Glacier volumes – introduction

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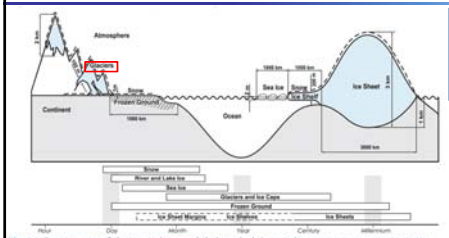
(with thanks to H. Frey, M. Zemp, F. Paul, T. Bolch)

IHCAP – Indian Himalayas Climate Change Adaptation Programme
Capacity building programme "Cryosphere" Level-2 (Jan 5 – Feb 13, 2015)

Components of the Cryosphere

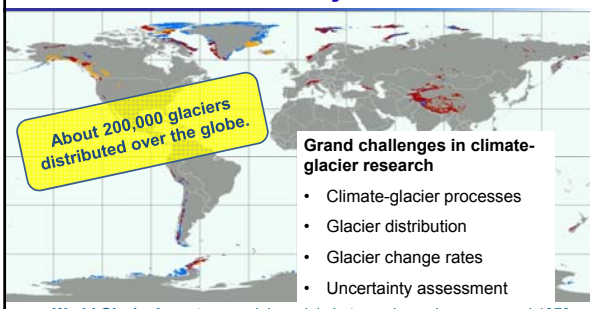


Cryosphere derives from the Greek term *kryo* (cold) and stands for one of the earth's sphere consisting of different components (e.g. snow) of frozen elements (e.g. water).

Fig. 1.1 Components of the cryosphere and their typical time scales. Source: Fig. 4.1 of IPCC (2007). WGMS (2008) UNEP (2007)

Components of the Cryosphere	Area Covered (million square km)	Ice Volume (million cubic km)	Potential Sea Level Rise (cm)
Snow on land (Northern Hemisphere) (annual minimum – maximum)	1.9 – 45.2	0.0005 – 0.005	0.1 – 1
Sea ice, Arctic and Antarctic (annual minimum – maximum)	19 – 27	0.019 – 0.025	0
Ice shelves	1.5	0.7	0
Ice sheets (total)	14.0	27.6	6390
Greenland	1.7	2.9	730
Antarctica	12.3	24.7	5860
Glaciers and ice caps (lowest and (highest) estimates)	0.51 ([0.54])	0.05 ([0.13])	15 ([37])
Permafrost (Northern Hemisphere)	22.8	4.5	~7
River and lake ice	(n/a)	(n/a)	(n/a)

World Glacier Inventory

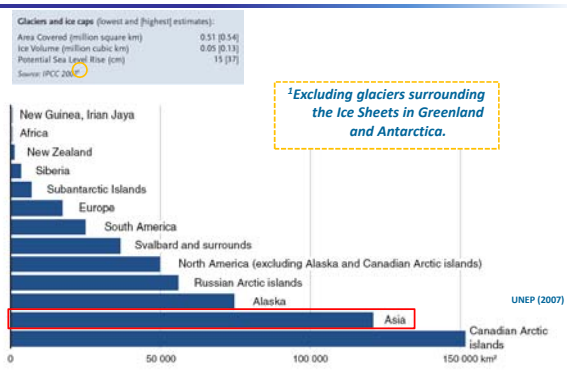


Grand challenges in climate-glacier research

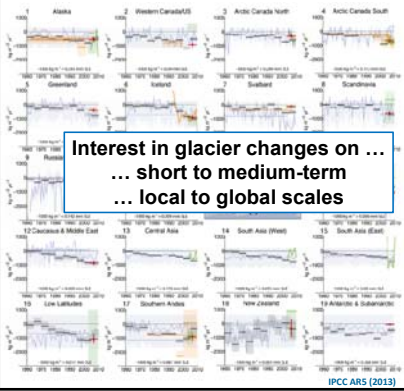
- Climate-glacier processes
- Glacier distribution
- Glacier change rates
- Uncertainty assessment

- **World Glacier Inventory:** mainly aerial photographs and maps around 1970s
- **GLIMS Inventory:** mainly satellite images after 2000
- **Randolph Glacier Map:** rough glacier outlines, rough time stamp, no attributes

How much glacier ice is out there?



How (fast) are glaciers changing?

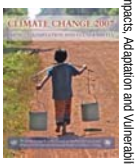


Methods:

- Remote Sensing
- Modelling with climate data
- Repeat gravimetry
- Glaciological observations
- Geodetic methods
- …

IPCC: Himalayan glacier error

- ***IPCC AR4, WGII:*** *"Glaciers in the Himalaya are* ***receding faster than*** **in any other part of the world** and, if the present rate continues, **the likelihood of them disappearing by the year 2035 and perhaps sooner is very high** if the Earth keeps warming at the current rate. Its total area will likely shrink from the present 500,000 to 100,000 km2 by the year 2035 (WWF, 2005)."



"Impacts, Adaptation and Vulnerability" Working Group II Report

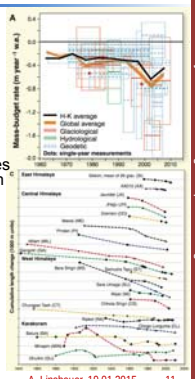
- ***IPCC AR4 Errata (from 20 Oct 2011):*** *"9) Page 493. Column 2.* Lines 32-43. **Delete this text,** through the first two words on line 43 **and replace with "Many Himalayan glaciers are retreating** (Karma et al., 2003; and see examples in Table 10.9)**"."**

- **→ Major gaps in our knowledge of the behavior of the Himalayan glaciers**

State and fate of Himalayan glaciers

Main findings of Bolch et al. 2012:

- The majority of the Himalayan glaciers are shrinking, but much less rapidly than predicted earlier.
- No major impact on the annual runoff of Indus, Ganges, and Brahmaputra, but a greater variability in the future and major impacts on some smaller mountain catchments.
- New forming and/or rapidly growing glacier lakes can pose a serious threat to the local population and infrastructure.
- Further research is required to close existing gaps of knowledge related to...
  - ...the variability of glacier changes within the region
  - ...the influence of debris cover on glacier melt
  - ...the role of avalanches in the glacier mass budget
- Important tasks
  - Fill gaps in the network of climatic and hydrologic stations (high elevation sites and N-S transects)
  - Thickness measurements on selected glaciers



Content / Schedule

	Mon 19/01	Tue 20/01	Wed 21/01	Thu 22/01	Fri 23/01
9.30 - 11.00	Lecture: glacier mapping	Lecture: glacier thickness, glacier volumes	Lecture: Overview on MB models	Glacier dynamics	Glacier dynamics
Tea					
11.15 - 12.45	Ex 1: manual glacier mapping	Ex 2: distributed ice thickness for 4 glaciers	Ex 3: Paper evaluation, focus on MB models	Glacier dynamics	Glacier dynamics
Lunch					
14.00 - 15.30	Ex 1: semi-automated glacier mapping	Ex 2: scalar derived volumes for 4 glaciers	Time to finish Ex 1 and 2	Glacier dynamics	Glacier dynamics
Tea					
15.45 - 17.15	Ex 1: semi-automated glacier mapping	Ex 2: glacier volume for an inventory dataset	Wrap-up, questions and answers	Glacier dynamics	Glacier dynamics

Sources and downloads: http://www.geo.uzh.ch/~alinsbau/ihcap/level2/