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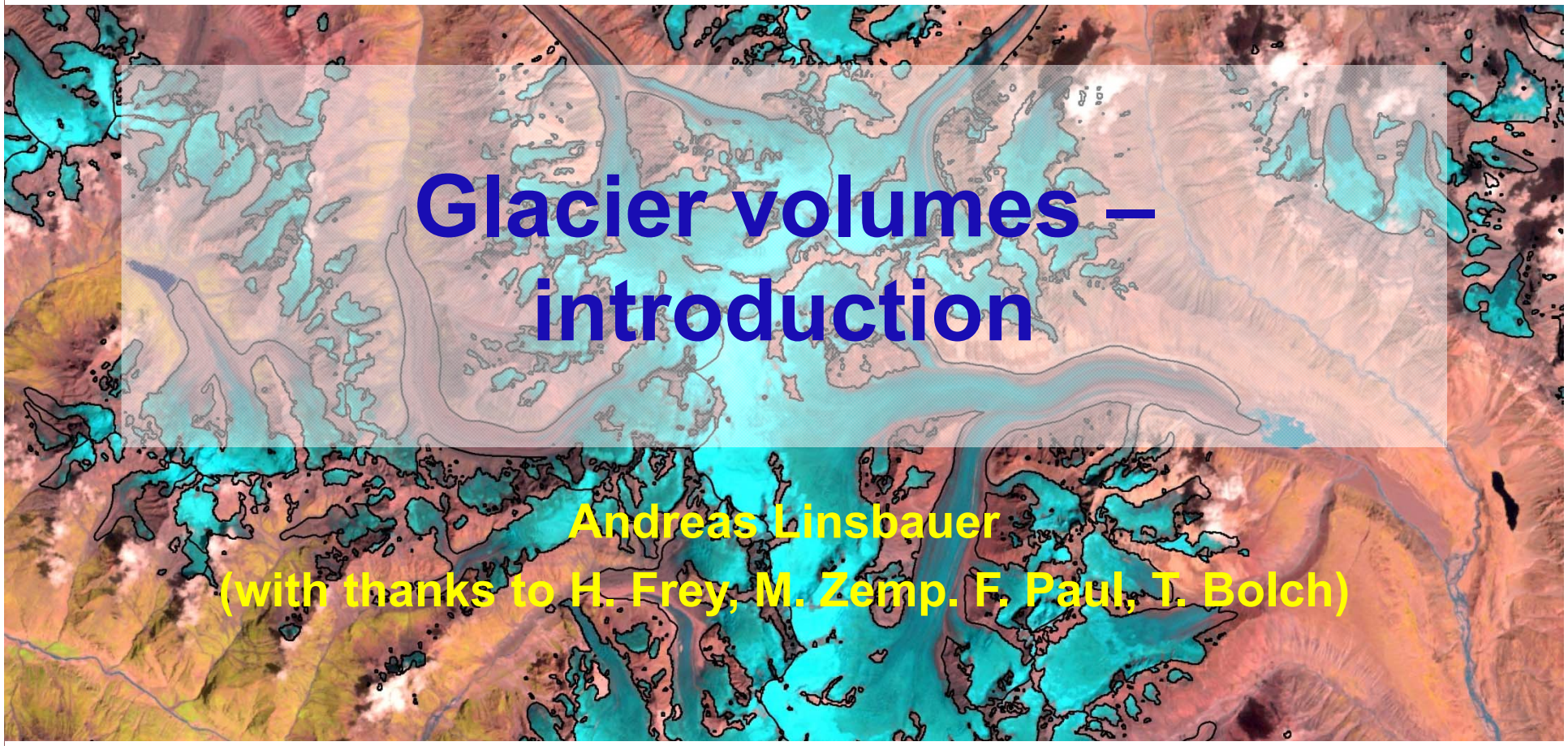

Glacier volumes – introduction

Andreas Linsbauer

(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)


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Components of the Cryosphere

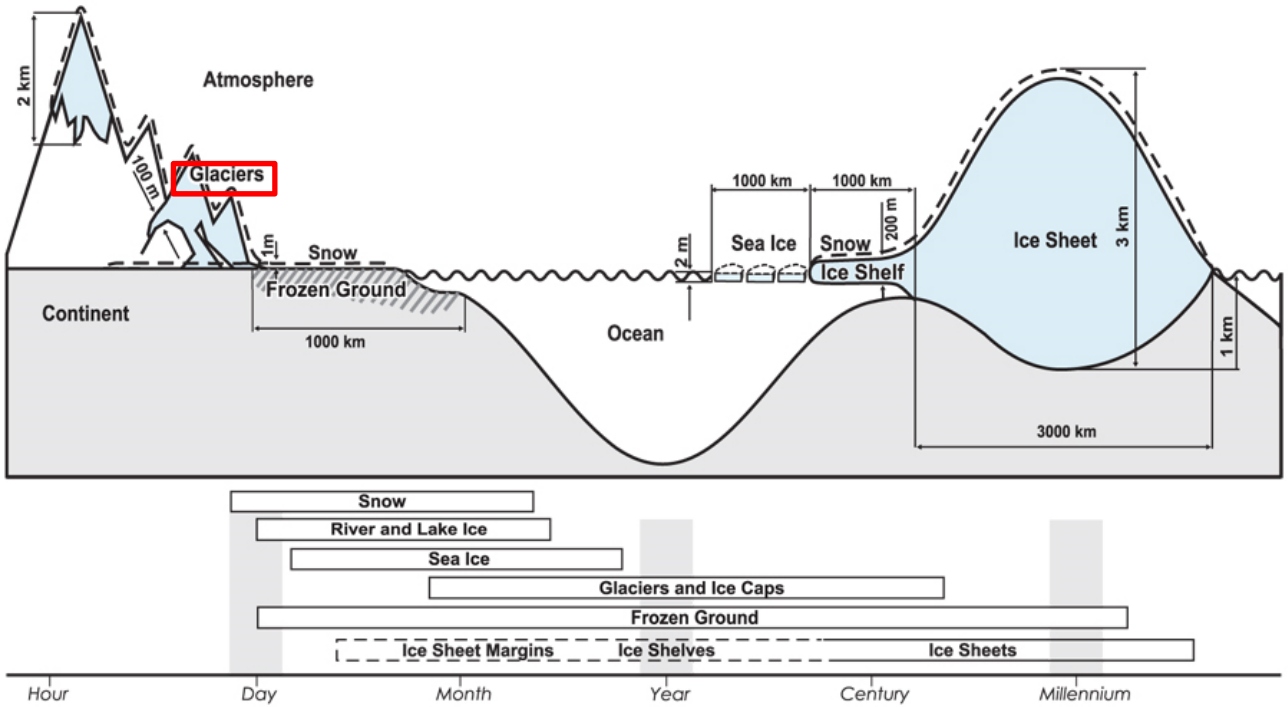


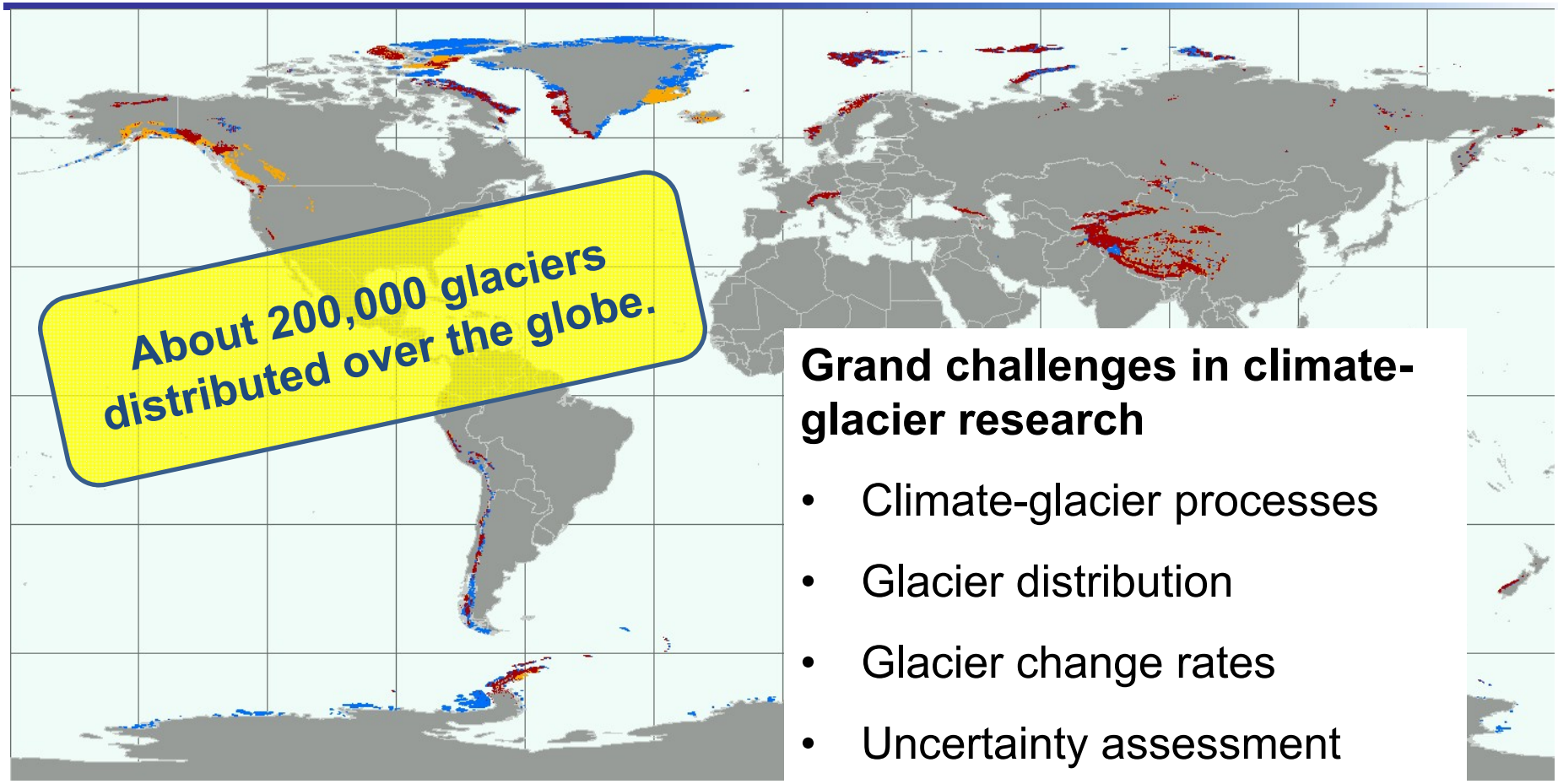
Fig. 1.1 Components of the cryosphere and their typical time scales. Source: Fig. 4.1 of IPCC (2007).

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).**

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	5660
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

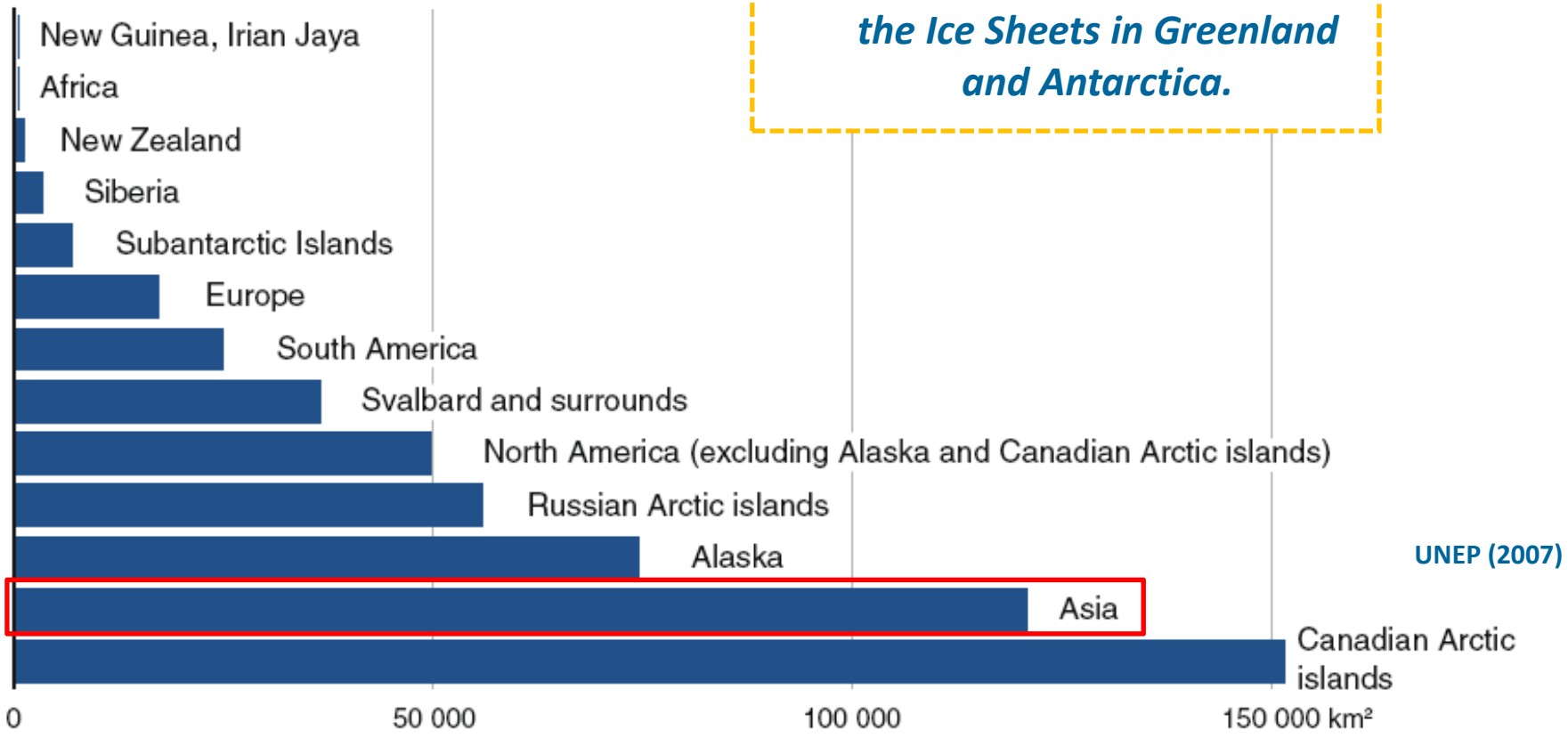
How much glacier ice is out there?

Glaciers and ice caps (lowest and [highest] estimates):

Area Covered (million square km)	0.51 [0.54]
Ice Volume (million cubic km)	0.05 [0.13]
Potential Sea Level Rise (cm)	15 [37]

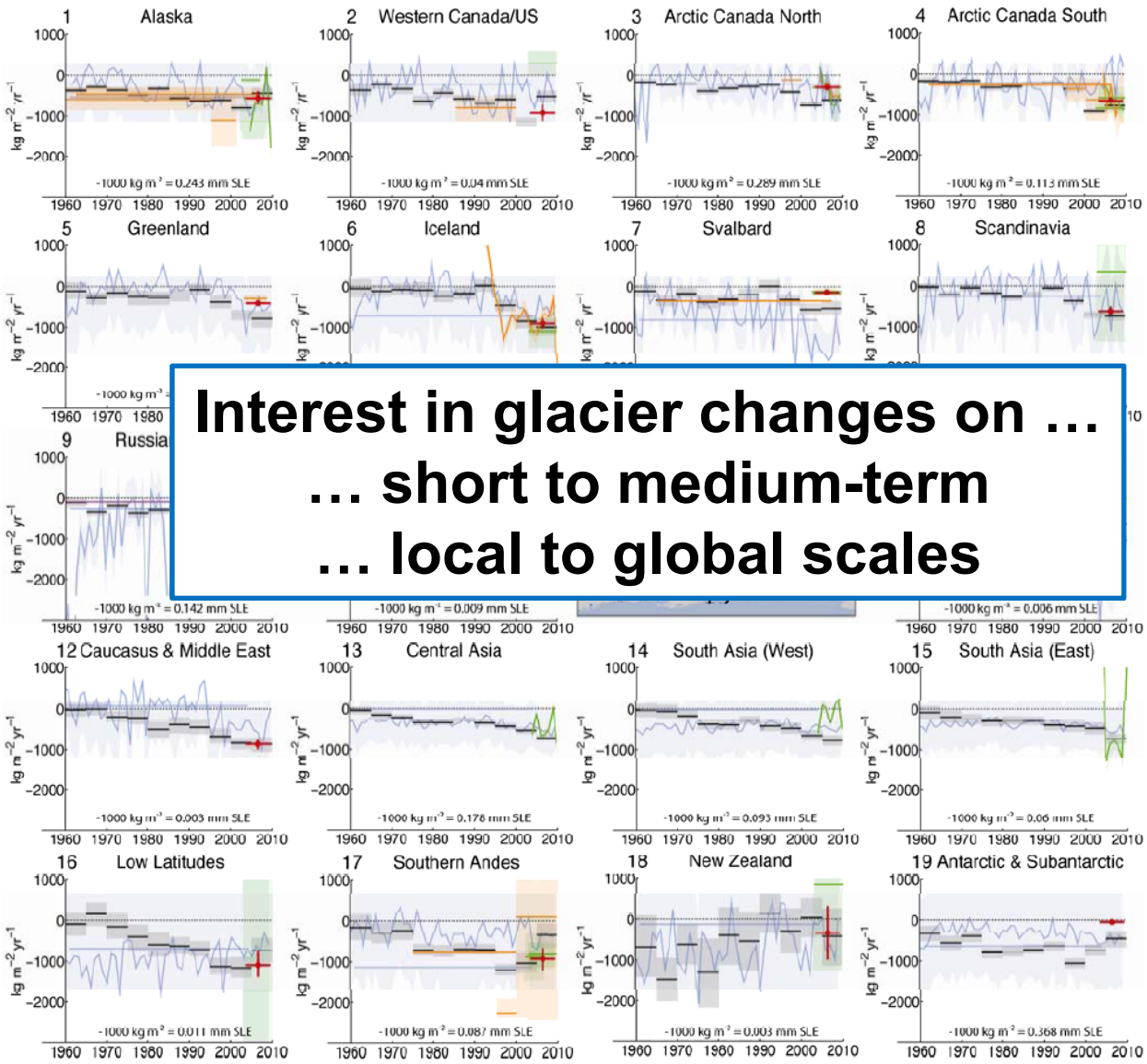
Source: IPCC 2007[1]

[1]Excluding glaciers surrounding the Ice Sheets in Greenland and Antarctica.



UNEP (2007)

How (fast) are glaciers changing?



Interest in glacier changes on …
… short to medium-term
… local to global scales

IPCC AR5 (2013)

Methods:

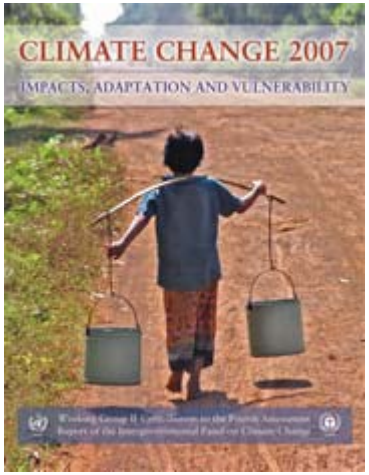
- Remote Sensing
- Modelling with climate data
- Repeat gravimetry
- Glaciological observations
- Geodetic methods
- …

IPCC: Himalayan glacier error

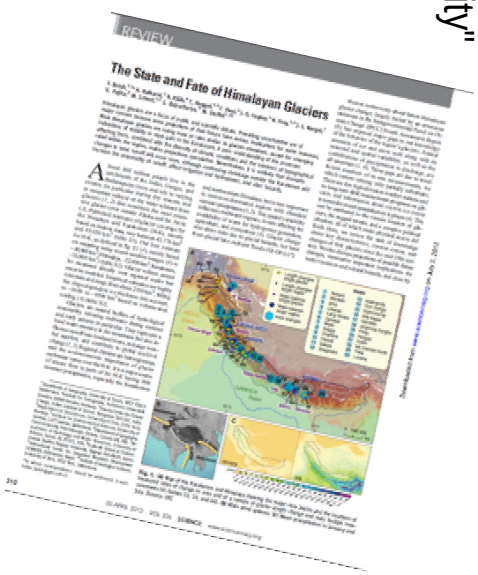
- ***IPCC AR4, WGII:*** *"Glaciers in the Himalaya are* ***receding faster than*** **in any other part of the world** and, if the present rate continues, **the likelihood of them disappearing by the year 2035 and perhaps sooner is very high** if the Earth keeps warming at the current rate. Its total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

- ***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**



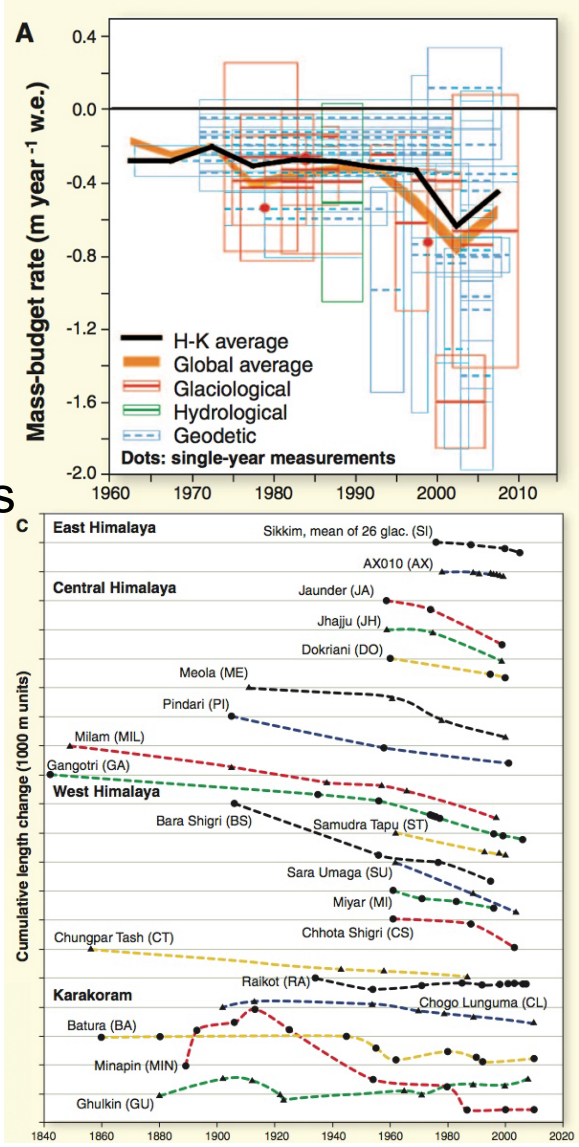
Working Group II Report
"Impacts, Adaptation and Vulnerability"



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/

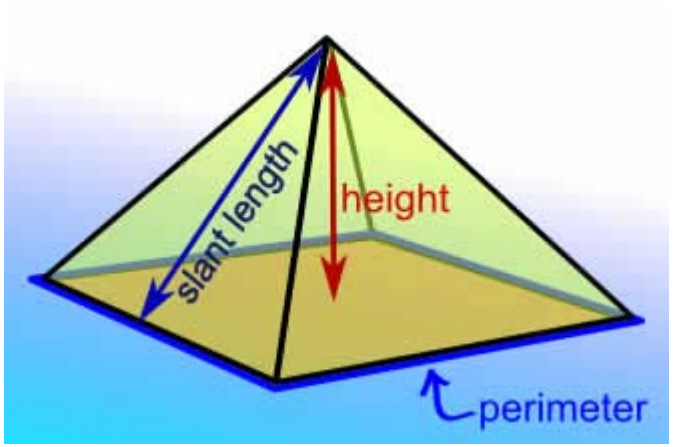
Galcier ice volume estimates

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 x d



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