

Glacier area – remote sensing of glaciers

Andreas Linsbauer
(with slides from H. Frey & M. Zemp)

IHCAP – Indian Himalayas Climate Change Adaptation Programme
Capacity building programme “Cryosphere” Level-2 (Sept 20 – Nov 22, 2013)

Glacier ice volume estimates

Use of glacier volumes

- Sea level rise
- Glacier evolution
- Runoff projection
- Hydrological modelling
- Future landscape
- Potential natural hazard assessment
- ...

How to calculate them?

- $V = A \times d$

1. Map glacier area (A)
2. Derive thickness (d)
3. Calculate volume (V)

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GTN-G observing strategy: WGI & GLIMS

- Glacier inventories repeated at time intervals of a few decades by using:
 - Topographic maps and moraine dating
 - Aerial photography
 - Satellite remote sensing

WGI: ~100,000 glaciers
GLIMS: ~80,000 glaciers

Fig. 3.6 Global glacier inventories
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GTN-G observing strategy: WGI & GLIMS

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Fig. by Frank Paul
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One-stop data-portal on www.gtn-g.org

- FoG WGMS
- WGI WGMS / NSIDC
- GLIMS NSIDC
- Glacier photos NSIDC

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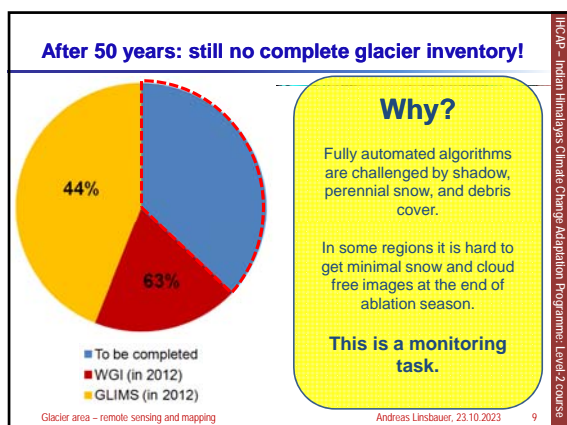
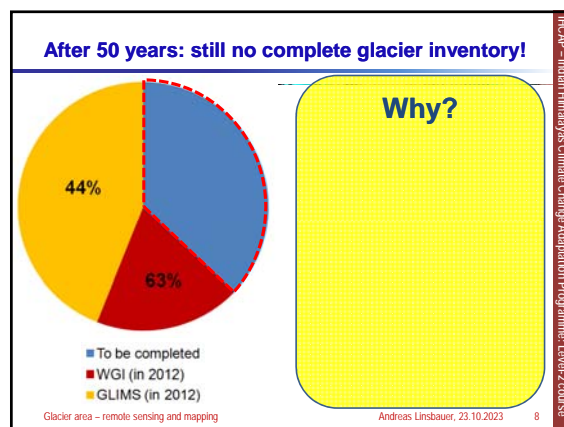
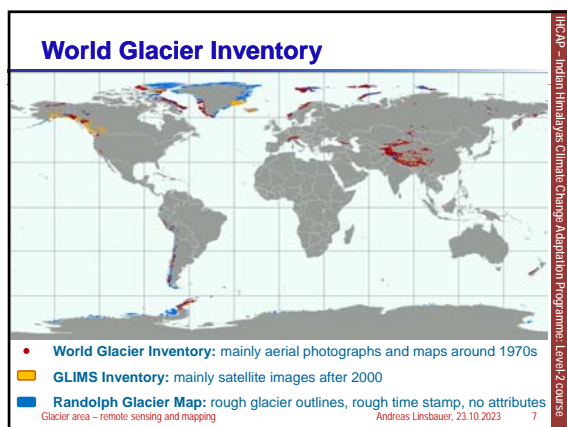
Randolph (Global Glacier Map)

Compiled to serve IPCC AR5

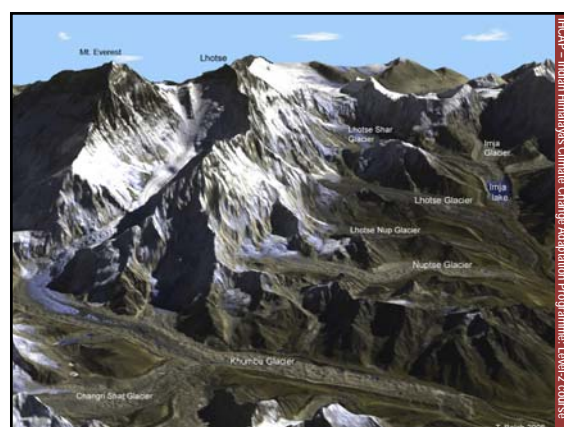
- main purpose: global SLR modelling
- by A. Arendt et al. from different source; mainly GLIMS, DCW, and WGI
- no attributes, no time stamp (1950-2010)
- final version available from GLIMS website
- additional high-quality outlines to be incorporated into GLIMS database

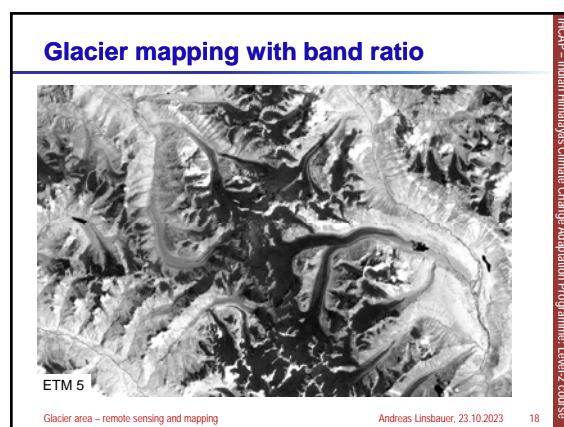
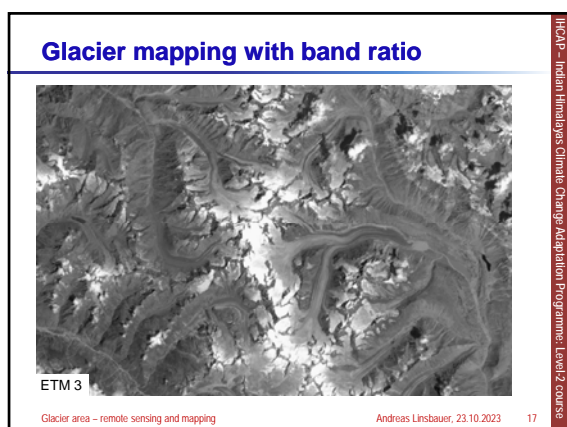
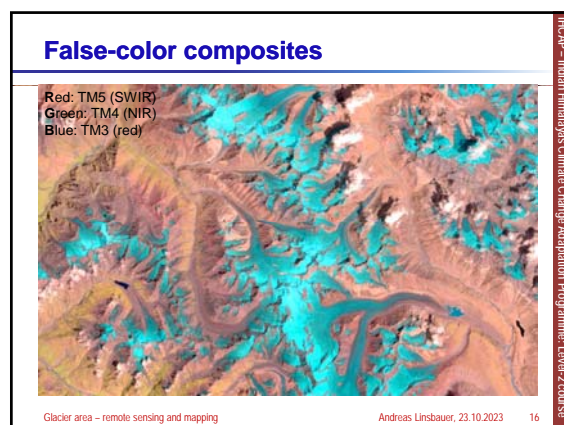
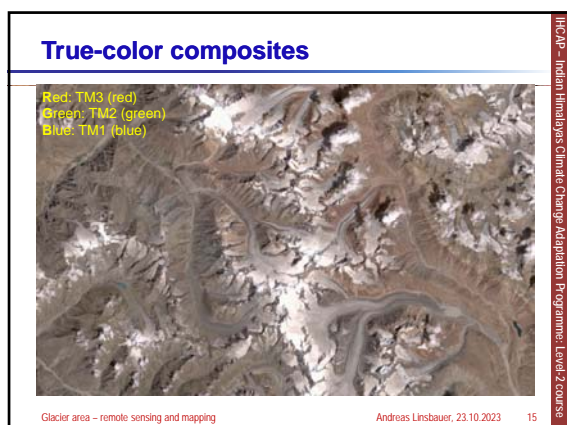
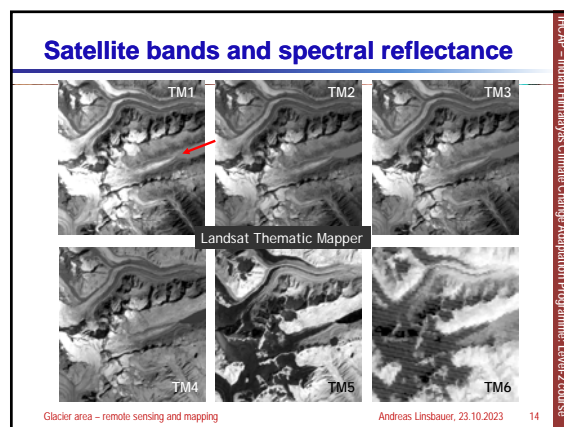
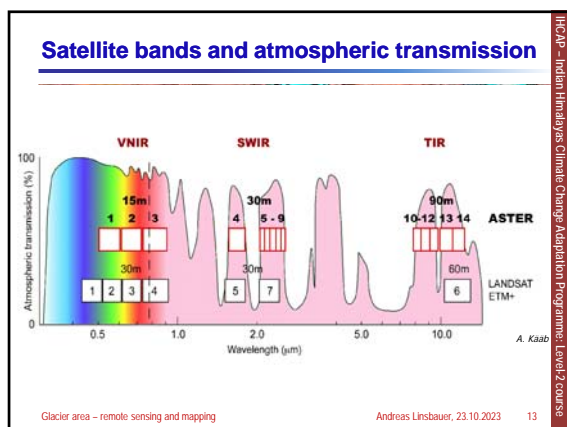
=> how to manage this task with the available resources?!

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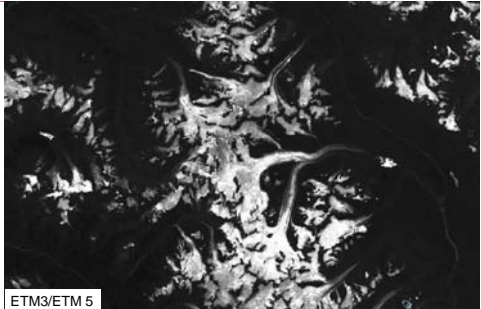


- ### Challenges
- Glacier mapping challenges:**
- Debris cover
 - Separation of glaciers (glacier branches / tributaries, along ridges)
 - Clouds
 - (Problems with DEMs)
- Further challenges:**
- Adverse snow conditions
 - Permafrost interactions
 - Frozen lakes / sea ice
 - Georeferencing of satellite imagery and DEMs
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Glacier mapping with band ratio



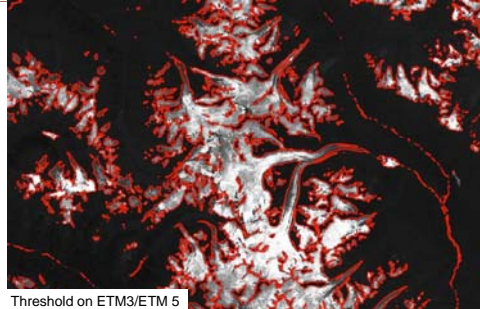
ETM3/ETM 5

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Glacier mapping with band ratio



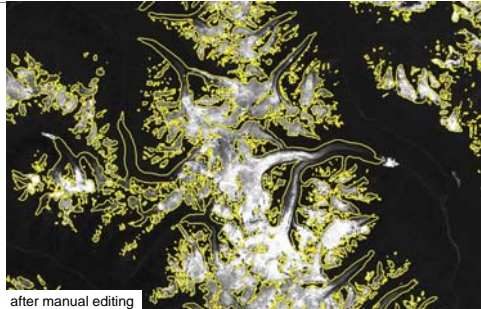
Threshold on ETM3/ETM 5

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Glacier mapping with band ratio



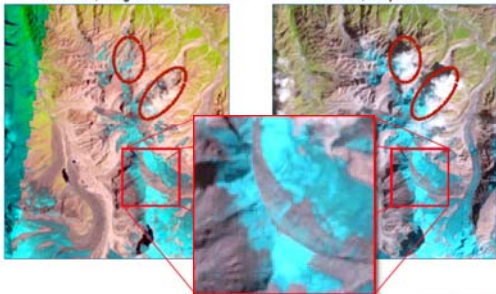
after manual editing

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Mapping challenges: snow, cloud, shadows



P145 R039, 1 Aug 2001

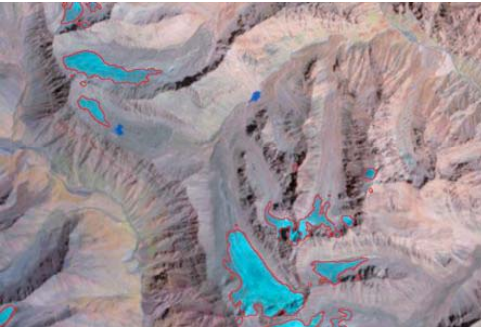
P146 R038, 9 Sept 2001

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Glacier-permafrost interactions

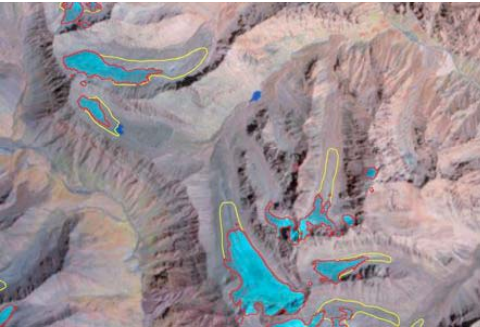


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Glacier-permafrost interactions



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Glacier-permafrost interactions

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Glacier-permafrost interactions

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Glacier-permafrost interactions

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Mapping of debris cover

coherence images from ALOS PALSAR image pairs (46 d baseline)

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Mapping of debris cover

coherence images from ALOS PALSAR image pairs (46 d baseline)

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Mapping of debris cover

coherence images from ALOS PALSAR image pairs (46 d baseline)

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Mapping of debris cover

coherence images from ALOS PALSAR image pairs (46 d baseline)

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Compilation procedure for glacier inventories

Orthorectified Landsat imagery from USGS

Thresholded band ratio (TM3/TM5)

Manual correction of debris cover, water, snow, shadows

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Compilation procedure for glacier inventories

Orthorectified Landsat imagery from USGS

Thresholded band ratio (TM3/TM5)

Manual correction of debris cover, water, snow, shadows

ID	catchments	catchments
01	48.00	5.00
02	49.00	5.00
03	50.00	5.00
04	51.00	5.00
05	52.00	5.00
06	53.00	5.00
07	54.00	5.00
08	55.00	5.00
09	56.00	5.00
10	57.00	5.00
11	58.00	5.00
12	59.00	5.00
13	60.00	5.00
14	61.00	5.00
15	62.00	5.00
16	63.00	5.00
17	64.00	5.00
18	65.00	5.00
19	66.00	5.00
20	67.00	5.00
21	68.00	5.00
22	69.00	5.00
23	70.00	5.00
24	71.00	5.00
25	72.00	5.00
26	73.00	5.00
27	74.00	5.00
28	75.00	5.00
29	76.00	5.00
30	77.00	5.00
31	78.00	5.00
32	79.00	5.00
33	80.00	5.00
34	81.00	5.00
35	82.00	5.00
36	83.00	5.00
37	84.00	5.00
38	85.00	5.00
39	86.00	5.00
40	87.00	5.00
41	88.00	5.00
42	89.00	5.00
43	90.00	5.00
44	91.00	5.00
45	92.00	5.00
46	93.00	5.00
47	94.00	5.00
48	95.00	5.00
49	96.00	5.00
50	97.00	5.00
51	98.00	5.00
52	99.00	5.00
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54	101.00	5.00
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57	104.00	5.00
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60	107.00	5.00
61	108.00	5.00
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74	121.00	5.00
75	122.00	5.00
76	123.00	5.00
77	124.00	5.00
78	125.00	5.00
79	126.00	5.00
80	127.00	5.00
81	128.00	5.00
82	129.00	5.00
83	130.00	5.00
84	131.00	5.00
85	132.00	5.00
86	133.00	5.00
87	134.00	5.00
88	135.00	5.00
89	136.00	5.00
90	137.00	5.00
91	138.00	5.00
92	139.00	5.00
93	140.00	5.00
94	141.00	5.00
95	142.00	5.00
96	143.00	5.00
97	144.00	5.00
98	145.00	5.00
99	146.00	5.00
100	147.00	5.00

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Choosing a digital elevation model (DEM)

Purposes:

- Calculation of topographic glacier parameters
- Derivation of hydrological drainage divides (separation of individual glaciers)

In India

- No national DEM publicly available
- SRTM DEM and ASTER GDEM (near-global coverage) provide a valuable alternative

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Choosing a digital elevation model (DEM)

SRTM InSAR February 2000 60°N - 56°S

ASTER GDEM Photogrammetric Scenes from 2000-2007 entire world (w/o poles)

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Choosing a digital elevation model (DEM)

Required to obtain topographic parameters and to delineate drainage divides

DEM differencing as a first quality assessment

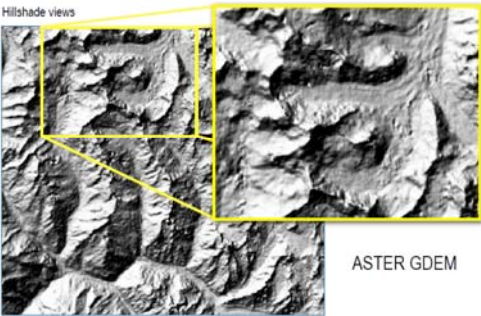
SRTM-GDEM differences (m)

- 609 - -154
- 153 - -126
- 125 - -98
- 97 - -69
- 68 - -41
- 40 - -13
- 12 - 15
- 16 - 43
- 44 - 72
- 73 - 100
- 101 - 128
- 129 - 1610

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Choosing a DEM for the Himalaya inventory

Hilshade views

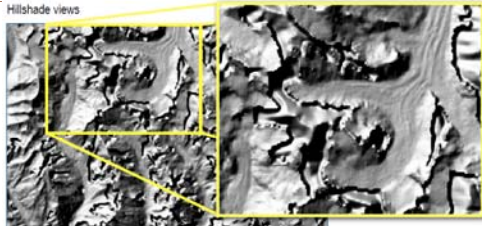


ASTER GDEM

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Choosing a DEM for the Himalaya inventory

Hilshade views



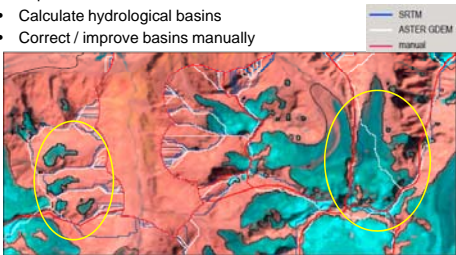
SRTM errors affect...
... the calculation of topographic parameters
... the determination of drainage divides
→ ASTER GDEM was chosen for the inventory compilation

SRTM

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Drainage divides

- Method from Bolch et al. (2010)
- Buffer around glacier outlines
- Clip DEM with this buffer
- Calculate hydrological basins
- Correct / improve basins manually



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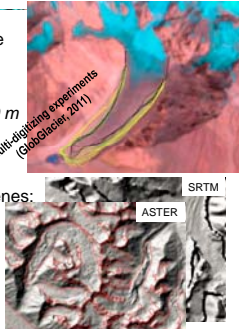
Sources of uncertainties

Glacier mapping

- Automated mapping of clean-ice parts: $\pm 5\%$
- Manual corrections of glacier outlines:
- margins: ± 60 m, terminus: ± 150 m

DEM inaccuracies

- Orthorectification of satellite scenes:
- Calculation of topographic parameters:
 - min-/max elevation: ± 45 m
 - mean elevation: ± 30 m
 - mean slope: $\pm 5^\circ$



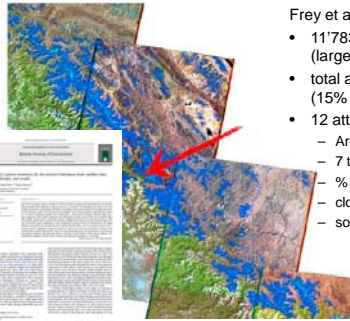
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Important points of this lecture

- Multispectral optical imagery allow semi-automated glacier mapping
- Major mapping challenges are related to debris-cover, clouds, snow, shadows, permafrost features, ...
- A DEM of sufficient quality is required to separate individual glaciers and to derive topographic glacier parameters
- Analyzing topographic parameters allows assessing glacier characteristics

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The glacier inventory for the W Himalayas



Frey et al. 2012:

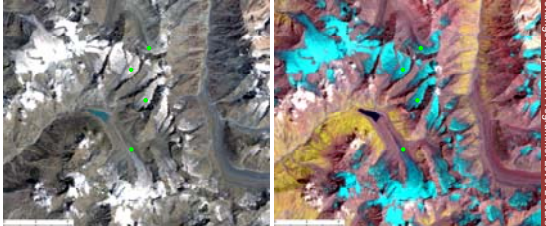
- 11'783 glaciers (larger than 0.02 km²)
- total area of 9'372 km² (15% debris-covered)
- 12 attributes for each glacier
 - Area
 - 7 topographic parameters
 - % debris cover
 - cloud-cover flag
 - source scene ID

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Exercise: glacier mapping

- Map the outlines and central flowlines of 4 glaciers
- Derive topographic parameter for the mapped glacier
- Answer questions about glacier mapping

→ http://www.geo.uzh.ch/~alinsbau/ihacp/level2/ex1_glacier_mapping



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