume VIII. Once a Glacier Number has been assigned to a glacier it will not be changed again. Please, therefore, refer to earlier volumes of the 'Fluctuations of Glaciers' or to the list on the Internet (http://geo.unizh.ch/wgms/fog/guidelines.html -> cf. List.pdf) when assigning the Glacier Number (= former PSFG number).
For glaciers **without** a (PSFG) number, the following guidelines are given for assigning the number: Glacier Number = number with max. 4 numerical digits or, as an exception, 5 digits.
In assigning the number to glaciers of present interest, it should be remembered that the need to number neighbouring glaciers may arise in the future. Accordingly, the numbering system which is adopted should leave 'spare numbers'. This could be done by using the left-hand digit(s) to denote geographical subdivisions, and the right-hand digit(s) to number single glaciers within each subdivision. The total number of digits used, 2–4, will depend on the size of the country and the degree of sophistication in identifying the geographical subdivisions. A glacier may advance or retreat enough to make it necessary in future to identify individual parts, e.g., a single front may become several distinct fronts, or else part of the glacier may become separated from the main glacier. In these exceptional cases, the fifth digit (alphabetic or numeric) should be used. Empty spaces should be filled with the digit 0.

3. Glacier Number in already published inventories
Only where a glacier number has been assigned in connection with a previously published National Glacier Inventory should this number be given.
Format: max. 16 digits.

4. Glacier Name
The name of the glacier should be written in **CAPITAL** letters.
Format: max. 15 column positions. If necessary, the name can be abbreviated; in this case, please give the full name under '16. Remarks'. In the case of uncertainty, please refer to earlier volumes of the 'Fluctuations of Glaciers' or to the list on the Internet:
http://geo.unizh.ch/wgms/fog/guidelines.html --> cf. List.pdf

5. Geographical Location (general)
By 'general geographical location' we mean the reference to a very large geographical entity (e.g., a large mountain range or a large political subdivision) which gives a rough idea of the location of the glacier without requiring the use of an atlas or map.
Examples: Western Alps, Southern Norway, Polar Ural, Tien Shan, Himalayas.
Format: similar to 4 (Glacier Name)

6. Geographical Location (more specific)
A more specific geographical location should be given here (mountain group, drainage basin, etc.) which can be found easily on a small-scale map of the country concerned.
Format: similar to 4 (Glacier Name)

7. Geographical Coordinates

The geographical coordinates should refer to a point in the upper ablation area; for small glaciers, this point may possibly lie outside the glacier.
As a general rule, the latitude and longitude should be indicated in sexagesimal degrees and minutes (no fraction of minutes) and be followed by the corresponding cardinal point.
Only where a small glacier is unnamed may it be necessary to give the coordinates more accurately for the sake of clear identification.
In such cases decimals of minutes - and not seconds - should be used.

8. Orientation

The main orientation of the accumulation area and of the ablation area should be given using the 8-point compass.

9. Highest Elevation

Altitude of the highest point of the glacier and the year of survey.

10. Median Elevation

Altitude of the contour line which halves the area of the glacier, and the year of survey.

11. Lowest Elevation

Altitude of the lowest point of the glacier and the year of survey.

12. Area

Total area of the glacier (in horizontal projection) and the year of survey.

13. Length

Maximum length of the glacier measured along the most important flowline (in horizontal projection) and the year of survey.

14. Rough Classification

This classification should be given in coded form according to 'Perennial Ice and Snow Masses' (Technical Papers in Hydrology, UNESCO/IAHS, 1970). The following information should be given:

- 'Primary classification' (Digit 1)
- 'Form' (Digit 2)
- 'Frontal characteristics' (Digit 3)

Code: (from 'Perennial Ice and Snow Masses', slightly revised)

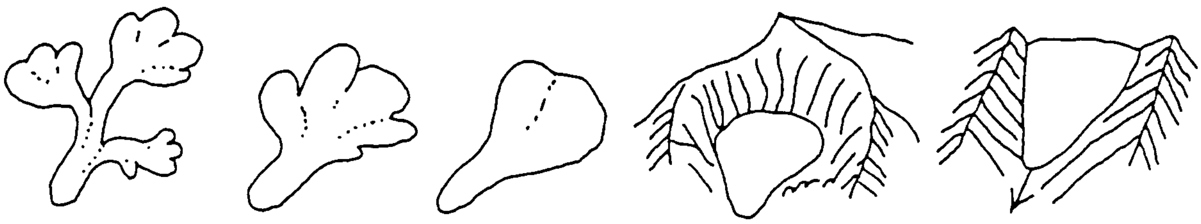
<u>Digit 1: Primary classification</u>

0	*Miscellaneous*	Any type not listed below (explain)
1	*Continental ice sheet*	Inundates areas of continental size
2	*Ice field*	Ice masses of sheet or blanket type of a thickness not sufficient to obscure the subsurface topography
3	*Ice cap*	Dome-shaped ice mass with radial flow
4	*Outlet glacier*	Drains an ice sheet, ice field or ice cap, usually of valley glacier form; the catchment area may not be clearly delineated
5	*Valley glacier*	Flows down a valley; the catchment area is well defined
6	*Mountain glacier*	Cirque, niche or crater type, hanging glacier; includes ice aprons and groups of small units

7	*Glacieret and snowfield*	Small ice masses of indefinite shape in hollows, river beds and on protected slopes, which has developed from snow drifting, avalanching and/or especially heavy accumulation in certain years; usually no marked flow pattern is visible; exists for at least two consecutive summers
8	*Ice shelf*	Floating ice sheet of considerable thickness attached to a coast nourished by glacier(s); snow accumulation on its surface or bottom freezing
9	*Rock glacier*	Lava-stream like debris mass containing ice in several possible forms and moving slowly downslope

Digit 2: Form

0	*Miscellaneous*	Any type not listed below (explain)
1	*Compound basins*	Two or more individual valley glaciers issuing from tributary valleys and coalescing (Fig. 1a)
2	*Compound basin*	Two or more individual accumulation basins feeding one glacier system (Fig. 1b)
3	*Simple basin*	Single accumulation area (Fig. 1c)
4	*Cirque*	Occupies a separate, rounded, steep-walled recess which it has formed on a mountain side (Fig. 1d)
5	*Niche*	Small glacier in V-shaped gully or depression on a mountain slope (Fig. 1e); generally more common than the genetically further developed cirque glacier
6	*Crater*	Occurring in extinct or dormant volcanic craters
7	*Ice apron*	Irregular, usually thin ice mass plastered along a mountain slope or ridge
8	*Group*	A number of similar small ice masses occurring in close proximity and too small to be assessed individually
9	*Remnant*	An inactive, usually small ice mass left by a receding glacier



1a 1b 1c 1d 1e

Digit 3: Frontal characteristics

0	*Miscellaneous*	Any type not listed below (explain)
1	*Piedmont*	Ice field formed on a lowland by lateral expansion of one or coalescence of several glaciers (Fig. 2a, 2b)

2	*Expanded foot*	Lobe or fan formed where the lower portion of the glacier leaves the confining wall of a valley and extends on to a less restricted and more level surface (Fig. 2c)
3	*Lobed*	Part of an ice sheet or ice cap, disqualified as an outlet or valley glacier (Fig. 2d)
4	*Calving*	Terminus of a glacier sufficiently extending into sea or lake water to produce icebergs; includes - for this inventory - dry land calving which would be recognisable from the 'lowest glacier elevation'

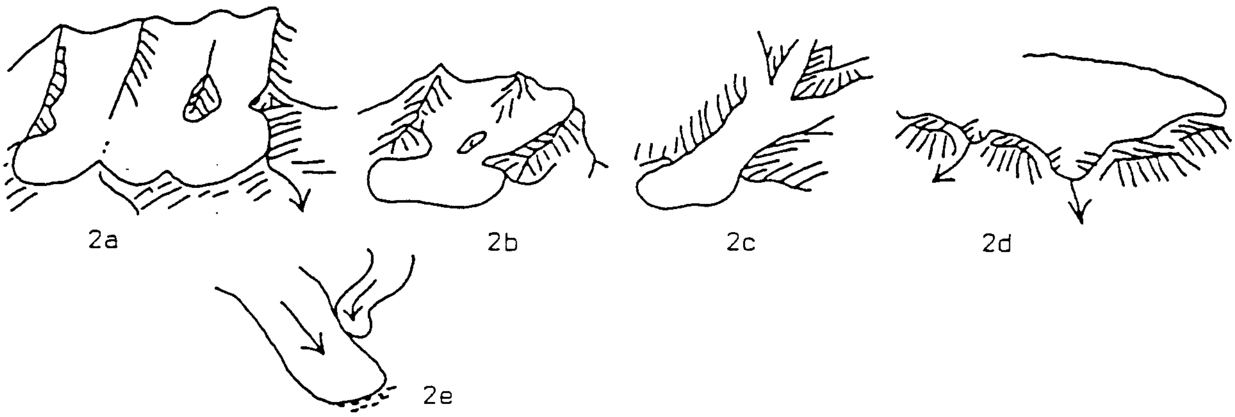
5 *Coalescing, non-contributing* (Fig. 2e)

6 *Irregular, mainly clean ice* (mountain or valley glaciers)

7 *Irregular, debris-covered* (mountain or valley glaciers)

8 *Single lobe, mainly clean ice* (mountain or valley glaciers)

9 *Single lobe, debris-covered* (mountain or valley glaciers)



15. Number of data sheets submitted
Number of data sheets submitted for this glacier concerning information on Variations in the Position of Glacier Fronts, Mass Balance Study Results - Summary Data etc.

16. Remarks
Any important information or comments not included above may be given here. Comments about the accuracy of the various numerical data may be made. No fields for quantitative accuracy ratings of the various data have been given on the data sheet; especially poor data should be marked with an asterisk on the right-hand side of the appropriate field. Only significant decimals should be given for area and length.

GUIDELINES FOR ELECTRONIC DATA TRANSFER FOR 'GENERAL INFORMATION ON THE OBSERVED GLACIERS 1995–2000'

For electronic submission of your data on 'General Information on the Observed Glaciers 1995–2000' please remember the following points:

1. Use either E-Mail (E-Mail address: **wgms@geo.unizh.ch**) and send your document on the 'General Information' as an attachment or

   send us a **MS-DOS or Macintosh formatted diskette** with your document on the 'General Information'.

2. The document must be saved as **plain ASCII code** and should be named '**GenInfo.country code**' (e.g. 'GenInfo.CH' for Switzerland).

3. Use the following **format** to enter your data:

   A record contains data belonging to one single glacier. A field within a record starts with a **code containing 3 digits**. Each code is attributed to a field name (e.g. area of the glacier) of the table on the 'General Information'. All codes and their meaning are listed below. The data fields follow exactly the order of the data sheets in paper form. Right after each code you enter **the data value belonging to the corresponding code**. **Separate the code and the corresponding field value by a blank (' ')**. After each line you enter a **carriage return**. If a field remains blank (because there are no data available or they were supplied in a previous stage) **give the code and enter a blank and a colon (:)** for the missing data. Please **do not enter a blank line to separate individual records**.

   Please strictly use the given format. This is essential for correctly transferring your data to the database.

   Codes and their corresponding meaning for 'General Information on the Observed Glaciers 1995–2000':

   101 COUNTRY OR TERRITORY (up to 20 characters allowed)

   102 COUNTRY ABBR. (for abbreviations, see Volume VII, p. 3)

   103 GLACIER NUMBER (former PSFG number)

   104 GLACIER NUMBER (in already published inventories)

   105 GLACIER NAME (up to 15 characters allowed)

   106 GENERAL GEOGRAPHICAL LOCATION (up to 15 characters allowed)

   107 MORE SPECIFIC GEOGRAPHICAL LOCATION (up to 15 characters allowed)

   108 LATITUDE (in degrees, e.g. 45.56)

   109 CARD. POINT LATITUDE (e.g. N)

   110 LONGITUDE (in degrees, e.g. 10.32)

   111 CARD. POINT LONGITUDE (e.g. W)

   112 ORIENTATION OF ACCUMULATION AREA (e.g. NW)

   113 ORIENTATION OF ABLATION AREA (e.g. SE)

   114 HIGHEST ELEVATION (m a.s.l.)

   115 MEASUREMENT YEAR OF HIGHEST ELEVATION

   116 MEDIAN ELEVATION (m a.s.l.)

   117 MEASUREMENT YEAR OF MEDIAN ELEVATION

   118 LOWEST ELEVATION (m a.s.l.)

   119 MEASUREMENT YEAR OF LOWEST ELEVATION

   120 AREA (km^2)

   121 MEASUREMENT YEAR OF AREA

   122 LENGTH (km)

   123 MEASUREMENT YEAR OF LENGTH

   124 ROUGH CLASSIFICATION (3 digits)

   125 NUMBER OF DATA SHEETS SUBMITTED FOR VARIATIONS IN THE POSITION OF GLACIER FRONTS

   126 NUMBER OF DATA SHEETS SUBMITTED FOR VARIATIONS ADDENDA FROM EARLIER YEARS

   127 NUMBER OF DATA SHEETS SUBMITTED FOR MASS BALANCE SUMMARY DATA

   128 NUMBER OF DATA SHEETS SUBMITTED FOR MASS BALANCE ADDENDA FROM EARLIER YEARS

   129 NUMBER OF DATA SHEETS SUBMITTED FOR MASS BALANCE VERSUS ALTITUDE

   130 NUMBER OF DATA SHEETS SUBMITTED FOR CHANGES IN AREA, VOLUME AND THICKNESS

   131 NUMBER OF DATA SHEETS SUBMITTED FOR HYDROMETEOROLOGICAL DATA

   132 NUMBER OF DATA SHEETS SUBMITTED FOR SPECIAL EVENTS

   133 REMARKS (up to 500 characters allowed)

   134 DATA SHEET COMPILED BY (up to 15 characters allowed)

4. ***Example of how the electronic data sheet 'General Information on the Observed Glaciers 1995–2000' should look like:***

101 SWITZERLAND
102 CH
103 00090
104 :
105 SILVRETTA
106 :
107 :
108 :
109 :
110 :
111 :
112 :
113 :
114 3150
115 2000
116 :
117 :
118 2450
119 2000
120 3.2
121 2000
122 2.8
123 2000
124 626
125 1
126 :
127 1
128 :
129 1
130 :
131 :
132 :
133 :
134 DR. M. HOELZLE
101 SWITZERLAND
102 CH
103 00053
104 :
105 STEIN
106 :
107 :
108 :
109 :
110 :
111 :
112 :
113 :

114 :
115 :
116 :
117 :
118 1950
119 2000
120 7.8
121 2000
122 5.2
123 2000
124 528
125 1
126 :
127 1
128 :
129 :
130 :
131 :
132 :
133 :
134 DR. M. HOELZLE

5. The previous explanations to the different record fields ('Notes on the Completion of the Data Sheet') apply equally to the electronic data entry - unless otherwise specified in the 'Guidelines for electronic data transfer'.

6. Please note that due to limited staff **electronic data can only be accepted when keeping strictly to the above-mentioned format**. Thank you for your collaboration!

WORLD GLACIER MONITORING SERVICE
MASS BALANCE STUDY RESULTS
SUMMARY DATA 1995–2000

NOTES ON THE COMPLETION OF THE DATA SHEET

The present data sheet tries to accommodate inherent ambiguities in mass balance data by providing several data fields. It is not expected that all fields on the data sheet can be completed fully.

The terminology used here mainly follows that given in the UNESCO/IAHS publication 'Combined heat, ice and water balances at selected basins' (Technical Papers in Hydrology No. 5, 1970, Appendix 2). To avoid confusion and to assure continuity of the reported data, the same terms are used as in Volumes III, IV, V, VI and VII. It remains the task of national correspondents to define the exact meaning of the given information as carefully as possible.

1. **Country or Territory**
   Name of country or territory where the glacier is located (for abbreviation, see Volume VII, p. 3).

2. **Glacier Number (former PSFG number)**
   See 'Notes on the completion of the data sheet: GENERAL INFORMATION ON THE OBSERVED GLACIERS'.

3. **Glacier Name**
   The name of the glacier should be written in **CAPITAL** letters.

4. **Start of continuous mass balance measurements**
   Year when continuous measurement of mass balance started.

5. **Time System**
   The appropriate code number should be entered here:
   1 = stratigraphic system
   2 = fixed date system
   3 = combined system
   4 = other (please explain under '22. Remarks')
   Where it is not clear whether the method of measurement corresponds to the 'stratigraphic' or to the 'fixed date' system, the box for 'other' should be marked and an appropriate comment made under '22. Remarks'. Note that observations with the 'combined system' (Mayo et al. 1972) contain more information than can be given in the data sheet.

6. **Number of Measurement Points**
   Number of minimum and maximum measurement sites in the accumulation and ablation areas.

7. **Beginning of Balance/Measurement Year**
   Day, month and year of the beginning of the balance year (stratigraphic system), if known, or day, month and year of the beginning of the measurement year (fixed date system). Format: DD-MMM-YYYY

8. **End of Winter Season**
   Day, month and year of the end of the winter season (if known). Format: as in 7.

9. **End of Balance/Measurement Year**
   Day, month and year of the end of the balance year (stratigraphic system), if known, or day, month and year of the end of the measurement year (fixed date system). Format: as in 7.

10. **Winter Balance (specific)**
    ('specific' means 'total' value divided by the total area of the glacier).

11. Summer Balance (specific)
Similar to 10.

12. Net Accumulation (specific)
Definition: 'net accumulation (specific)' = 'net accumulation (total)' divided by the area of the accumulation area.

13. Net Ablation (specific)
Similar to 12.

14. Net/Annual Balance (specific)
Similar to 10.
Sign: + : mass increase
- : mass decrease

15. Accumulation Area

16. Ablation Area

17. Total Area

18. Accumulation Area Ratio
Accumulation area (15.) divided by the total area (17.) multiplied by 100.

19. Equilibrium Line/Annual Equilibrium Line
Mean altitude (averaged over the glacier) of the equilibrium line/annual equilibrium line.

20. Investigator(s)
Name(s) of the person(s) or agency doing the field work and/or the name(s) of the person(s) or agency processing the data.

21. Sponsoring Agency

Full name, abbreviation and address of the agency where the data are held.

22. Remarks
Any important information or comments not included above may be given here. If a regular survey has been discontinued for some reason, it should be indicated here.

GUIDELINES FOR ELECTRONIC DATA TRANSFER FOR 'MASS BALANCE STUDY RESULTS SUMMARY DATA 1995–2000'

For electronic submission of your data on 'Mass Balance Study Results Summary Data 1995–2000' please remember the following points:

1. Use either E-Mail (E-Mail address: **wgms@geo.unizh.ch**) and send your document on the 'Mass Balance Study Results' as an attachment or

   send us a **MS-DOS or Macintosh formatted diskette** with your document on the 'Mass Balance Study Results'.

2. The document must be saved as **plain ASCII code** and should be named '**MassBal.country code**' (e.g. 'MassBal.CH' for Switzerland). If you send data as an **'Addenda from earlier years'**, use the following name: '**MassAdd.country code'** (e.g. 'MassAdd.CH' for Switzerland).

3. Use the following **format** to enter your data:

   A record contains data belonging to one single glacier. A field within a record starts with a **code containing 3 digits**. Each code is attributed to a field name (e.g. Winter Balance specific) of the table on 'Mass Balance Study Results'. All codes and their meaning are listed below. Please note that there are **different codes (4 digits) for data you supply as 'Addenda from earlier years'**. Right after each code you enter **the data value belonging to the corresponding code**. **Separate the code and the corresponding field value by a blank (' ')**. After each line you enter a **carriage return**. If a field remains blank (because there are no data available) **give the code and enter a blank and a colon (:)** for the missing data. Please **do not enter a blank line to separate individual records**.

Please strictly use the given format. This is essential for correctly transferring your data to the database.

Codes and their corresponding meaning for 'Mass Balance Study Results Summary Data 1995-2000':

401 COUNTRY OR TERRITORY (up to 20 characters allowed)

402 GLACIER NUMBER (former PSFG number)

403 GLACIER NAME (up to 15 characters allowed)

404 START OF CONTINUOUS MASS BALANCE MEASUREMENTS (e.g., 1978)

405 TIME SYSTEM (1, 2, 3, or 4; see 'Notes on the Completion of the Data Sheet: Mass Balance Study Results Summary Data 1995-2000; 5. Time System)

406 NUMBER OF MINIMUM MEASUREMENT POINTS IN THE ACCUMULATION AREA

407 NUMBER OF MAXIMUM MEASUREMENT POINTS IN THE ACCUMULATION AREA

408 NUMBER OF MINIMUM MEASUREMENT POINTS IN THE ABLATION AREA

409 NUMBER OF MAXIMUM MEASUREMENT POINTS IN THE ABLATION AREA

Codes for Balance/Measurement Year 1995/96:

410 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1995)

411 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1995)

412 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1996)

413 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1996)

414 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1996)

415 WINTER BALANCE SPECIFIC (in mm w.e.)

416 SUMMER BALANCE SPECIFIC (in mm w.e.)

417 NET ACCUMULATION SPECIFIC (in mm w.e.)

418 NET ABLATION SPECIFIC (in mm w.e.)

419 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

420 ACCUMULATION AREA (in km^2)

421 ABLATION AREA (in km^2)

422 TOTAL AREA (in km^2)

423 AAR (in %)

424 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

Codes for Balance/Measurement Year 1996/97:

425 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1996)

426 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1996)

427 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1997)

428 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1997)

429 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1997)

430 WINTER BALANCE SPECIFIC (in mm w.e.)

431 SUMMER BALANCE SPECIFIC (in mm w.e.)

432 NET ACCUMULATION SPECIFIC (in mm w.e.)

433 NET ABLATION SPECIFIC (in mm w.e.)

434 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

435 ACCUMULATION AREA (in km^2)

436 ABLATION AREA (in km^2)

437 TOTAL AREA (in km^2)

438 AAR (in %)

439 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

Codes for Balance/Measurement Year 1997/98:

440 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1997)

441 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1997)

442 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1998)

443 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1998)

444 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1998)

445 WINTER BALANCE SPECIFIC (in mm w.e.)

446 SUMMER BALANCE SPECIFIC (in mm w.e.)

447 NET ACCUMULATION SPECIFIC (in mm w.e.)

448 NET ABLATION SPECIFIC (in mm w.e.)

449 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

450 ACCUMULATION AREA (in km^2)

451 ABLATION AREA (in km^2)

452 TOTAL AREA (in km^2)

453 AAR (in %)

454 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

Codes for Balance/Measurement Year 1998/99:

455 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1998)

456 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1998)

457 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1999)

458 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1999)

459 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1999)

460 WINTER BALANCE SPECIFIC (in mm w.e.)

461 SUMMER BALANCE SPECIFIC (in mm w.e.)

462 NET ACCUMULATION SPECIFIC (in mm w.e.)

463 NET ABLATION SPECIFIC (in mm w.e.)

464 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

465 ACCUMULATION AREA (in km^2)

466 ABLATION AREA (in km^2)

467 TOTAL AREA (in km^2)

468 AAR (in %)

469 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

Codes for Balance/Measurement Year 1999/2000:

470 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1999)

471 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1999)

472 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-2000)

473 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-2000)

474 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-2000)

475 WINTER BALANCE SPECIFIC (in mm w.e.)

476 SUMMER BALANCE SPECIFIC (in mm w.e.)

477 NET ACCUMULATION SPECIFIC (in mm w.e.)

478 NET ABLATION SPECIFIC (in mm w.e.)

479 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

480 ACCUMULATION AREA (in km^2)

481 ABLATION AREA (in km^2)

482 TOTAL AREA (in km^2)

483 AAR (in %)

484 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

485 INVESTIGATOR(S)

486 SPONSORING AGENCY

487 REMARKS (up to 500 characters allowed)

488 DATA SHEET COMPILED BY (up to 15 characters allowed)

Codes and their corresponding meaning for 'Mass Balance Study Results Summary Data, Addenda from earlier years':

5001 COUNTRY OR TERRITORY (up to 20 characters allowed)

5002 GLACIER NUMBER (former PSFG number)

5003 GLACIER NAME (up to 15 characters allowed)

5004 START OF CONTINUOUS MASS BALANCE MEASUREMENTS (e.g., 1978)

5005 TIME SYSTEM (1, 2, 3, or 4; see 'Notes on the Completion of the Data Sheet: Mass Balance Study Results Summary Data 1995-2000; 5. Time System)

5006 NUMBER OF MINIMUM MEASUREMENT POINTS IN THE ACCUMULATION AREA

5007 NUMBER OF MAXIMUM MEASUREMENT POINTS IN THE ACCUMULATION AREA

5008 NUMBER OF MINIMUM MEASUREMENT POINTS IN THE ABLATION AREA

5009 NUMBER OF MAXIMUM MEASUREMENT POINTS IN THE ABLATION AREA

Codes for Balance/Measurement Year 19../19..:

5010 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1984)

5011 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1984)

5012 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1985)

5013 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1985)

5014 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1985)

5015 WINTER BALANCE SPECIFIC (in mm w.e.)

5016 SUMMER BALANCE SPECIFIC (in mm w.e.)

5017 NET ACCUMULATION SPECIFIC (in mm w.e.)

5018 NET ABLATION SPECIFIC (in mm w.e.)

5019 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

5020 ACCUMULATION AREA (in km^2)

5021 ABLATION AREA (in km^2)

5022 TOTAL AREA (in km^2)

5023 AAR (in %)

5024 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

Codes for Balance/Measurement Year 19../..:

5025 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1985)

5026 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1985)

5027 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1986)

5028 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1986)

5029 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1986)

5030 WINTER BALANCE SPECIFIC (in mm w.e.)

5031 SUMMER BALANCE SPECIFIC (in mm w.e.)

5032 NET ACCUMULATION SPECIFIC (in mm w.e.)

5033 NET ABLATION SPECIFIC (in mm w.e.)

5034 NET/ANNUAL BALANCE SPECIFIC (in mm w.e.)

5035 ACCUMULATION AREA (in km^2)

5036 ABLATION AREA (in km^2)

5037 TOTAL AREA (in km^2)

5038 AAR (in %)

5039 EQUILIBRIUM LINE/ANNUAL EQUILIBRIUM LINE (m a.s.l.)

etc.

5991 INVESTIGATOR(S)

5992 SPONSORING AGENCY

5993 REMARKS (up to 500 characters allowed)

5994 DATA SHEET COMPILED BY (up to 15 characters allowed)

4. *Example of how the electronic data sheet 'Mass Balance Study Results Summary Data, Addenda from earlier years' should look like:*

5001 SWITZERLAND

5002 00090

5003 SILVRETTA

5004 1960

5005 2

5006 2

5007 3

5008 3

5009 5

5010 :

5011 01-SEP-1984

5012 15-MAY-1985

5013 :

5014 01-SEP-1985

5015 2100

5016 -1800

5017 :

5018 :

5019 300

5020 1.8

5021 1.4

5022 3.2

5023 56

5024 2750

5025 :

5026 01-SEP-1985

5027 23-MAY-1986

5028 :

5029 01-SEP-1986

5030 2450

5031 -3100

5032 :

5033 :

5034 -650

5035 0.8

5036 2.4

5037 3.2

5038 25

5039 2920

5991 DEPARMENT OF GEOGRAPHY, UNIVERSITY OF ZURICH

5992 DEPARMENT OF GEOGRAPHY, UNIVERSITY OF ZURICH

5993 :

5994 DR. M. HOELZLE

5. The previous explanations to the different record fields ('Notes on the Completion of the Data Sheet') apply equally to the electronic data entry - unless otherwise specified in the 'Guidelines for electronic data transfer'.

6. Please note that due to limited staff **electronic data can only be accepted when keeping strictly to the above-mentioned format**. Thank you for your collaboration!

WORLD GLACIER MONITORING SERVICE
MASS BALANCE VERSUS ALTITUDE FOR SELECTED GLACIERS

GUIDELINES FOR ELECTRONIC DATA TRANSFER FOR 'MASS BALANCE VERSUS ALTITUDE FOR SELECTED GLACIERS'

For electronic submission of your data on 'Mass Balance versus Altitude' please remember the following points:

1. Use either E-Mail (E-Mail address: **wgms@geo.unizh.ch**) and send your document on the 'Mass Balance versus Altitude' as an attachment or

   send us a **MS-DOS or Macintosh formatted diskette** with your document on the 'Mass Balance versus Altitude'.

2. The document must be saved as **plain ASCII code** and should be named '**BalvsAlt.country code**' (e.g. 'BalvsAlt.CH' for Switzerland).

3. Use the following **format** to enter your data:

   A record contains data belonging to one single glacier. A field within a record starts with a **code containing 6 digits**. Each code is attributed to a field name (e.g. Mean Specific Winter Balance) of the table on 'Mass Balance versus Altitude'. All codes and their meaning are listed below. Right after each code you enter **the data value belonging to the corresponding code**. **Separate the code and the corresponding field value by a blank (' ')**. After each line you enter a **carriage return**. If a field remains blank (because there are no data available) **give the code and enter a blank and a colon (:)** for the missing data. Please **do not enter a blank line to separate individual records**.

   Please strictly use the given format. This is essential for correctly transferring your data to the database.

   Codes and their corresponding meaning for 'Mass Balance versus Altitude for Selected Glaciers':

   600001 COUNTRY ABBR. (for abbreviations, see Volume VII, p. 3)

   600002 GLACIER NUMBER (former PSFG number)

   600003 GLACIER NAME (up to 15 characters allowed)

   600004 MEASUREMENTS SINCE (DD-MMM-YYYY, e.g. 01-SEP-1975)

   Codes for Balance/Measurement Year 19../..:

   600005 TIME SYSTEM (1, 2, 3, or 4; see 'Notes on the Completion of the Data Sheet: Mass Balance Study Results Summary Data 1995-2000; 5. Time System)

   600006 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1995)

   600007 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1995)

   600008 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1996)

   600009 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1996)

   600010 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1996)

   600011 MEASUREMENT YEAR (if the investigated measurement period is e.g. 1995-1996, then the measurement year is 1996)

   Codes for Altitude Interval from .... m to .... m:

   600012 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1200 m a.s.l.)

   600013 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1300 m a.s.l.)

   600014 AREA (in km^2; area of altitude interval)

   600015 MEAN SPECIFIC WINTER BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

   600016 MEAN SPECIFIC SUMMER BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

   600017 MEAN SPECIFIC NET OR ANNUAL BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

   Codes for Altitude Interval from .... m to .... m:

600018 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1300 m a.s.l.)

600019 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1400 m a.s.l.)

600020 AREA (in km^2; area of altitude interval)

600021 MEAN SPECIFIC WINTER BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

600022 MEAN SPECIFIC SUMMER BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

600023 MEAN SPECIFIC NET OR ANNUAL BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

etc.

600991 TOTAL AREA (in km^2; sum of the area of all altitude intervals)

600992 MEAN SPECIFIC WINTER BALANCE COMPUTED FROM DATA OF THE INDIVIDUAL ALTITUDE INTERVALS (in mm w.e.)

600993 MEAN SPECIFIC SUMMER BALANCE COMPUTED FROM DATA OF THE INDIVIDUAL ALTITUDE INTERVALS (in mm w.e.)

600994 MEAN SPECIFIC NET OR ANNUAL BALANCE COMPUTED FROM DATA OF THE INDIVIDUAL ALTITUDE INTERVALS (in mm w.e.)

Codes for Balance/Measurement Year 19../..:

601001 TIME SYSTEM (1, 2, 3, or 4; see 'Notes on the Completion of the Data Sheet: Mass Balance Study Results Summary Data 1995-2000; 5. Time System)

601002 BEGIN OF BALANCE YEAR (DD-MMM-YYYY, e.g. 22-SEP-1996)

601003 BEGIN OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1996)

601004 END OF WINTER SEASON (DD-MMM-YYYY, e.g. 08-MAY-1997)

601005 END OF BALANCE YEAR (DD-MMM-YYYY, e.g. 15-SEP-1997)

601006 END OF MEASUREMENT YEAR (DD-MMM-YYYY, e.g. 01-SEP-1997)

601007 MEASUREMENT YEAR (if the investigated measurement period is e.g. 1995-1996, then the measurement year is 1996)

Codes for Altitude Interval from .... m to .... m:

601008 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1200 m a.s.l.)

601009 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1300 m a.s.l.)

601010 AREA (in km^2; area of altitude interval)

601011 MEAN SPECIFIC WINTER BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

601012 MEAN SPECIFIC SUMMER BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

601013 MEAN SPECIFIC NET OR ANNUAL BALANCE OF THE ALTITUDE INTERVAL (in mm w.e.)

Codes for Altitude Interval from .... m to .... m:

601014 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1300 m a.s.l.)

etc.

601991 TOTAL AREA (in km^2; sum of the area of all altitude intervals)

601992 MEAN SPECIFIC WINTER BALANCE COMPUTED FROM DATA OF THE INDIVIDUAL ALTITUDE INTERVALS (in mm w.e.)

601993 MEAN SPECIFIC SUMMER BALANCE COMPUTED FROM DATA OF THE INDIVIDUAL ALTITUDE INTERVALS (in mm w.e.)

601994 MEAN SPECIFIC NET OR ANNUAL BALANCE COMPUTED FROM DATA OF THE INDIVIDUAL ALTITUDE INTERVALS (in mm w.e.)

4. *Example of how the electronic data sheet 'Mass Balance versus Altitude' should look like:*

600001 CH

600002 00090

600003 SILVRETTA

600004 01-JAN-60

600005 2

600006 :

600007 01-SEP-1995

600008 08-MAY-1996

600009 :

600010 01-SEP-1996
600011 1996
600012 2400
600013 2500
600014 0.031
600015 :
600016 :
600017 -2960
600018 2500
600019 2600
600020 0.385
600021 :
600022 :
600023 -1790
etc.
600991 3.15
600992 :
600993 :
600994 -250
601001 2
601002 :
601003 01-SEP-1996
601004 15-MAY-1997
601005 :
601006 01-SEP-1997
601007 1997
601008 2400
601009 2500
601010 0.031
601011 :
601012 :
601013 -3360
601014 2500
601015 2600
601016 0.385
601017 :
601018 :
601019 -2140
etc.
601991 3.15
601992 :
601993 :
601994 -530

5. Please note that due to limited staff **electronic data can only be accepted when keeping strictly to the above-mentioned format**. Thank you for your collaboration!

WORLD GLACIER MONITORING SERVICE
VARIATIONS IN THE POSITION OF GLACIER FRONTS 1995–2000

NOTES ON THE COMPLETION OF THE DATA SHEET

1. **Country or Territory**
Name of country or territory where the glacier is located (for abbreviation, see Volume VII, p. 3).

2. **Glacier Number (former PSFG number)**
See 'Notes on the completion of the data sheet: GENERAL INFORMATION ON THE OBSERVED GLACIERS'.

3. **Glacier Name**
The name of the glacier should be written in **CAPITAL** letters.

4. **Observed since**
Year of the first known quantitative survey.

5. **Date of Initial Survey for Reported Period**
'Initial survey' is defined here as the last survey performed before 1996, whereby the position or the variation in the position of the glacier front was determined quantitatively.
The 'initial survey' will normally be the 1995 survey. If no survey was carried out in 1995, or if only qualitative data are available for 1995, the 'initial survey' will, of course, be an earlier **quantitative** one.

6. **Variation (Previous Survey to 19.. Survey)**
(refers also to 9, 12, 15 and 18)
Variation in horizontal projection between previous survey and present survey.
Units: metres
Sign: + advance
- retreat
<u>Qualitative data:</u>
If no quantitative data are available for a particular year, but qualitative data are available, then variations should be denoted by using the following symbols:
ST : no apparent variation (stationary)
+X : apparent advance (numerical value unknown)
-X : apparent retreat (numerical value unknown)
SN : glacier tongue is covered with snow making survey impossible.
In the case of qualitative data, the variations will be understood with reference to the previous survey, whether quantitative or qualitative.

7. **Altitude of Snout/Lowest Point**
(refers also to 10, 13, 16 and 19)
If the altitude of the snout or the lowest point of the glacier has also been measured, it should be indicated in the corresponding data field and the inappropriate term (i.e., snout or lowest point) should be deleted.

8. **Date of Survey**
(refers also to 11, 14, 17 and 20)
For each survey performed, please indicate the complete date (day, month, year, Format: DD-MMM-YYYY).
Day unknown or day and month unknown: put 01-JAN-YYYY.

21. **Error**
Estimated maximum error

22. Method

The following indications should be given here:
A = aerial photogrammetry
B = terrestrial photogrammetry
C = geodetic ground survey (theodolite, tape, etc.)
D = combination of a, b or c (please explain under '25. Remarks')
E = other methods (please explain under '25. Remarks') or no information

23. Investigator(s)

Name(s) of the person(s) or agency doing the field work and/or the name(s) of the person(s) or agency processing the data.

24. Sponsoring Agency

Full name, abbreviation and address of the agency where the data are held.

25. Remarks

Any important information or comments not included above may be given here. If a **regular** survey has been discontinued for some reason, this should be indicated here.

GUIDELINES FOR ELECTRONIC DATA TRANSFER FOR 'VARIATIONS IN THE POSITION OF GLACIER FRONTS 1995-2000'

For electronic submission of your data on 'Variations in the Position of Glacier Fronts 1995–2000' please remember the following points:

1. Use either E-Mail (E-Mail address: **wgms@geo.unizh.ch**) and send your document on the 'Variations in the Position of Glacier Fronts' as an attachment or

   send us a **MS-DOS or Macintosh formatted diskette** with your document on the 'Variations in the Position of Glacier Fronts'.

2. The document must be saved as **plain ASCII code** and should be named '**VarFront.country code**' (e.g. 'VarFront.CH' for Switzerland). If you send data as an **'Addenda from earlier years'**, use the following name: '**VarAdd.country code'** (e.g. 'VarAdd.CH' for Switzerland).

3. Use the following **format** to enter your data:

   A record contains data belonging to one single glacier. A field within a record starts with a **code containing 3 digits**. Each code is attributed to a field name (e.g. Variation) of the table on 'Variations in the Position of Glacier Fronts'. All codes and their meaning are listed below. Please note that there are **different codes (4 digits) for data you supply as 'Addenda from earlier years'**. The data fields follow exactly the order of the data sheets in paper form. Right after each code you enter **the data value belonging to the corresponding code**. **Separate the code and the corresponding field value by a blank (' ')**. After each line you enter a **carriage return**. If a field remains blank (because there are no data available) **give the code and enter a blank and a colon (:)** for the missing data. Please **do not enter a blank line to separate individual records**.

   Please strictly use the given format. This is essential for correctly transferring your data to the database.

   Codes and their corresponding meaning for 'Variations in the Position of Glacier Fronts 1995-2000':

   201 COUNTRY OR TERRITORY (up to 20 characters allowed)

   202 GLACIER NUMBER (former PSFG number)

   203 GLACIER NAME (up to 15 characters allowed)

   204 OBSERVED SINCE (year)

   205 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1996)

   206 DATE OF PREVIOUS SURVEY PRIOR TO 1996 SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1995)

207 QUANTITATIVE VARIATION (previous survey to 1996, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

208 QUALITATIVE VARIATION (previous survey to 1996, e.g. +X for an apparent advance)

209 ALTITUDE OF SNOUT (m a.s.l.)

210 ALTITUDE OF LOWEST POINT (m a.s.l.)

211 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1997)

212 DATE OF PREVIOUS SURVEY PRIOR TO 1997 SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1996)

213 QUANTITATIVE VARIATION (previous survey to 1997, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

214 QUALITATIVE VARIATION (previous survey to 1997, e.g. +X for an apparent advance)

215 ALTITUDE OF SNOUT (m a.s.l.)

216 ALTITUDE OF LOWEST POINT (m a.s.l.)

217 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1998)

218 DATE OF PREVIOUS SURVEY PRIOR TO 1998 SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1997)

219 QUANTITATIVE VARIATION (previous survey to 1998, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

220 QUALITATIVE VARIATION (previous survey to 1998, e.g. +X for an apparent advance)

221 ALTITUDE OF SNOUT (m a.s.l.)

222 ALTITUDE OF LOWEST POINT (m a.s.l.)

223 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1999)

224 DATE OF PREVIOUS SURVEY PRIOR TO 1999 SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1998)

225 QUANTITATIVE VARIATION (previous survey to 1999, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

226 QUALITATIVE VARIATION (previous survey to 1999, e.g. +X for an apparent advance)

227 ALTITUDE OF SNOUT (m a.s.l.)

228 ALTITUDE OF LOWEST POINT (m a.s.l.)

229 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-2000)

230 DATE OF PREVIOUS SURVEY PRIOR TO 2000 SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1999)

231 QUANTITATIVE VARIATION (previous survey to 2000, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

232 QUALITATIVE VARIATION (previous survey to 2000, e.g. +X for an apparent advance)

233 ALTITUDE OF SNOUT (m a.s.l.)

234 ALTITUDE OF LOWEST POINT (m a.s.l.)

235 ERROR IN VARIATIONS (in m, e.g. 5 for an error of ± 5 m)

236 ERROR IN ALTITUDES (in m, e.g. 10 for an error of ± 10 m)

237 METHOD (e.g. 'A' for aerial photogrammetry)

238 INVESTIGATOR(S)

239 SPONSORING AGENCY

240 REMARKS (up to 500 characters allowed)

241 DATA SHEET COMPILED BY (up to 15 characters allowed)

Codes and their corresponding meaning for 'Variations in the Position of Glacier Fronts, Addenda from earlier years':

3001 COUNTRY OR TERRITORY (up to 20 characters allowed)

3002 GLACIER NUMBER (former PSFG number)

3003 GLACIER NAME (up to 15 characters allowed)

3004 OBSERVED SINCE (year)

3005 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1983)

3006 DATE OF PREVIOUS SURVEY PRIOR TO 19?? SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1982)

3007 QUANTITATIVE VARIATION (previous survey to 19??, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

3008 QUALITATIVE VARIATION (previous survey to 19??, e.g. +X for an apparent advance)

3009 ALTITUDE OF SNOUT (m a.s.l.)

3010 ALTITUDE OF LOWEST POINT (m a.s.l.)

3011 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1984)

3012 DATE OF PREVIOUS SURVEY PRIOR TO 19?? SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1983)

3013 QUANTITATIVE VARIATION (previous survey to 19??, in m, e.g. 34.5 for an advance of 34.5 m or -34.5 for a retreat of 34.5 m)

3014 QUALITATIVE VARIATION (previous survey to 19??, e.g. +X for an apparent advance)

3015 ALTITUDE OF SNOUT (m a.s.l.)

3016 ALTITUDE OF LOWEST POINT (m a.s.l.)

3017 DATE OF SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1985)

3018 DATE OF PREVIOUS SURVEY PRIOR TO 19?? SURVEY (DD-MMM-YYYY, e.g. 01-SEP-1984)

etc.

3991 ERROR IN VARIATIONS (in m, e.g. 5 for an error of ± 5 m)

3992 ERROR IN ALTITUDES (in m, e.g. 10 for an error of ± 10 m)

3993 METHOD (e.g. 'A' for aerial photogrammetry)

3994 INVESTIGATOR(S)

3995 SPONSORING AGENCY

3996 REMARKS (up to 500 characters allowed)

3997 DATA SHEET COMPILED BY (up to 15 characters allowed)

4. *Example of how the electronic data sheet 'Variations in the Position of Glacier Fronts, Addenda from earlier years' should look like:*

3001 SWITZERLAND

3002 00090

3003 SILVRETTA

3004 1956

3005 01-SEP-1982

3006 01-SEP-1981

3007 25.6

3008 :

3009 :

3010 2445

3011 01-SEP-1983

3012 01-SEP-1982

3013 -20.0

3014 :

3015 :

3016 2448

3017 01-SEP-1984

3018 01-SEP-1983

3019 -5.6

3020 :

3021 :

3022 2450

3991 0.1

3992 0.2

3993 C
3994 DEPARMENT OF GEOGRAPHY, UNIVERSITY OF ZURICH
3995 DEPARMENT OF GEOGRAPHY, UNIVERSITY OF ZURICH
3996 :
3997 DR. M. HOELZLE

5. The previous explanations to the different record fields ('Notes on the Completion of the Data Sheet') apply equally to the electronic data entry - unless otherwise specified in the 'Guidelines for electronic data transfer'.

6. Please note that due to limited staff **electronic data can only be accepted when keeping strictly to the above-mentioned format**. Thank you for your collaboration!

WORLD GLACIER MONITORING SERVICE
CHANGES IN AREA, VOLUME AND THICKNESS

GUIDELINES FOR ELECTRONIC DATA TRANSFER FOR 'CHANGES IN AREA, VOLUME AND THICKNESS'

For electronic submission of your data on 'Changes in Area, Volume and Thickness' please remember the following points:

1. Use either E-Mail (E-Mail address: **wgms@geo.unizh.ch**) and send your document on the 'Changes in Area, Volume and Thickness' as an attachment or

   send us a **MS-DOS or Macintosh formatted diskette** with your document on 'Changes in Area, Volume and Thickness'.

2. The document must be saved as **plain ASCII code** and should be named '**Changes.country code**' (e.g. 'Changes.CH' for Switzerland).

3. Use the following **format** to enter your data:

   A record contains data belonging to one single glacier. A field within a record starts with a **code containing 6 digits**. Each code is attributed to a field name (e.g. Area Change) of the table on 'Changes in Area, Volume and Thickness'. All codes and their meaning are listed below. Right after each code you enter **the data value belonging to the corresponding code**. **Separate the code and the corresponding field value by a blank (' ')**. After each line you enter a **carriage return**. If a field remains blank (because there are no data available) **give the code and enter a blank and a colon (:)** for the missing data. Please **do not enter a blank line to separate individual records**.

   Please strictly use the given format. This is essential for correctly transferring your data to the database.

   Codes and their corresponding meaning for 'Changes in Area, Volume and Thickness':

   700001 COUNTRY ABBR. (for abbreviations, see Volume VII, p. 3)

   700002 GLACIER NUMBER (former PSFG number)

   700003 GLACIER NAME (up to 15 characters allowed)

   Codes for Measurement Period 19.. to 19..:

   700004 BEGIN OF MEASUREMENT PERIOD (DD-MMM-YYYY, e.g. 01-SEP-1995)

   700005 END OF MEASUREMENT PERIOD (DD-MMM-YYYY, e.g. 01-SEP-1996)

   Codes for Altitude Interval from .... m to .... m:

   700006 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1200 m a.s.l.)

   700007 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1300 m a.s.l.)

   700008 MEAN AREA (in 1000 m^2; mean area of altitude interval for period of change)

   700009 AREA CHANGE (in 1000 m^2; change in area of altitude interval for period of change)

   700010 VOLUME CHANGE (in 1000 m^3; change in volume of altitude interval for period of change)

   700011 THICKNESS CHANGE (in mm; change in thickness of altitude interval for period of change)

   Codes for Altitude Interval from .... m to .... m:

   700012 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1300 m a.s.l.)

   700013 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1400 m a.s.l.)

   700014 MEAN AREA (in 1000 m^2; mean area of altitude interval for period of change)

   700015 AREA CHANGE (in 1000 m^2; change in area of altitude interval for period of change)

   700016 VOLUME CHANGE (in 1000 m^3; change in volume of altitude interval for period of change)

   700017 THICKNESS CHANGE (in mm; change in thickness of altitude interval for period of change)

   etc.

700991 TOTAL MEAN AREA (in 1000 m^2; sum of the mean area of all altitude intervals)

700992 TOTAL AREA CHANGE (in 1000 m^2; sum of the area change of all altitude intervals)

700993 TOTAL VOLUME CHANGE (in 1000 m^3; sum of the volume change of all altitude intervals)

700994 MEAN THICKNESS CHANGE (in mm; mean of the thickness change of all altitude intervals)

Codes for Measurement Period 19.. to 19..:

701001 BEGIN OF MEASUREMENT PERIOD (DD-MMM-YYYY, e.g. 01-SEP-1996)

701002 END OF MEASUREMENT PERIOD (DD-MMM-YYYY, e.g. 01-SEP-1997)

Codes for Altitude Interval from .... m to .... m:

701003 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1200 m a.s.l.)

701004 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1300 m a.s.l.)

701005 MEAN AREA (in 1000 m^2; mean area of altitude interval for period of change)

701006 AREA CHANGE (in 1000 m^2; change in area of altitude interval for period of change)

701007 VOLUME CHANGE (in 1000 m^3; change in volume of altitude interval for period of change)

701008 THICKNESS CHANGE (in mm; change in thickness of altitude interval for period of change)

Codes for Altitude Interval from .... m to .... m:

701009 ALTITUDE FROM (in m a.s.l.; this is the lower boundary of the altitude interval, e.g. 1300 m a.s.l.)

701010 ALTITUDE TO (in m a.s.l.; this is the upper boundary of the altitude interval, e.g. 1400 m a.s.l.)

701011 MEAN AREA (in 1000 m^2; mean area of altitude interval for period of change)

701012 AREA CHANGE (in 1000 m^2; change in area of altitude interval for period of change)

701013 VOLUME CHANGE (in 1000 m^3; change in volume of altitude interval for period of change)

701014 THICKNESS CHANGE (in mm; change in thickness of altitude interval for period of change)

etc.

701991 TOTAL MEAN AREA (in 1000 m^2; sum of the mean area of all altitude intervals)

701992 TOTAL AREA CHANGE (in 1000 m^2; sum of the area change of all altitude intervals)

701993 TOTAL VOLUME CHANGE (in 1000 m^3; sum of the volume change of all altitude intervals)

701994 MEAN THICKNESS CHANGE (in mm; mean of the thickness change of all altitude intervals)

etc.

4. *Example of how the electronic data sheet 'Changes in Area, Volume and Thickness' should look like:*

700001 CH

700002 00003

700003 GRIES (AEGINA)

700004 01-SEP-1979

700005 01-SEP-1986

700006 2300

700007 2400

700008 2

700009 -4

700010 :

700011 :

700012 2400

700013 2500

700014 174

700015 -20

700016 -200

700017 -1140

etc.

700991 6293

700992 -88
700993 -2350
700994 -400

5. Please note that due to limited staff **electronic data can only be accepted when keeping strictly to the above-mentioned format**. Thank you for your collaboration!

WORLD GLACIER MONITORING SERVICE
SPECIAL EVENTS 1995–2000

NOTES ON THE COMPLETION OF THE DATA SHEET

This data sheet should be completed in cases of extraordinary events, especially those concerning glacier hazards and dramatic changes of glaciers (cf. Point 4.).

1. **Country or Territory**
   Name of country or territory where the glacier is located (for abbreviation, see Volume VII, p. 3).

2. **Glacier Number (former PSFG number)**
   See 'Notes on the completion of the data sheet: GENERAL INFORMATION ON THE OBSERVED GLACIERS'.

3. **Glacier Name**
   The name of the glacier should be written in **CAPITAL** letters.

4. **Year of Event**
   Year of occurrence of the special event.

5. **Type of Event**
   Mark one (or more) of the corresponding rows with an X:
   905 = glacier surge
   906 = calving instability
   907 = glacier flood, debris flow, mudflow
   908 = large ice avalanche
   909 = tectonic impact (earthquake, volcanic eruption)
   910 = other

6. **Short Description**
   Please give quantitative information wherever possible, for example:
   - surge: date and location of onset, duration, flow or advance velocities, discharge anomalies, periodicity;
   - calving instability: rate of retreat, iceberg discharge, ice flow velocity and water depth at calving front;
   - glacier flood, debris flow, mudflow: outburst volume, outburst mechanism, peak discharge, sediment load, reach and propagation velocity of flood wave or front of debris flow/mudflow;
   - ice avalanche: volume released, runout distance, overall slope of avalanche path;
   - tectonic impact: volumes, runout distances and overall slopes of rock slides on glacier surfaces, amount of geothermal melting in craters, etc.

7. **Reference or Most Important Data Source**
   Please indicate at least one or two references or sources which could help the reader to locate more detailed information, or give the name(s) of contact person(s) who would be able to supply additional information.

8. **Remarks**
   Amount or kind of possible destruction, particular technical measures taken against glacier hazards, or special studies carried out in connection with this event could be mentioned.

GUIDELINES FOR ELECTRONIC DATA TRANSFER FOR 'SPECIAL EVENTS 1995–2000'

For electronic submission of your data on 'General Information on the Observed Glaciers 1995–2000' please remember the following points:

1. Use either E-Mail (E-Mail address: **wgms@geo.unizh.ch**) and send your document on the 'Special Events 1995–2000' as an attachment or

   send us a **MS-DOS or Macintosh formatted diskette** with your document on 'Special Events 1995–2000'.

2. The document must be saved as **plain ASCII code** and should be named '**Special.country code**' (e.g. 'Special.CH' for Switzerland).

3. Use the following **format** to enter your data:

   A record contains data belonging to one single glacier. A field within a record starts with a **code containing 3 digits**. Each code is attributed to a field name (e.g. glacier name) of the table on 'Special Events 1995–2000'. All codes and their meaning are listed below. Right after each code you enter **the data value belonging to the corresponding code**. **Separate the code and the corresponding field value by a blank (' ')**. After each line you enter a **carriage return**. If a field remains blank (because there are no data available) **give the code and enter a blank and a colon (:)** for the missing data. Please **do not enter a blank line to separate individual records**.

   Please strictly use the given format. This is essential for correctly transferring your data to the database.

   Codes and their corresponding meaning for 'Special Events 1995–2000':

   901 COUNTRY OR TERRITORY (up to 20 characters allowed)

   902 GLACIER NUMBER (former PSFG number)

   903 GLACIER NAME (up to 15 characters allowed)

   904

   905 GLACIER SURGE (give a 'X' if true)

   906 CALVING INSTABILITY (give a 'X' if true)

   907 GLACIER FLOOD, DEBRIS FLOW, MUDFLOW (give a 'X' if true)

   908 LARGE ICE AVALANCHE (give a 'X' if true)

   909 TECTONIC IMPACT (give a 'X' if true)

   910 OTHER (give a 'X' if true; describe under 'Short Description')

   911 SHORT DESCRIPTION (up to 5000 characters allowed)

   912 REFERENCE OR MOST IMPORTANT DATA SOURCE (up to 100 characters allowed)

   913 REMARKS (up to 500 characters allowed)

   914 DATA SHEET COMPILED BY (up to 15 characters allowed)

4. ***Example of how the electronic data sheet 'Special Events 1995–2000' should look like:***

   901 SWITZERLAND

   902 00353

   903 EIGER (WEST)

   904 1998

   905 :

   906 :

   907 :

   908 X

   909 :

   910 :

   910 ICE AVALANCHES REPEATEDLY OCCUR AT A STEEP HANGING GLACIER IN THE WEST FACE OF EIGER. ETC.

   911 INTERNAL VAW REPORTS

912 :

913 DR. M. HOELZLE

5. The previous explanations to the different record fields ('Notes on the Completion of the Data Sheet') apply equally to the electronic data entry - unless otherwise specified in the 'Guidelines for electronic data transfer'.

6. Please note that due to limited staff **electronic data can only be accepted when keeping strictly to the above-mentioned format**. Thank you for your collaboration!