IUGG, Global Observing Systems, July 4, 2007

Worldwide Glacier Monitoring

present state and current challenges

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Martin Hoelzle, Andi Kääb, Jeff Kargel, Frank Paul and Bruce Raup

NSIDC
National Snow and Ice Data Center

GLIMS

wgms

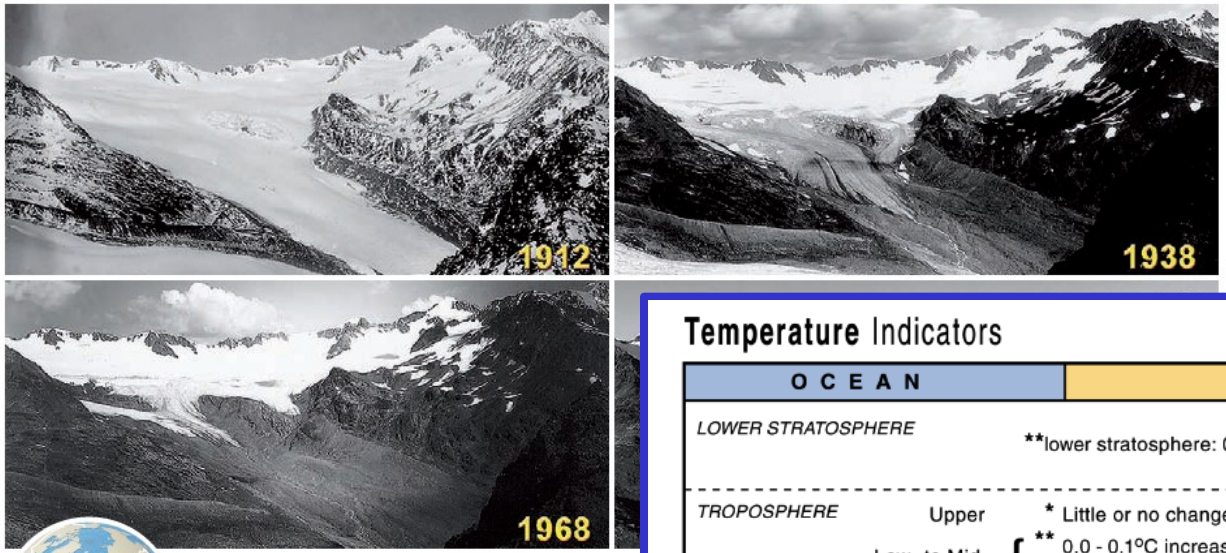


Figure 6B.4: Shrinking of Vernagtferner, Austria. more than 50% in mass between 1912 and 200

Source: Data and photos, taken by O. Gruber (1912), H the Commission for Glaciology of the Bavarian Academy

Zemp et al. (2007)

Temperature Indicators

OCEAN	LAND	OCEAN

LOWER STRATOSPHERE

** lower stratosphere: 0.5 to 2.5°C decrease since 1979

TROPOSPHERE

Upper: * Little or no change since 1979

Low- to Mid-: ** 0.0 - 0.1°C increase since 1979 - satellites & balloons; * 0.2 to 0.4°C increase since ~1960

NEAR-SURFACE

** N.H. Spring snow cover extent: since 1987 10% below 1966-86 mean

* 1990s warmest decade of the millennium and 1998 warmest year for at least the N.H.

** marine air temperature: 0.4 to 0.7°C increase since late-19th Century

*** sea surface temperature: 0.4 to 0.8°C increase since the late 19 th century.

* global ocean (to 300m depth) heat content increase since 1940s equal to 0.03°C / decade

*** massive retreat of mountain glaciers during 20th Century

increasing at twice the rate of daytime temperatures since 1950

** lake and river ice retreat at mid and high latitudes since the late 19th century (2 week

*** land air temperatures: 0.4 to 0.8°C increase since late 19th Century

* Arctic sea ice: summer thickness decrease of 40% and 10-15% decrease in extent during spring and summer since 1950s

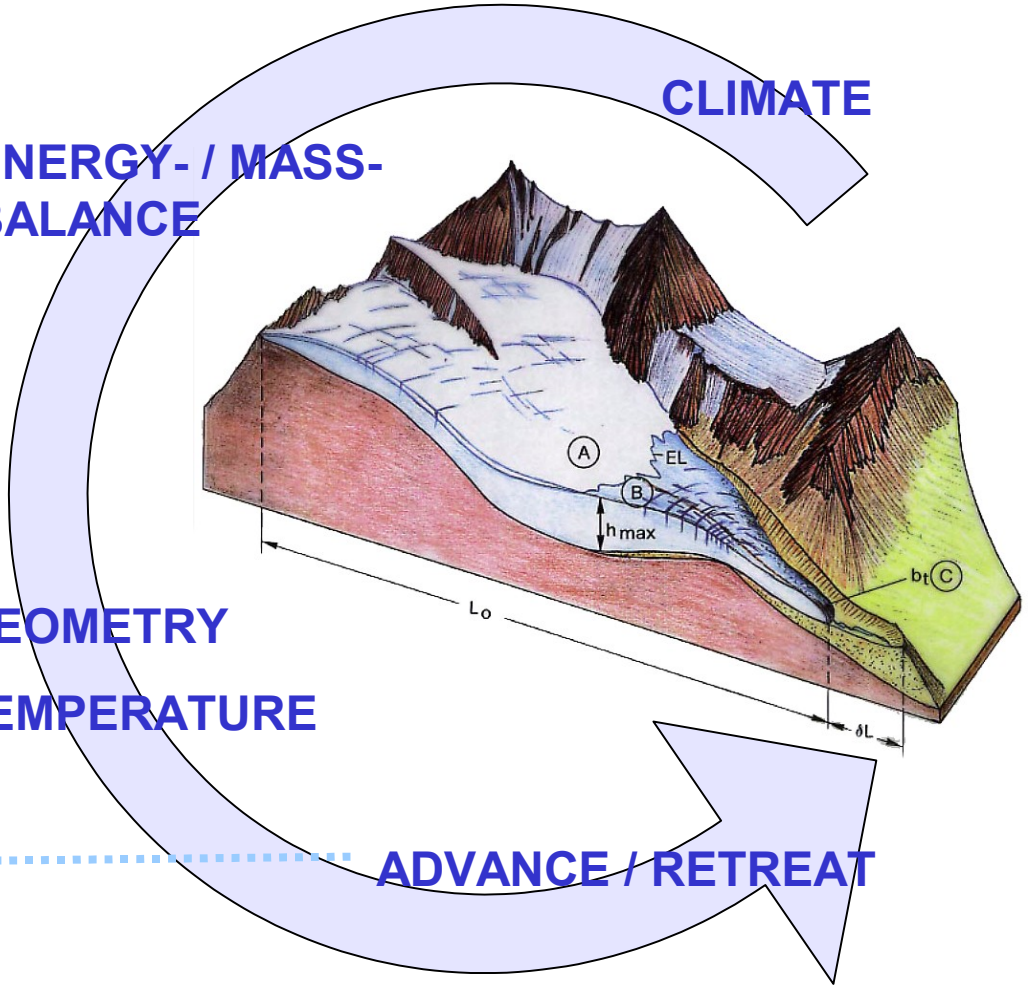
? Antarctic sea ice: no significant change since 1978

Likelihood:

*** Virtually certain (probability > 99%)
** Very likely (probability ≥ 90% but ≤ 99%)
* Likely (probability > 66% but < 90%)
? Medium likelihood (probability > 33% but ≤ 66%)

IPCC (2001)

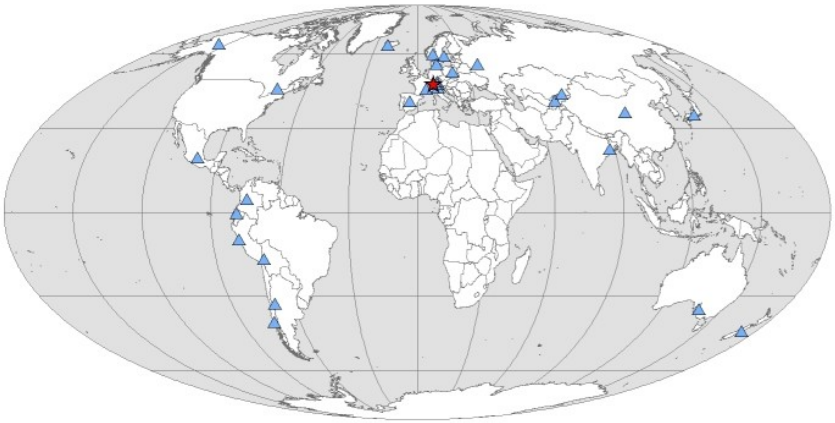
Glacier crash course: climate-glacier process chain



Haeberli (1998)

About the World Glacier Monitoring Service (WGMS)

- Internationally coordinated glacier observation **initiated in 1894** by the International Glacier Commission



- Combination of former ICSI services (PSFG, TTS/WGI) into UCCS service **WGMS in 1986**

- Since then WGMS continues to **collect and publish standardised worldwide glacier data**
  - Glacier changes with time (glacier fluctuations)
  - Spatial distribution of perennial surface ice (glacier inventories)

- **WGMS:**
  - Central service located in Zurich, Switzerland
  - Network of National Correspondents in 30 countries

wgms

WGMS products and links to other organisations

- Fluctuations of Glaciers
  - FoG I–IX
  - GMBB 1–9
  - Assessment reports
- World Glacier Inventory
  - WGI (1989)
- Special events
  - drastic changes
  - glacier-related hazards

wgms

IPCC, UNEP, EEA, GTOS, GCOS, …

=> status reports

=> change assessments

Global Land Ice Measurements from Space (GLIMS)

=> continues WGI

National Snow and Ice Data Center (NSIDC)

=> stores WGI & GLIMS data

Glacier and Permafrost Hazards in Mountains (GAPHAZ)

=> compiles hazard data

Organisational structures and funding situation

WGMS

- Data collection through global cooperative network of National Correspondents and Principal Investigators
- Data compilation, analysis and publication through central service
- Central service staff: 200%
- Central service is funded by Swiss National Science Foundation, University of Zurich, and scientific projects
- Small amounts from international Organisations (e.g., UNEP, UNESCO, CAGS)

GLIMS

- Data collection through global cooperative network of Regional Centers and local Stewards
- Data compilations is a NASA funded activity at NSIDC to build and host the GLIMS Glacier Database and website, and to develop new tools for the GLIMS glacier production and analysis

NSIDC/University of Colorado

- Archives, manages and distributes all types of cryospheric data, creates tools for data access, supports data users, performs scientific research, and educats the public about the cryopshere

=> secure financial basis with national and international funding!

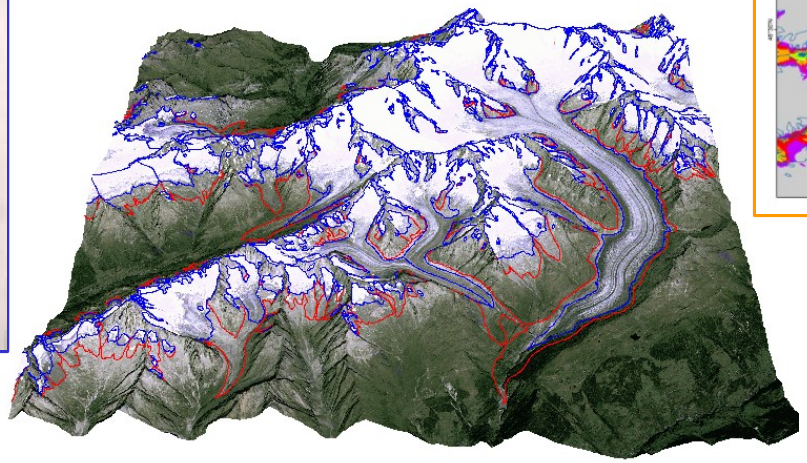
Global Terrestrial Network for Glaciers

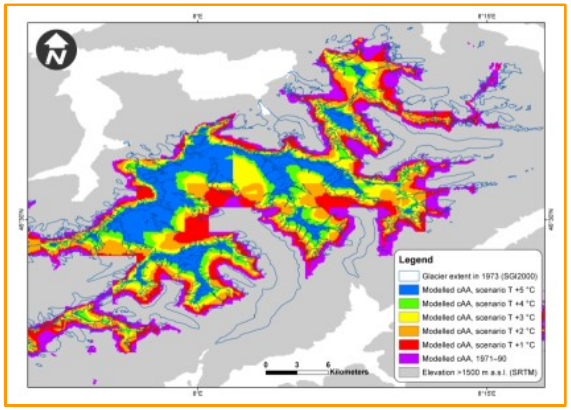
WGMS runs the **Global Terrestrial Network for Glaciers** (GTN-G) as part of GTOS/GCOS for the UNFCCC.

This network follows the 5-level GHOST-strategy, integrating **in-situ measurements**, **remote sensing** and **numerical modelling**.

GTOS
GLOBAL TERRESTRIAL OBSERVATION SYSTEM

FAO FIAT PANIS ICSU UNESCO UNEP WMO





GTN-G observing strategy

Haeberli et al. (2000)

main goals of long-term observations:

- process understanding
- model validation
- change detection
- impact assessments

change detection:

- rate of change
- acceleration trends
- pre-industrial variability
- change patterns

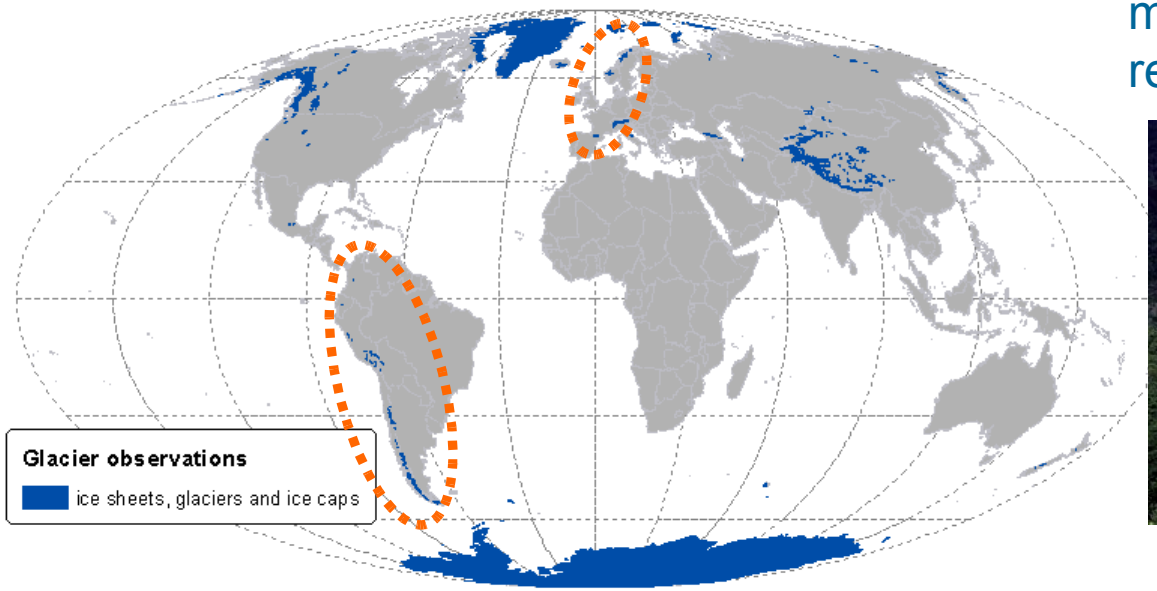
integrated /tiered observing strategy

Tier 1: multi-component obs. system across environmental gradients
Tier 2: process understanding and model calibration
=> extensive energy/mass balance, flow
Tier 3: regional indicators
=> mass change (index stakes, photogrammetry, LIDAR)
Tier 4: regional representativeness
=> cumulative length change of selected glaciers
Tier 5: global coverage
=> inventories (remote sensing/geoinformatics)

GTN-G observing strategy: Tier 1

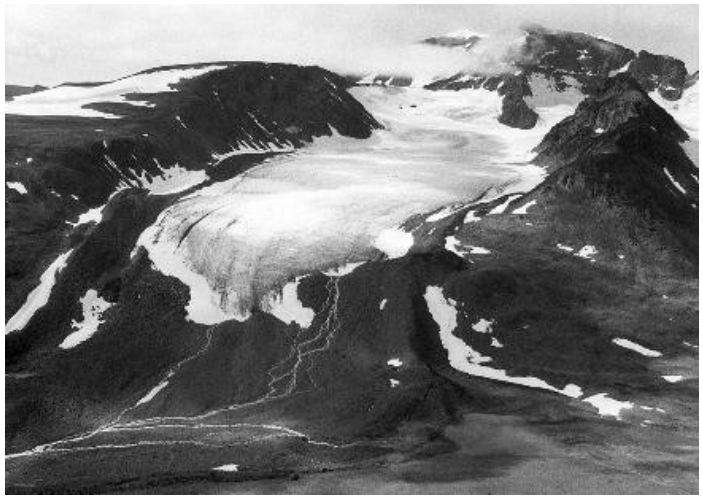
Ts. Tuyuksuyskiy Glacier, KZ
(V.N. Vinokhodov)

- Cover spatial diversity over large scales (continental-type) or elevation belts
- Include long-term measurements
- Overcome national boundaries
- Planning of monitoring network must be based on feasibility and relevance



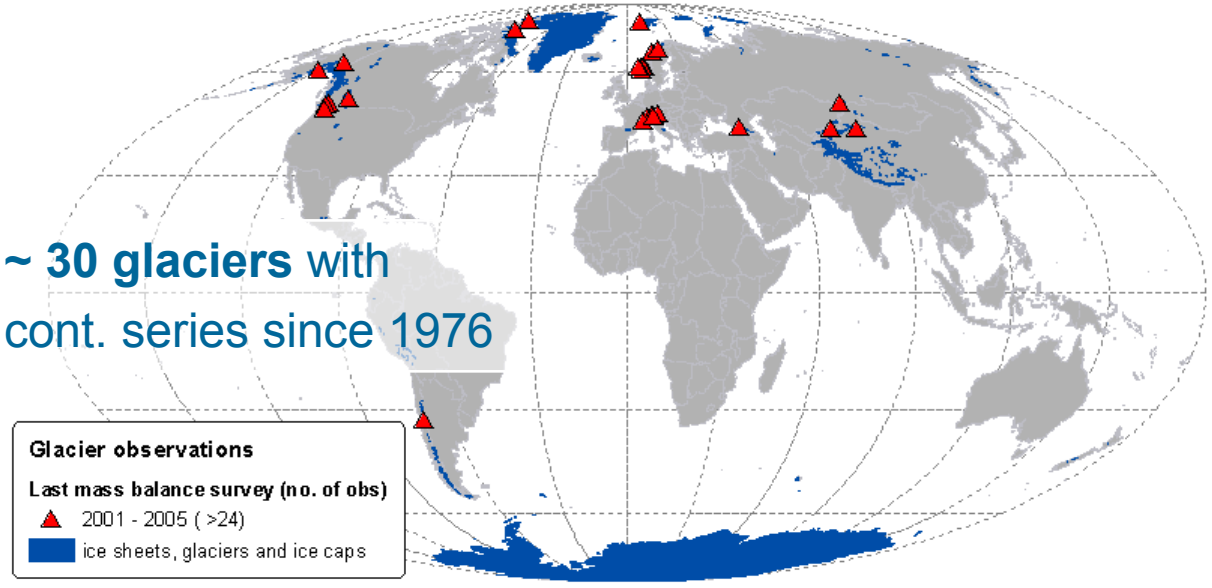
Franz Josef Glacier, NZ
(M. Hambrey)

GTN-G observing strategy: Tier 2

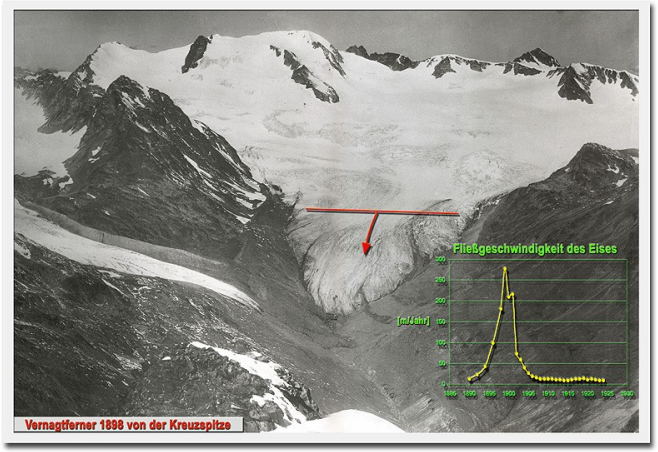


Storglaciaeren, SE,
photo by P. Holmlund

- Extensive and process-oriented glacier energy/mass balance and flow studies
- Used to improve process understanding and model validation



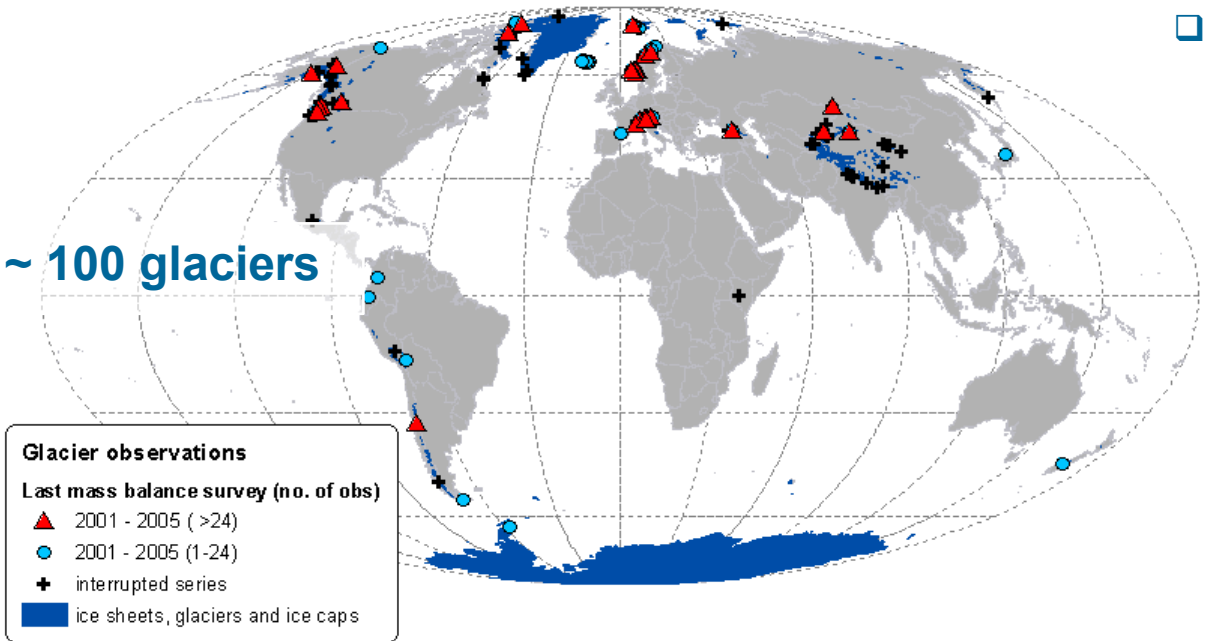
~ 30 glaciers with
cont. series since 1976

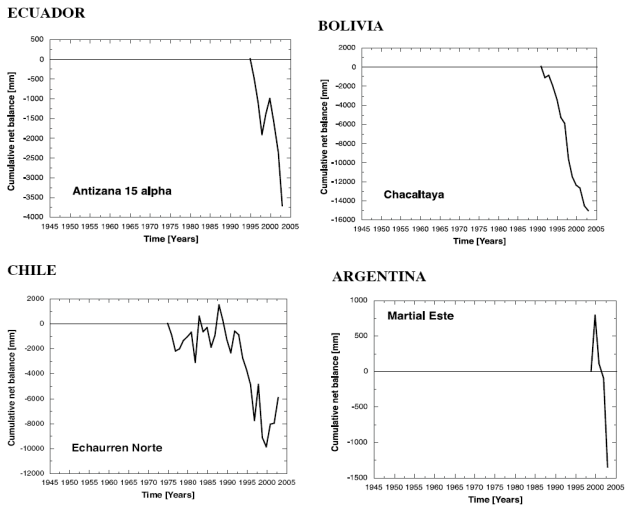


Vernagtferner, AT,
www.glaziologie.de

GTN-G observing strategy: Tier 3

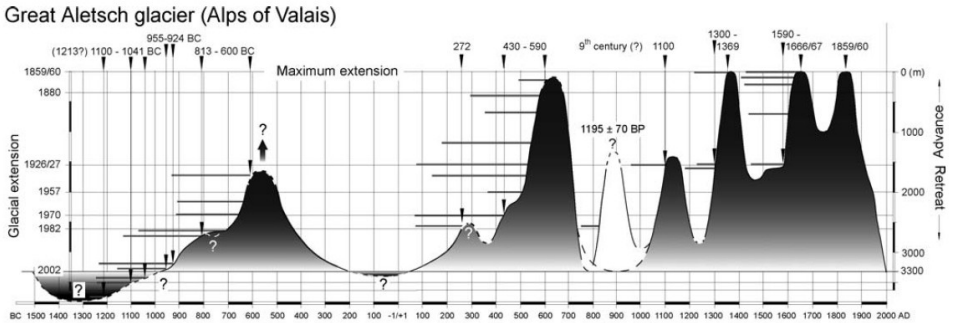
- Determination or regional glacier volume change using cost-saving methods, such as:
  - Mass balance measurements with reduced stake network
  - Selected index stakes
  - Photogrammetry
  - LIDAR
  - DEM differencing





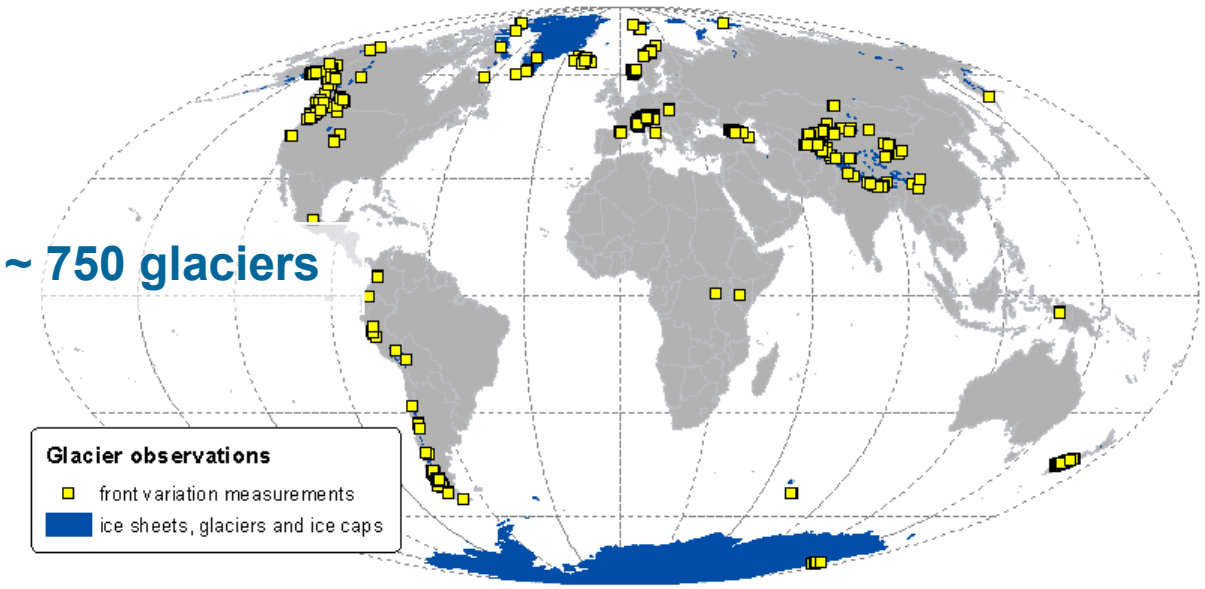
GMBB (2005)

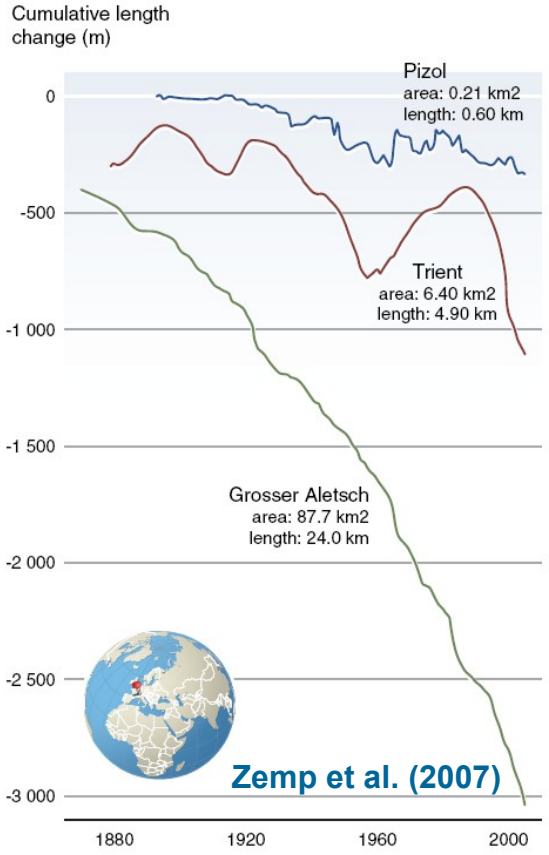
GTN-G observing strategy: Tier 4



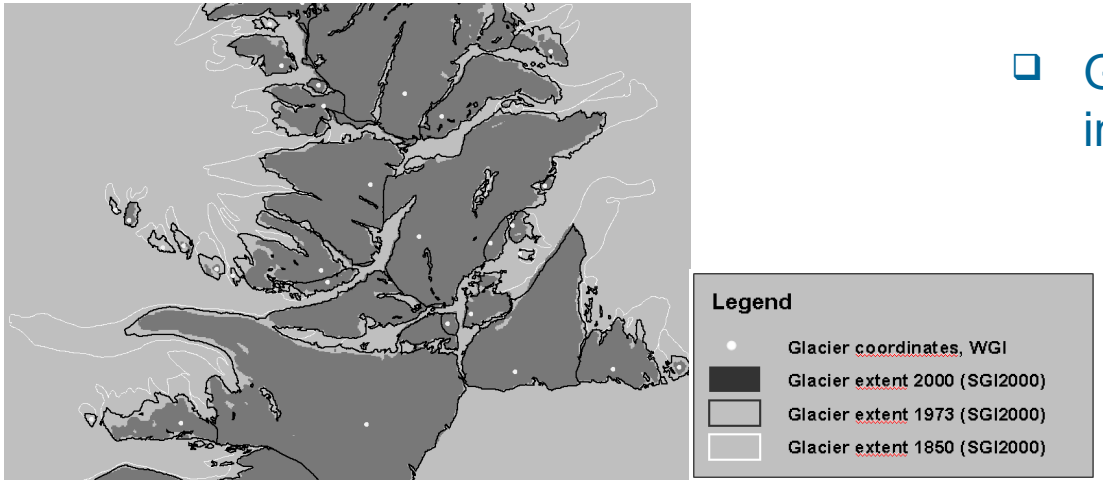
Holzhauser et al. (2005)

- Long-term observations of glacier length change for assessing the representativity of mass balance and volume change measurements

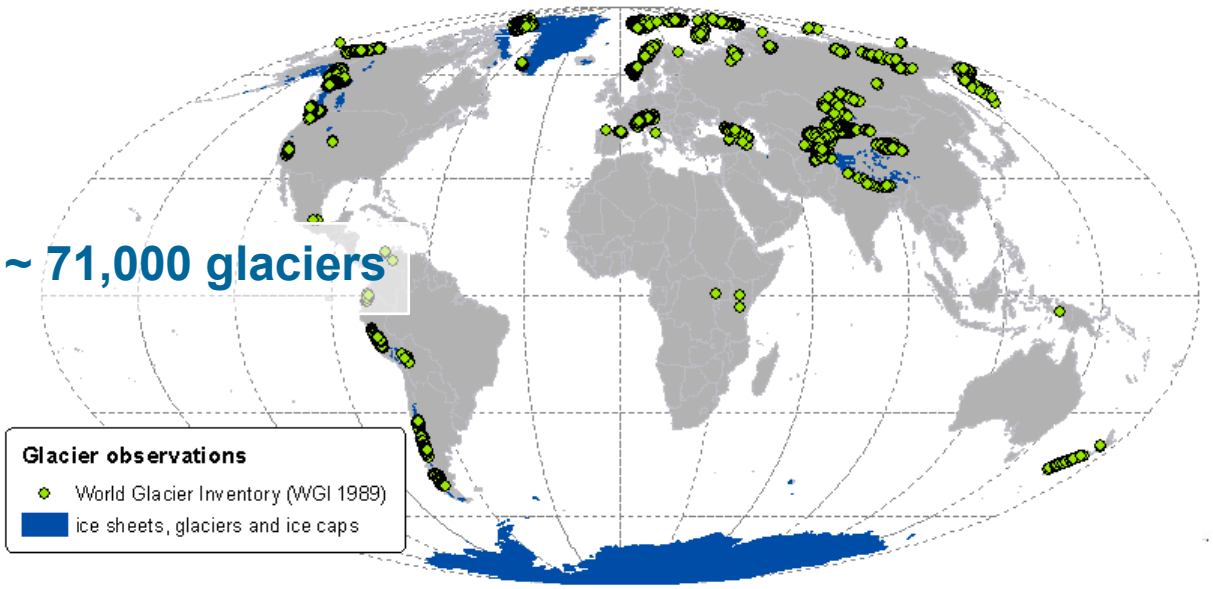


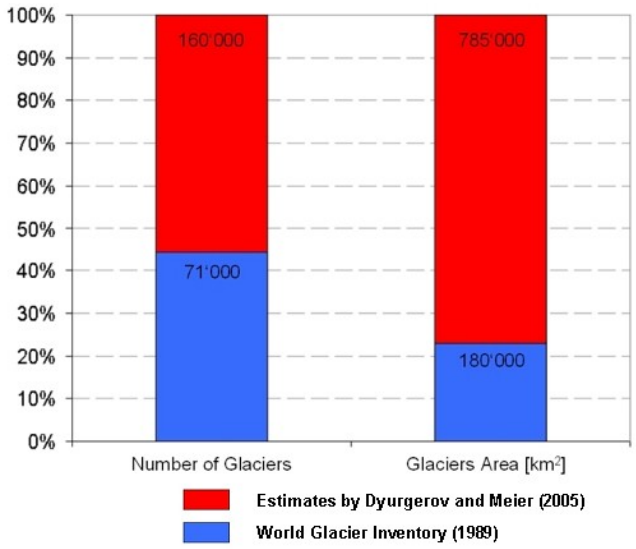


GTN-G observing strategy: Tier 5, WGI

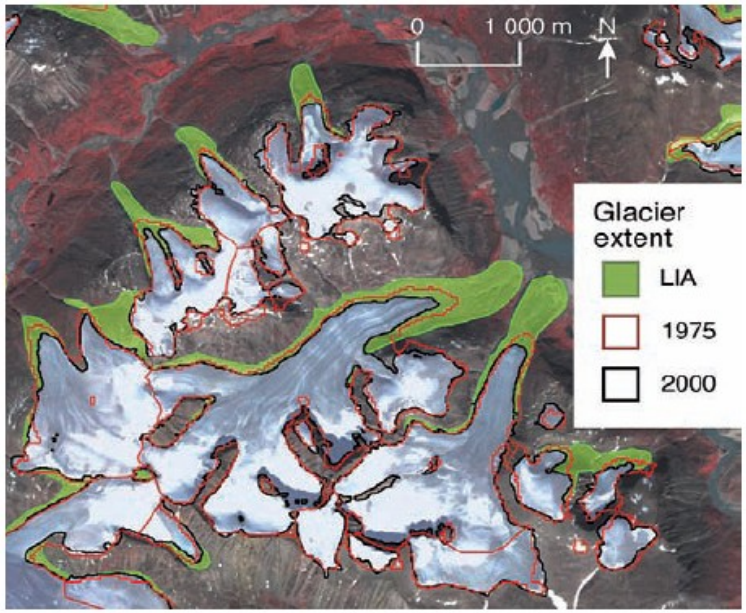


- Glacier inventories repeated at time intervals of a few decades by using:
  - Topographic maps and moraine dating
  - **Aerial photography**
  - Satellite remote sensing



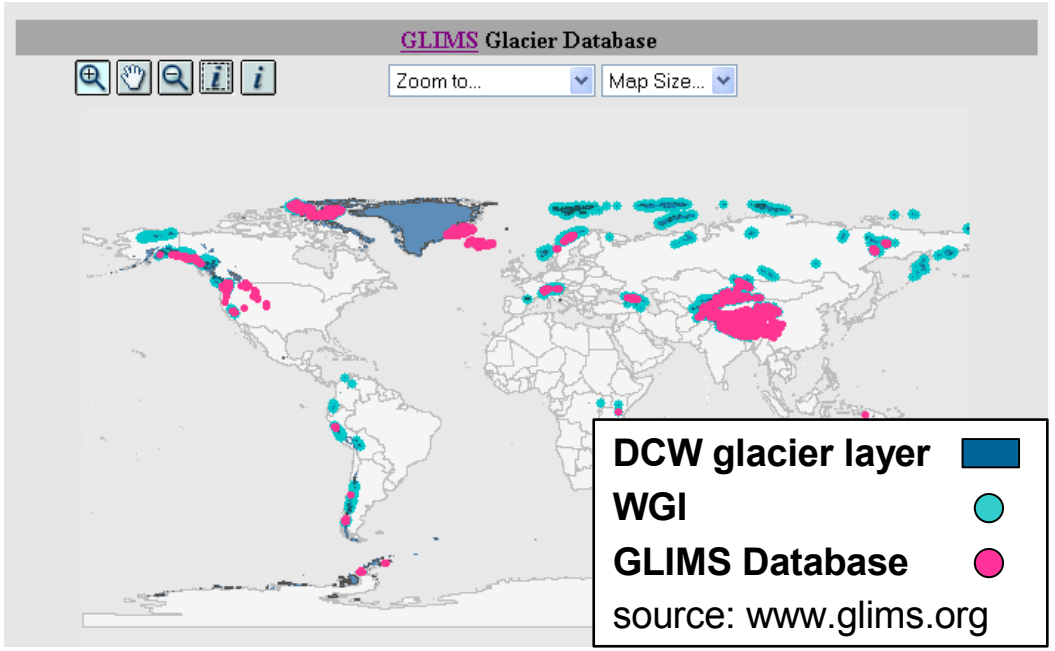


GTN-G observing strategy: Tier 5, GLIMS



Baffin Island, Canadian Arctic, F. Svoboda & F. Paul

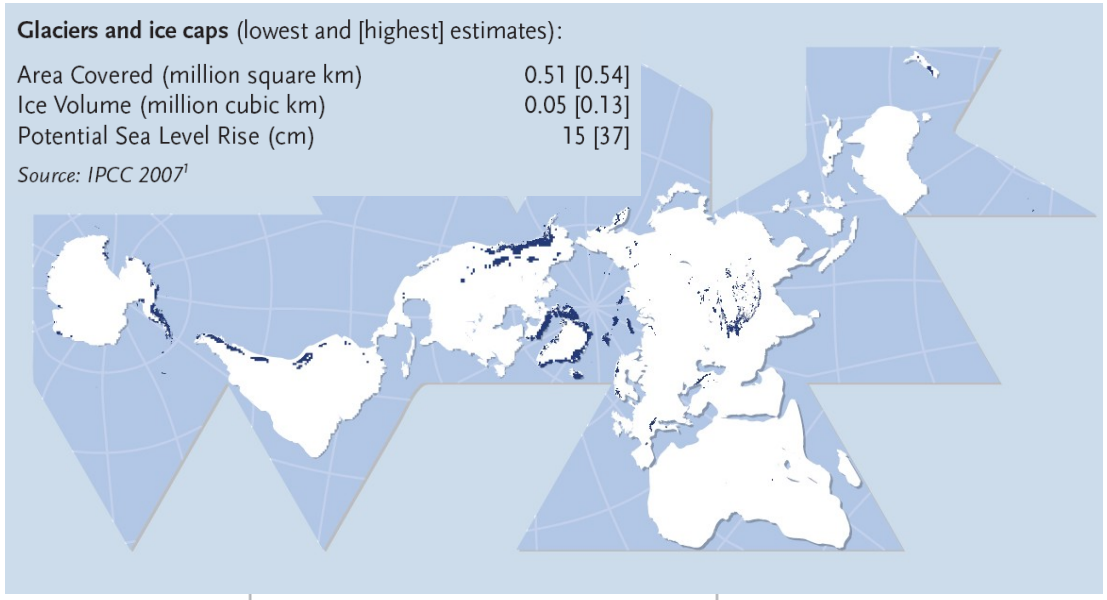
- Glacier inventories repeated at time intervals of a few decades by using:
  - Topographic maps and moraine dating
  - Aerial photography
  - **Satellite remote sensing**



esa EO Applications Development Data User Element European Space Agency

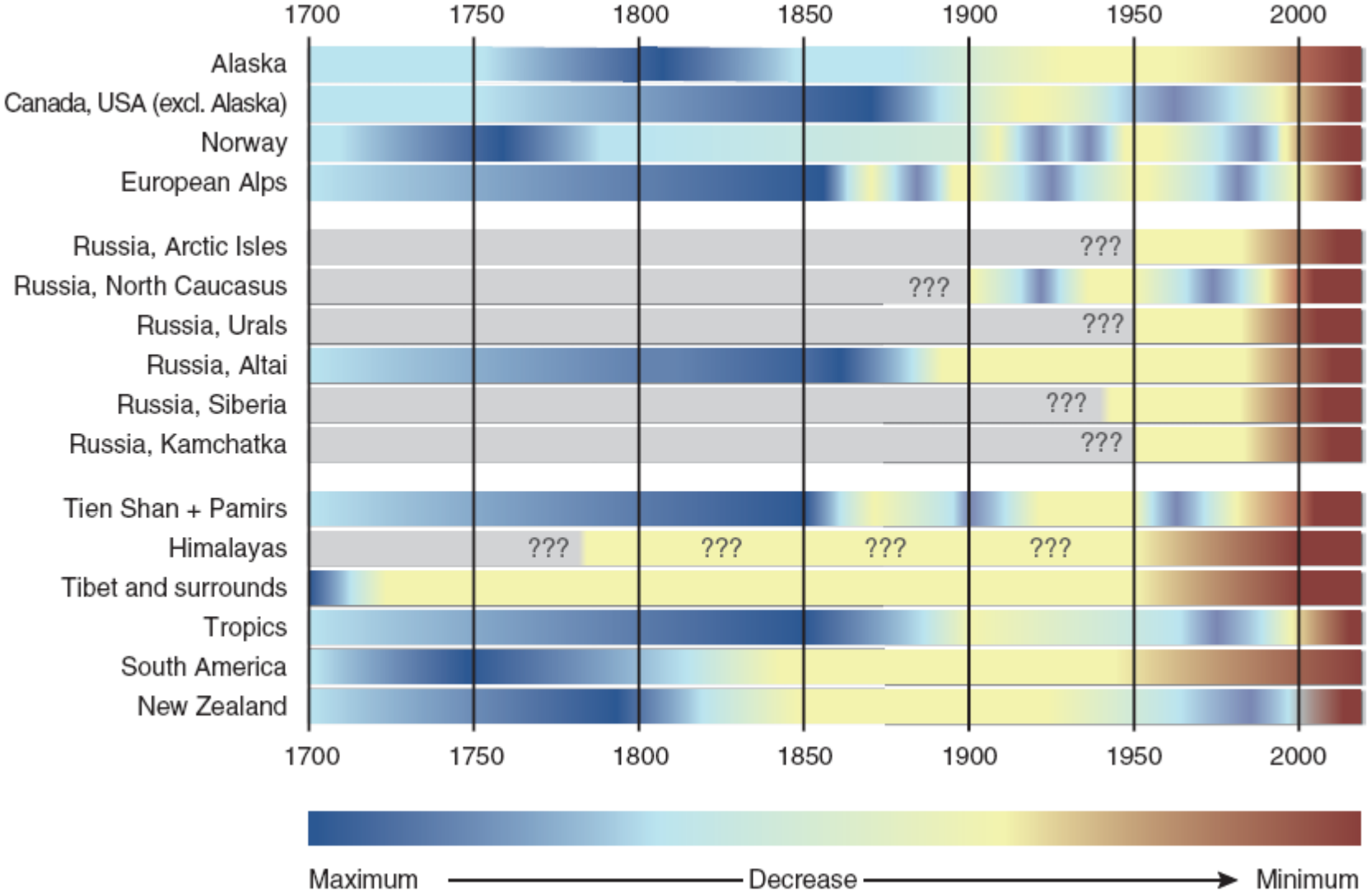
GlobGlacier

Glacier distribution around the world



Zemp et al. (2007), based on Dyurgerov and Meier (2005)

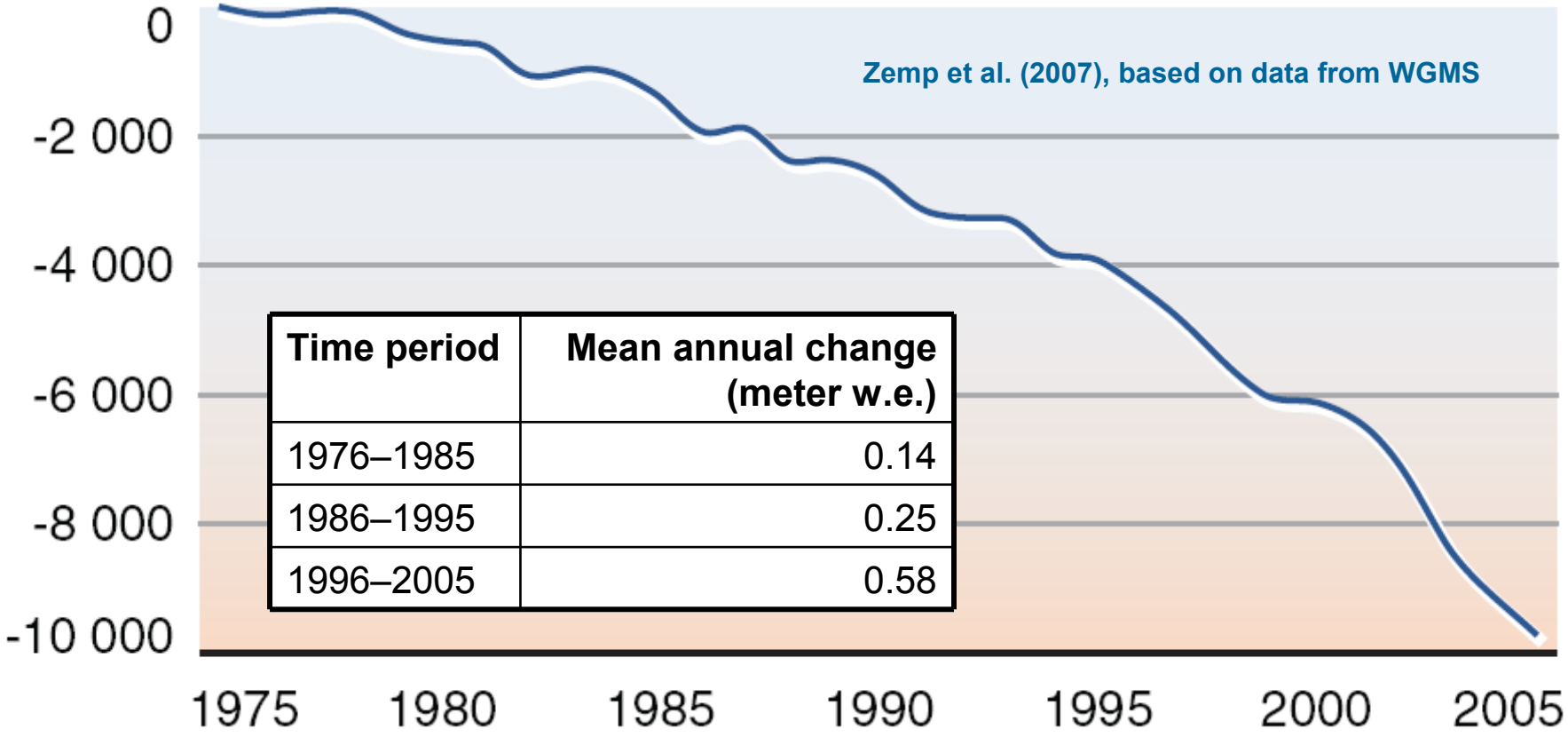
Glacier fluctuations in selected mountain ranges



Zemp et al. (2007), based on front variation and mass balance observations

Mass balance data from continuous observations

Cumulative mean annual mass balance
of 30 reference glaciers in 9 mountain Ranges (mm w.e.)



Time period	Mean annual change (meter w.e.)
1976–1985	0.14
1986–1995	0.25
1996–2005	0.58

Impacts of glacier changes

www.vivendamiranda.com

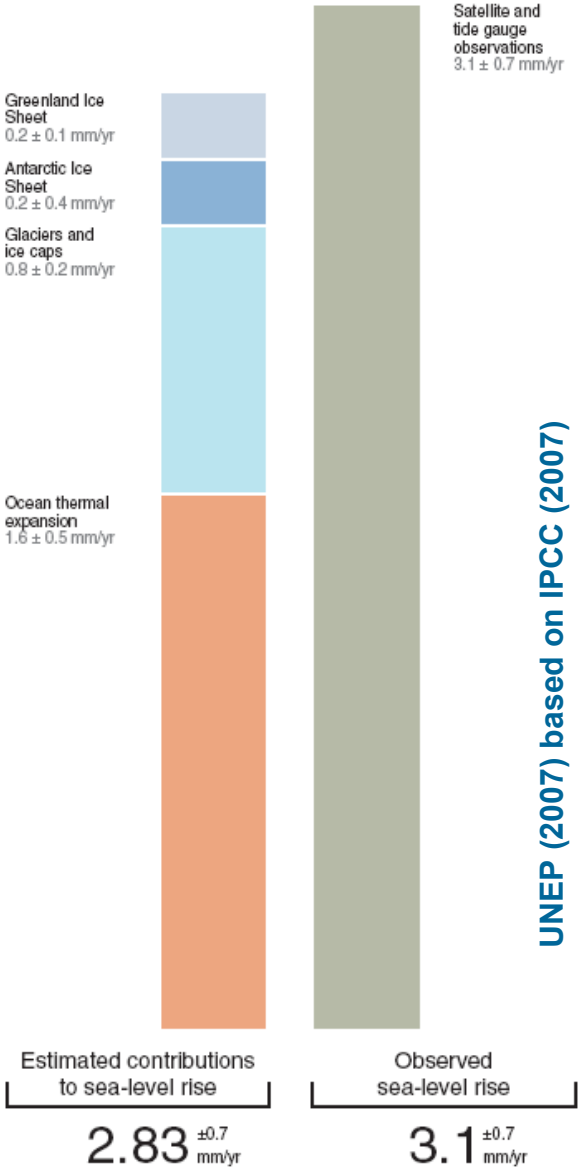
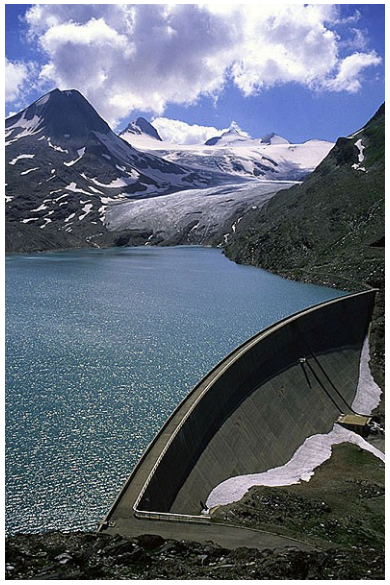


Figure 6C.4: Estimated contributions to sea-level rise from 1993 to 2003 (uncertainty intervals are 5 to 95%).

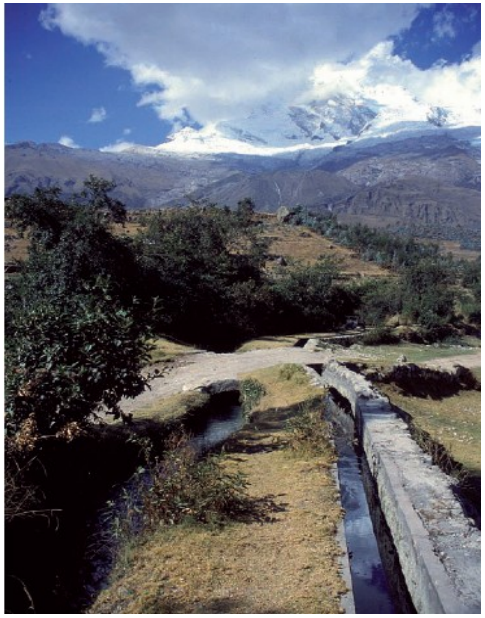
Impacts of glacier changes

Gurschen Glacier,
Switzerland. Photo: Reuters.



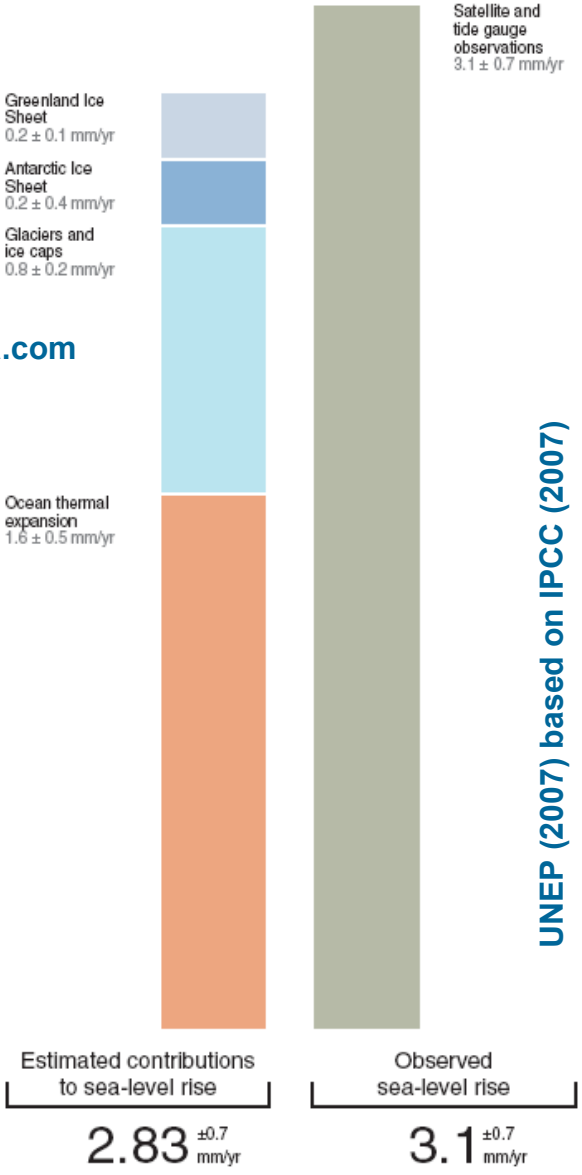
Dam at Gries Glacier,
Switzerland
Photo by J. Alean.

www.vivendamiranda.com



Irrigation ditches, Huascarán, Peru.
Photo by M. Hambrey.

Collapsing side moraine,
Grindelwald Glacier, Switzerland.



UNEP (2007) based on IPCC (2007)

Figure 6C.4: Estimated contributions to sea-level rise from 1993 to 2003 (uncertainty intervals are 5 to 95%).

- Glacier changes constitute a **key element for global climate-related monitoring.**
- International glacier monitoring has **started already in the late 19th century** and resulting in an **unprecedented dataset.**
- The present monitoring network is based on a **cooperative, scientific network** coordinated by the central services, i.e. **WGMS, NSIDC and GLIMS**.
- The organisational structures of the **central services must be professionalized and based on a secure funding basis** in order to face the current challenges of fast changes in nature and science.
- On a century scale, **glacier shrinking is global, fast and accelerating**, with intermittent regional re-advances on a decadal scale.
- Continued **glacier melt could lead beyond historical/holocene variability** and may lead to the deglaciation of many mountain regions within decades with **severe impacts on human activities and wellfare**.

Our sincere thanks go to the national correspondents and principal investigators of the WGMS and to the GLIMS community for the collection and free exchange of important data over many years.

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