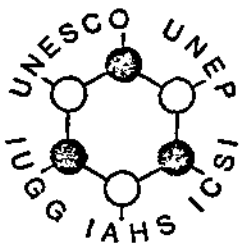

Instructions for Compilation and Assemblage of Data for a World Glacier Inventory

by

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INTRODUCTION

The UNESCO/IASH publication "Perennial ice and snow masses" (Technical Papers in Hydrology, No. 1, Paris, 1970) constituted the first guide for a World Glacier Inventory. To promote and coordinate this work UNESCO, UNEP, IUGG, IAHS and ICSI have set up the Temporarry Technical Secretariat (TTS) for the World Glacier Inventory at the Department of Geography, Swiss Federal Institute of Technology (ETH) in Zürich. The present "Instructions for Compilation and Assemblage of Data for a World Glacier Inventory" consist essentially of the guidelines already mentioned but, in addition, contain refinements and supplementations. They can also be applied to large parts of the Antarctic and to Greenland, but investigators should get in touch with the TTS before they start work on those areas.

SNOW AND ICE MASSES TO BE REGISTERED

All perennial snow and ice masses should be registered in the World Glacier Inventory. Measurements of glacier dimensions should be made with respect to the carefully delineated drainage area for each ice stream. Tributaries should be included with main streams when they are not differentiated from one another. If no flow takes place between separate parts of a continuous ice mass they should be treated as separate units.

Delineation of visible ice, firn and snow from rock and debris surfaces for an individual glacier (see Fig. 1) will affect various inventory measurements. Inactive ice must be included in the inventory for hydrological purposes. Marginal and terminal moraines should be included if they contain ice. The "inactive" ice aprons which are frequently to be found above bergschrunds should be regarded as part of the glacier. Glacierets and snow patches of large enough size - if perennial - should also be included in the inventory. Rock glaciers should be included if there is evidence of large ice content.

SOURCE MATERIAL

The primary sources of information are maps, photographs and published accounts. In general, standard topographical maps will be the basic data source. The minimum scale suitable is probably 1:250'000 but, wherever available, larger scales should be used. Unfortunately many topographical maps do not depict the exact shape and precise extent of glaciers and perennial snow fields; consequently it is frequently necessary to check the glaciological information depicted on the map. Inaccuracies must be corrected with the aid of photographs etc. In addition to the largest scale maps available, a regional map of smaller scale - perhaps at 1:500'000 or less, depending upon the size and nature of the glacierized area - will be required to work out the identification and coding system.

Aerial, terrestrial or satellite photographs must be used to substantiate and, where necessary, to improve the glaciological information on the map. In particular, photographs are needed to assess the snow line which is rarely shown on ordinary maps. Much useful information, e.g. relating to firn line position or tongue activity can be found in various publications. It should be incorporated in the inventory and a reference given under 'Remarks'.

DATA ORGANIZATION

A data sheet should be completed for every glacier (see following page) and the data should be punched according to a standard format (cf. appendix). Normally a data sheet contains 41 parameters. The largest possible number of parameters should be aimed at, even if not all of them can be assessed. The data should be punched standardized in accordance with the example given (right-oriented, except 'Glacier name' which should be punched left-oriented). The total number of punch cards per glacier varies from a minimum of 3 to a maximum of 99. Detailed instructions for the determination of the different parameters are given on the following pages. The instruc-

WORLD GLACIER INVENTORY

Standard Data Sheet

Identification / Glacier number 1 12

Glacier name 13 28

Latitude 30 38

Longitude 39 48

Co-ordinates 49 63

Number of drainage basins 65

Number of independent states 66

Topographical map used: scale 68 71

: year 72 73

Photographs used: type 74

: year 75 76

Total number of punch cards 77 78

Running number of punch card 1 79 80

Surface area: total (km2) 13 19

: accuracy 21

: total in the state concerned (km2) 22 28

: exposed (km2) 29 35

Area of ablation (km2) 36 42

Mean width (km) 44 48

Mean length (km) 50 54

Maximum length: total (km) 56 60

: exposed (km) 62 66

: ablation area (km) 68 72

Orientation: accumulation area 74 75

: ablation area 77 78

Running number of punch card 2 79 80

Highest glacier elevation (m a s l) 14 17

Mean glacier elevation (m a s l) 19 22

Lowest glacier elevation: total (m a s l) 24 27

: exposed (m a s l) 29 32

Mean elevation accumulation area (m a s l) 34 37

Mean elevation ablation area (m a s l) 39 42

Classification 44 49

Period for which tongue activity was assessed 51 53

Moraines 57 58

Snow line for total glacier: elevation (m a s l) 60 63

: accuracy 65

: date (day/mo./yr.) 66 73

Mean depth (m) 74 77

accuracy 78

Running number of punch card 3 79 80

Data compiled by:

tions are based upon the previously mentioned UNESCO/IASH publication. However, specification of the Accumulation Area Ratio AAR and volume of ice are omitted in the present instructions; the AAR can be easily computed from 'Area of ablation' and 'Surface area total' whilst the volume of ice is expressed by 'Mean depth' and 'Surface area total'. In most cases the ice thickness must be estimated. Appropriate models should be developed for each area by the local investigators to make regional assessments of ice volumes. For example, the following model was used for the Swiss Alps:

$$\bar{h} = a + b\sqrt{F}$$

where $\bar{h}$ is the mean depth, F the surface area total and a and b are arbitrary parameters that are empirically determined.

The parameters shown in the data sheet must be assessed unchanged as described on the following pages. Additional information will, of course, be welcome and should be given under 'Remarks'.

THE DATA BANK

The data bank set up by the TTS will consist of:

- complete data for the National Inventories on magnetic tape if possible. The TTS should be consulted first to ensure compatibility of magnetic tapes.
- key maps depicting the various drainage basins.
- index maps with glacier numbers.
- brief topographical and climatological descriptions of the areas of investigation.
- topographical maps of the glacierized areas at the largest possible scale.
- detailed assessments of the ice volumes for each area together with details of the method of estimation. Glacier volumes assessed from local knowledge rather than by a general model would also be valuable.

COMPLETION OF THE DATA SHEET

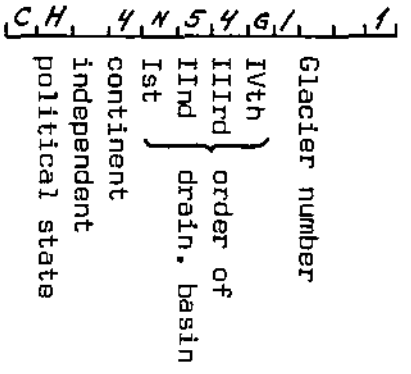
- Accuracy

index	area (%)	altitude (m)	depth (%)
1	0 - 5	0 - 25	0 - 5
2	5 - 10	25 - 50	5 - 10
3	10 - 15	50 - 100	10 - 20
4	15 - 25	100 - 200	20 - 30
5	> 25	> 200	> 30

- Identification / Glacier number

Each glacier must have an address which gives, in the first three digits, the name of an independent political state (cf. appendix). The fourth digit indicates the continent in which the study area lies (cf. appendix). The study area must then be divided and subdivided into drainage basins of first-order (A-Z), second-order (0-9), third-order (0-9) and, if necessary, fourth-order (A-Z), see supplement Identification. The lettering and numbering should start from the mouth of the major stream and proceed clockwise around the basin. A key map, or sequence of maps, must be drawn to show the assigned letters and numbers. Finally, each glacier within the third- or fourth-order drainage basin must be numbered with a maximum of three digits (1-999). Once again the numbering should start at the outlet of the drainage basin and proceed clockwise to 999. Index maps showing the numbering of glaciers should be given.

Example:

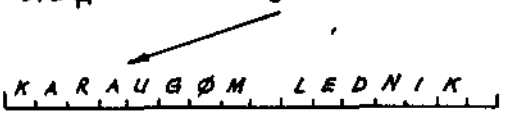


Investigators working on the same drainage basin should exchange information.

- Glacier name

If no official name has been assigned to a glacier, then only a well established unofficial name should be given. If a name is too long a meaningful abbreviation of it should be entered. The spelling of the name must be in the Latin alphabet and may consist only of the following characters: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z . In many cases the name must be transliterated into the Latin alphabet.

Example: ЛЕДНИК КАРАУГОМ



(left-oriented)

- Latitude, Longitude and Co-ordinates

The location of each glacier should be given, as exactly as possible, in geographical co-ordinates and - wherever possible - in map co-ordinates, e.g. UTM co-ordinates. The point on the glacier whose co-ordinates are given should be in the upper part of the ablation area, in the main stream and sufficiently high so as not to be lost if the glacier retreats. The coding of the map co-ordinates is left unspecified with a maximum of 14 available digits.

- Number of drainage basins

An ice mass will often drain into several drainage basins (treated as separate units of the identification code) but cannot be split into separate units. The total number of drainage basins should be given in this field, e.g. 1 for one drainage basin. For identification purposes, however, the ice mass should be assigned to the drainage basin which contains the largest portion of the surface area.

- Number of independent states

Many glaciers cross international boundaries. The number of states concerned should be noted - even if it is only one - and each state should record its share of the glacier surface under the heading 'Surface area: total in the state concerned'. The glacier as a whole, however, will be treated by the investigator of one country only (by agreement between investigators).

Topographical Maps and Photographs

Depending upon the type of data sources used the following information must be given:

Data sources for the inventory	Information
official maps only	top. map: scale and year
photographs only, e.g. satellite images	photos: type and year
official maps corrected with photographs	top. map: scale and year photos: type and year
new maps based upon photographs	top. map: scale photos: type and year

- Topographical map used: scale

Should be given in units of 1'000, e.g. 100 for scale 1:100'000. If several maps of different scales are used the scale of the map covering the largest fraction of the surface area should be given.

- Topographical map used: year

When possible the year corresponding to the depicted glacier boundaries should be given, otherwise the year of publication of the map covering the largest fraction of the surface area should be given (e.g. 73 for 1973).

- Photographs used: type

Give type of photo-coverage of the largest fraction of the surface area.

		analyzed with autograph	analyzed with stereoscope	not analyzed with stereoscope
Vertical aerial photographs	Mp ≦ 25'000	A	E	I
	Mp > 25'000	B	F	J
Oblique aerial photographs		C	G	K
Terrestrial photographs		D	H	L

Mp = photoscale denominator

Satellite images:

Specified resolution (e.g. LANDSAT 2)	79 x 79 m	M
Specified resolution significantly better than (e.g. LANDSAT 3)	79 x 79 m	N
Specified resolution significantly worse than (e.g. NIMBUS)	79 x 79 m	O

- Photographs used: year

Give year (e.g. 73 for 1973) for photographs covering largest fraction of the surface.

- Total number of punch cards

Total number of punch cards for the glacier concerned (including 'Remarks').

- Surface area: total in the state concerned

Must only be given if a glacier crosses international boundaries.

- Surface area: exposed

Comprises the part of the total surface area which is not covered with coarse stone material.

- Mean width

If a glacier has a uniform width near the tongue, as with valley or outlet glaciers, the mean width should be measured there. Otherwise the corresponding 6 digits should be left blank. An average width, representative of the whole glacier, can be easily obtained from the total surface area and the mean length.

- Mean length

The average of the lengths of each tributary along its longest flowline to the glacier snout.

- Maximum length: total

The longest flowline of the whole glacier. For glaciers which have been ruptured by sliding, only the lengths above and below the rupture should be measured.

- Orientation

Orientation of the down-glacier direction according to the eight cardinal points (N, NE, E, SE, S, SW, W, NW) should be given.

- Mean glacier elevation

The contour line which divides the glacier surface in half.

- Mean elevation accumulation area, Mean elevation ablation area

The contour lines which divide the accumulation and ablation areas respectively in half.

- Classification

A morphological matrix-type classification and description is proposed. Each glacier may be coded as a 6-digit number, the 6 digits being the vertical columns of Table 1; the individual numbers for each digit (horizontal row numbers) must be read on the left-hand side. This scheme is a simple key for the classification of all types of glaciers all over the world. It goes without saying, therefore, that it will seem too simple for certain regions.

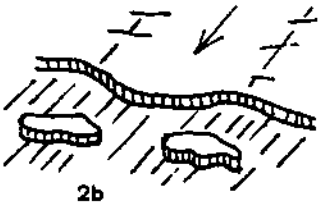
Digit 1	Primary classification	
1	Continental ice sheet	Inundates areas of continental size.
2	Ice-field	More or less horizontal ice mass of sheet or blanket type of a thickness not sufficient to obscure the subsurface topography. It varies in size from features just larger than glacierets to those of continental size.
3	Ice cap	Dome-shaped ice mass with radial flow.
4	Outlet glacier	Drains an ice-field or ice cap, usually of valley glacier form; the catchment area may not be clearly delineated (Fig. 2a).
5	Valley glacier	Flows down a valley; the catchment area is in most cases well defined.
6	Mountain glacier	Any shape, sometimes similar to a valley glacier, but much smaller; frequently located in cirque or niche.
7	Glacieret and snowfield	A glacieret is a small ice mass of indefinite shape in hollows, river beds and on protected slopes developed from snow

	Digit 1 Primary classification	Digit 2 Form	Digit 3 Frontal characteristic	Digit 4 Longitudinal profile	Digit 5 Major source of nourishment	Digit 6 Activity of tongue
0	Uncertain or misc.	Uncertain or misc.	Normal or misc.	Uncertain or misc.	Uncertain or misc.	Uncertain
1	Continental ice sheet	Compound basins	Piedmont	Even; regular	Snow and/or drift snow	Marked retreat
2	Ice-field	Compound basin	Expanded foot	Hanging	Avalanche ice and/or ava- lanche snow	Slight retreat
3	Ice cap	Simple basin	Lobed	Cascading	Superimposed ice	Stationary
4	Outlet glacier	Cirque	Calving	Ice-fall		Slight advance
5	Valley glacier	Niche	Confluent	Interrupted		Marked advance
6	Mountain glacier	Crater				Possible surge
7	Glacieret and snowfield	Ice apron				Known surge
8	Ice shelf	Group				Oscillating
9	Rock glacier	Remnant				

Table 1 : Glacier classification and description

		drifting, avalanching and/or especially heavy accumulation in certain years; usually no marked flow pattern is visible and, therefore, no clear distinction from snowfield is possible. Exists for at least two consecutive summers.
	8 Ice shelf	A floating ice sheet of considerable thickness attached to a coast, nourished by glacier(s), snow accumulation on its surface or bottom freezing (Fig. 2b).
	9 Rock glacier	A glacier-shaped mass of angular rock either with interstitial ice, firn and snow or covering the remnants of a glacier, moving slowly downslope. If in doubt about the ice content, the frequently present surface firn fields should be classified as 'Glacieret and snowfield'.

2a



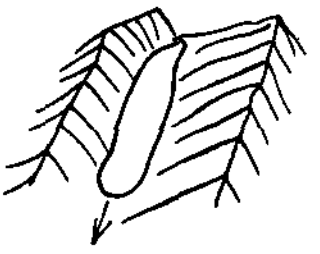
2b

Digit 2 Form

	1 Compound basins	Two or more tributaries of valley glacier type, coalescing (Fig. 3a).
	2 Compound basin	Two or more accumulation basins feeding one glacier (Fig. 3b).
	3 Simple basin	Single accumulation area (Fig. 3c).
	4 Cirque	Occupies a separate, rounded, steep-walled recess on a mountain side (Fig. 3d).
	5 Niche	Small glacier formed in initially V-shaped gulley or depression on a mountain slope (Fig. 3e).
	6 Crater	Occuring in and/or on volcanic craters.
	7 Ice aprons	An irregular, usually thin, ice mass plastered along a mountain slope.
	8 Group	A number of similar 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.

3a 3b 3c 3d



3e

Digit 3 Frontal characteristic

1	Piedmont	Ice field formed on a lowland by the lateral expansion of one or the coalescence of several glaciers (Fig. 4a, 4b).
2	Expanded foot	Lobe or fan of ice 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. Lateral expansion markedly less than for Piedmont (Fig. 4c).
3	Lobed	Tonguelike form of an ice-field or ice cap, see Fig. 4d.
4	Calving	Terminus of glacier sufficiently extending into sea or occasionally lake water to produce icebergs; includes - for this inventory - dry land calving.
5	Confluent	Glaciers whose tongues come together and flow in parallel without coalescing (Fig. 4e).

Digit 4 Longitudinal profile

1	Even; regular	Includes the regular or slightly irregular and stepped longitudinal profile.
2	Hanging	Perched on a steep mountain side, or in some cases issuing from a steep hanging valley.
3	Cascading	Descending in a series of marked steps with some crevasses and séracs.
4	Ice-fall	A glacier with a considerable drop in the longitudinal profile at one point causing heavily broken surface.
5	Interrupted	Glacier that breaks off over a cliff and reconstitutes below.

Digit 5 Major source of nourishment

Self-explanatory

Digit 6 Activity of tongue

A simple-point qualitative statement regarding advance or retreat of the glacier tongue in recent years, if made for all glaciers on earth, would provide most useful information. The assessment for an individual glacier (strongly or slightly advancing or retreating, etc.) should be made in terms of the world picture and not just that of the local area; however, it seems very difficult to establish an objective, i.e. quantitative basis for the assessment of the tongue activity. A change of frontal position of up to 20 m per year might be classed as a 'slight' advance or retreat. If the frontal change takes place at a greater rate it would be called 'marked'. Very strong advances or surges might shift the glacier front by more than 500 m per year.

Digit 6 expresses qualitatively the annual tongue activity. If observations are not available on an annual basis then an average annual activity should be given. In either case the period of measurement should be given under 'Period for which tongue activity was assessed' in field 51-55 of punch card 3 on the data sheet.

In case the tongue activity is inferred qualitatively on the basis of tongue shape or other criterion (i.e. no previous observations) only the last two digits in field 51-55 of punch card 3 ('Period for which tongue activity was assessed') should be given to denote the date of the observed tongue state.

- Period for which tongue activity was assessed

See Classification, Digit 6.

- Moraines

Two digits to be given.

Digit 1: moraines in contact with present-day glacier

Digit 2: moraines farther downstream

0 no moraines
1 terminal moraine
2 lateral and/or medial moraine
3 push moraine
4 combination of 1 and 2
5 combination of 1 and 3
6 combination of 2 and 3
7 combination 1, 2 and 3
8 debris, uncertain if morainic
9 moraines, type uncertain or not listed.

- Snow line for total glacier

Under 'Snow line for total glacier' that height of the transient snow line should be given which is closest to the height of the firn line for the year concerned. By definition, the highest position of the transient snow line at the end of the budget year is called firn line ("Altschneelinie"). The transient snow line marks the lower edge of the receding snow cover of the winter just past, at any one point of time.

To assess the height of the snow line, a contour line must be chosen in such a way that the snow-covered area below it is of the same size as the snow-free area above it. However, the snow line is frequently dispersed, i.e. it forms several small islands. In this case, when calculating the height of the snow line, one has to take into account the differences in the height of the snow line and that of the islands (weighting: surface x difference in height). Ideally, the snow line data for all the glaciers of an area should refer to the same year.

- Mean depth

Only to be shown on the data sheet if the depths of large parts of the glacier bed are known.

- Remarks

Remarks should be in English. The manner of presentation is left to the investigator. It must, however, be explained in order to facilitate access to the data. In field 14-15 of the first card for remarks (punch card 4) the 'Total number of punch cards with remarks' must be entered. The remarks can, for instance, consist of the following information:

- Critical comments on any of the 41 parameters of the data sheet (e.g. how close is the snow line to the firn line, comparison of year concerned with other years).
- Special glacier types and glacier characteristics which, because of the nature of the classification scheme, are not described in sufficient detail (e.g. ogives, "melt structures", glacier dammed lakes).
- Additional parameters of special interest to the country concerned, e.g. area of altitudinal zones, inclination, etc.
- It is often useful to divide the snow line into several sections (because of different exposition or nourishment). In such cases the snow line data of each section can be recorded separately here. However, a 'Snow line for total glacier' should be given in any case on punch card 3, i.e. even if the snow line has been divided.
- Literature on the glacier concerned (transliterated).
- Any other remarks.

APPENDIX

Denotation of political states

Denotation of continents

Standard Data Sheet (with example)

Specimen punch cards (with example)

Denotation of political states

(based on official abbreviations for automobiles,
* no official abbreviations, denotation given by TTS)

AFG	Afghanistan
AL	Albania
DZ	Algeria
AND	Andorra
AN	*Angola
RA	Argentina
AUS	Australia
A	Austria
BS	Bahamas
BRN	Bahrain
BA	*Bangladesh
BDS	Barbados
B	Belgium
BU	*Bhutan
RB	Bolivia
RB	Botswana
BR	Brazil
BG	Bulgaria
BUR	Burma
RU	Burundi
BRU	Brunei
TC	Cameroun
CDN	Canada
WL	*Cape Verde Islands
RCA	Central African Republic
TCH	Chad
RCH	Chile
CN	*China
CO	Colombia
CM	*Comoro Islands
RCB	Congo
CR	Costa Rica
C	Cuba
CY	Cyprus
CS	Czechoslovakia
DY	Dahomey
DK	Denmark
DOM	Dominican Republic
EC	Ecuador
ET	Egypt
ES	*El Salvador
GE	*Equatorial Guinea
ETH	Ethiopia
FI	*Fiji
SF	Finland
F	France
GA	*Gabon
WAG	Gambia
D	Germany, Federal Republic
DDR	Germany, Democratic Republic
GH	Ghana
GR	Greece
GB	Great Britain and Northern Ireland
GN	*Grenada
GCA	Guatemala
GU	*Guinea
PG	*Guinea-Bissau
GUY	Guyana
RH	Haiti
BH	Honduras
H	Hungary
IS	Iceland
IND	India
RI	Indonesia
IR	Iran
IRQ	Iraq
EIR	Irish Republic
IL	Israel
I	Italy
CI	Ivory Coast
JA	Jamaica
J	Japan
HKJ	Jordan, Hashemite Kingdom of
EAK	Kenya
K	Khmer Republic (Cambodia)
ROK	Korea, North
KOR	Korea, South
KWT	Kuwait
LAS	Laos
RL	Lebanon
LS	Lesotho
LI	*Liberia
LA	*Libyan Arab Republic
FL	Liechtenstein
L	Luxembourg

Denotation of political states (cont.)

RM	Madagascar
MW	Malawi
MAL	Malaysia
ML	*Maldives
RMM	Mali
M	Malta
MU	*Mauritania
MS	Mauritius
MEX	Mexico
MO	*Moçambique
MC	Monaco
MN	*Mongolian People's Republic
MA	Morocco
NA	*Nauru
NEP	Nepal
NL	Netherlands
NZ	New Zealand
NIC	Nicaragua
RN	Niger
WAN	Nigeria
N	Norway
OM	*Oman
PAK	Pakistan
PA	Panama
PN	*Papua New Guinea
PY	Paraguay
PE	Peru
RP	Philippines
PL	Poland
P	Portugal
QA	*Qatar
RSR	Rhodesia
R	Romania
RWA	Rwanda
RSM	San Marino
ST	*Sao Tomé e Principe
SA	Saudi Arabia
SN	Senegal
SY	Seychelles
WAL	Sierra Leone
SGP	Singapore
SP	*Somali Democratic Republic
ZA	South Africa
E	Spain
CL	Sri Lanka
SJ	*Sudan, Democratic Republic
SME	Surinam
SD	Swaziland
S	Sweden
CH	Switzerland
SYR	Syria
RT	Taiwan
EAT	Tanzania
T	Thailand
TG	Togo
TO	*Tonga
TA	*Transkei
TI	Trinidad and Tobago
TN	Tunisia
TR	Turkey
EAU	Uganda
SU	Union of Soviet Socialist Republics
AE	*United Arab Emirates
USA	United States of America
HV	Upper Volta
U	Uruguay
V	Vatican City State
YV	Venezuela
VN	*Vietnam
WS	Western Samoa
YMN	Yemen, Arab Republic (North Yemen)
Y	*Yemen, People's Democratic Republic (South Yemen)
YU	Yugoslavia
CGO	Zaire
RNR	Zambia

Denotation of continents

digit	continent
0	
1	South America
2	North America
3	Africa
4	Europe
5	Asia
6	Australia and New Zealand
7	Pacific
8	Antarctica