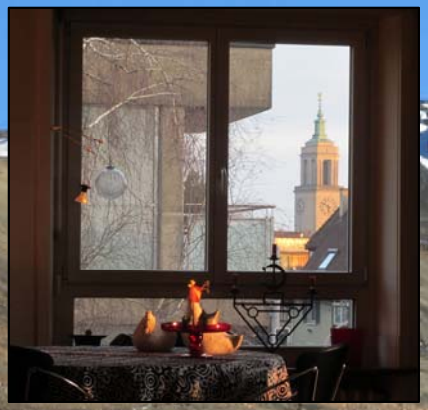
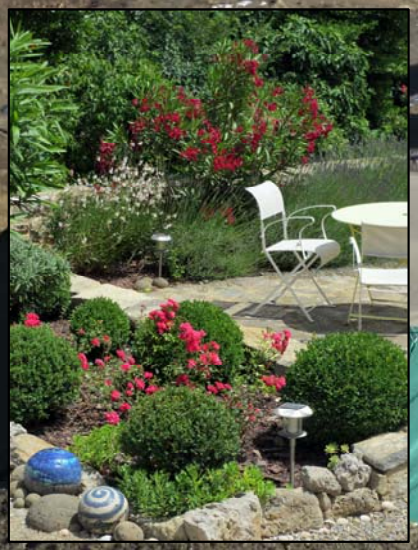
Wilfried Haeberli
Geography Department
University of Zurich

# *30 years*
# *World Glacier Monitoring Service*

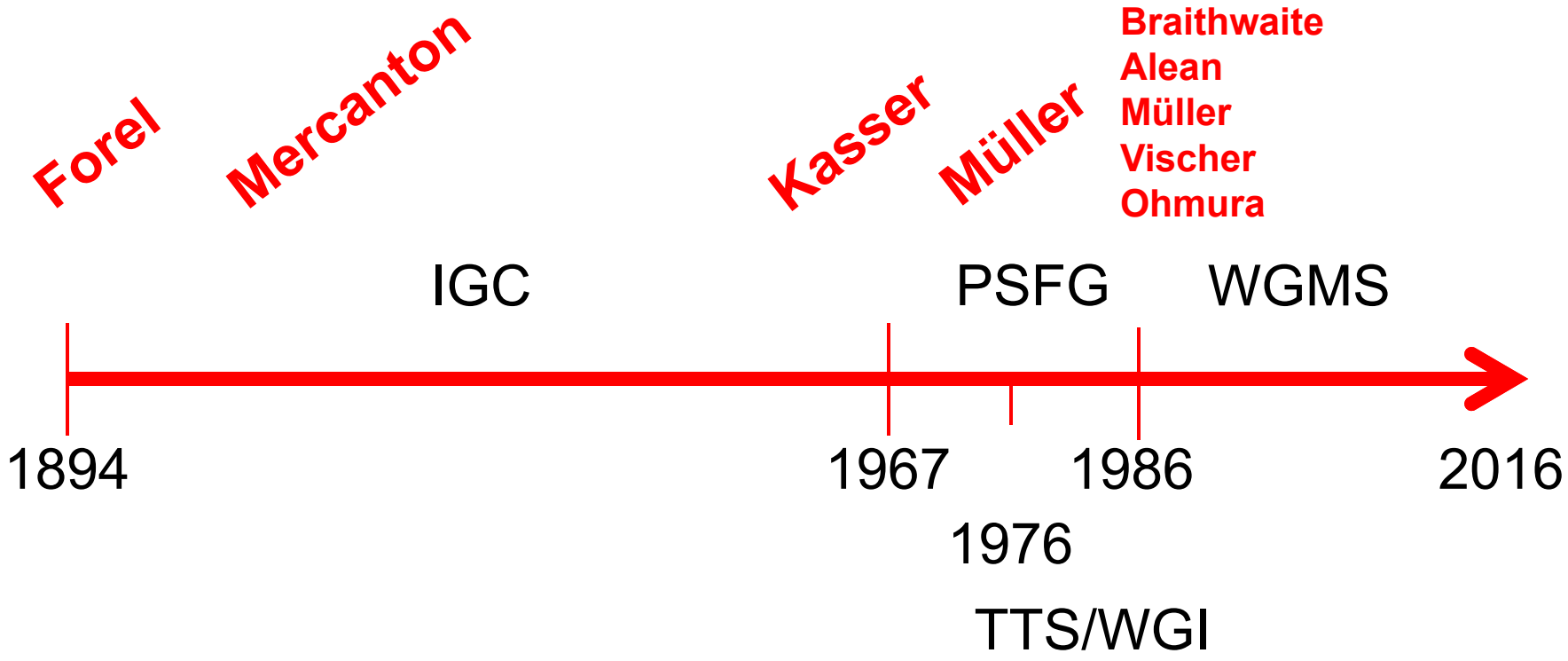




Glaciar Suyuparina
Cordillera de Vilcanota
Peru

*some reflections (on gardening and window cleaning …)*

# *122 years of internationally coordinated glacier monitoring*




| | |
|---|---|
| IGC | International Glacier Commission |
| PSFG | Permanent Service on the Fluctuations of Glaciers |
| TTS/WGI | Temporary Technical Secretariat for the World Glacier Inventory |
| WGMS | World Glacier Monitoring Service |

## *scientific monitoring means:*

**observations must be**

long-term

calibrated

comparable

**corresponding concepts must have**

defined goals

corresponding measuring strategies

**and the resulting data must be**

directly measured

open access

## *policy-related monitoring means:*

**observations must be**

relevant

feasable

integrative

**corresponding strategies must be**

future-oriented

coherent

**and the resulting products must be**

useful

understandable

# *cryosphere/climate system*

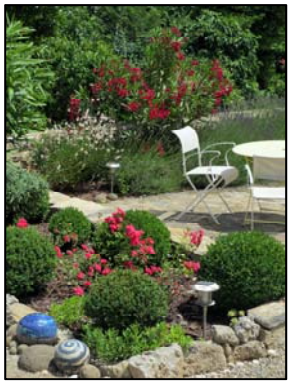
| | | *Surface* $10^6$ km$^2$ | *Volume* $10^6$ km$^3$ |
|---|---|---|---|
| ***Continental Ice Sheets*** | | | |
| | Greenland | 1.7 | 2.95 |
| | W-Antarctica | 2.4 | 3.40 |
| | E-Antarctica | 9.9 | 25.92 |
| | Antarctic shelfs | 1.6 | 0.79 |
| ***Lake and River Ice*** | | < 1.0 | |
| ***Glaciers and Ice Caps*** | | 0.6 | 0.09 |
| ***Snow*** | NH-winter | 46.3 | < 0.01 |
| | NH-summer | 3.7 | |
| | SH-winter | 0.9 | |
| | SH-summer | < 0.1 | |
| ***Sea Ice*** | NH-winter | 16.0 | 0.05 |
| | NH-summer | 9.0 | 0.03 |
| | SH-winter | 19.0 | 0.03 |
| | SH-summer | 3.5 | < 0.01 |
| ***Permafrost*** | | 24.9 | 0.16 |

**drivers**

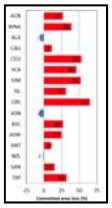
**indicators**

**interactions**
**feedbacks**

# *understanding the process chain*



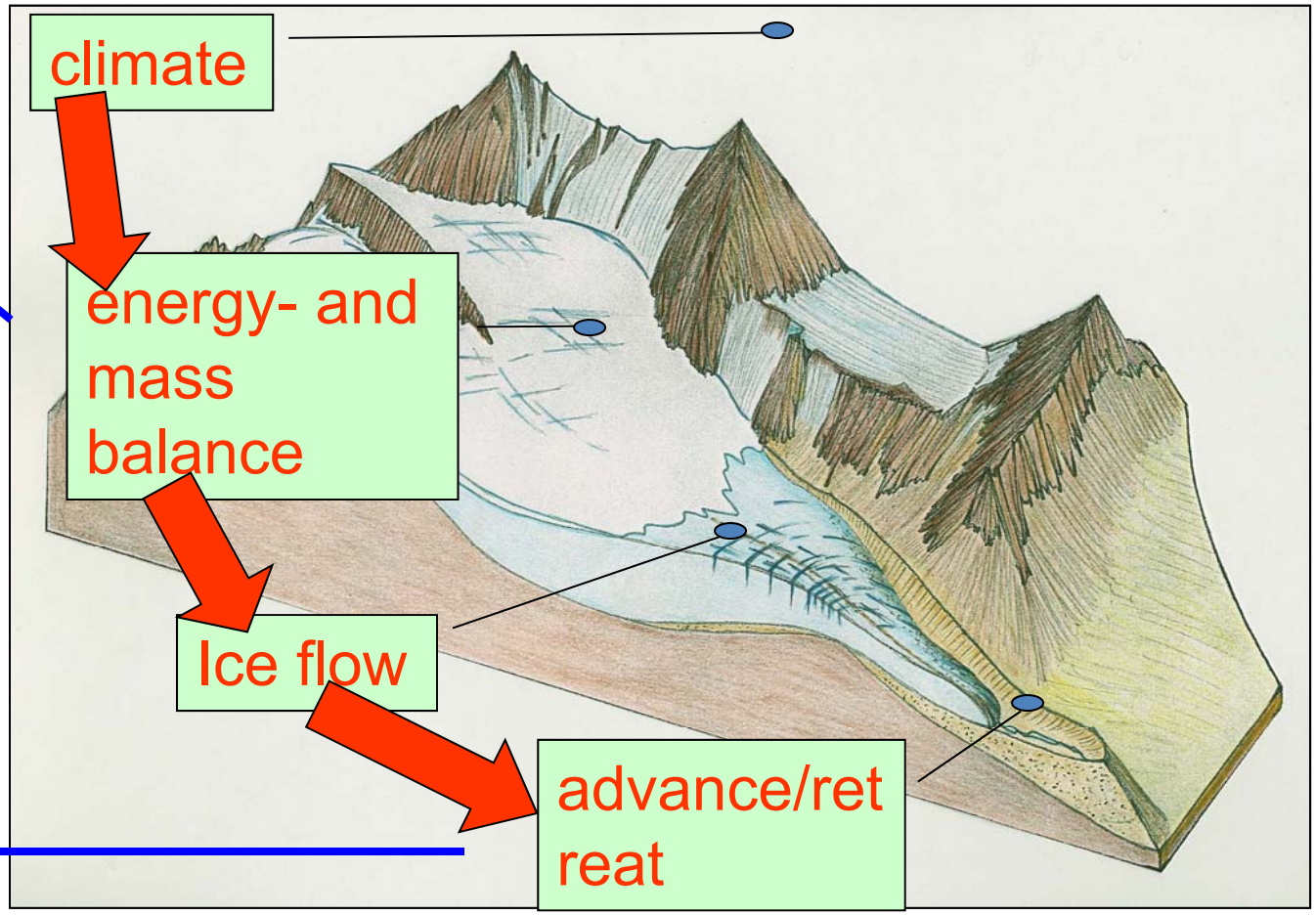
direct,
undelayed
signal



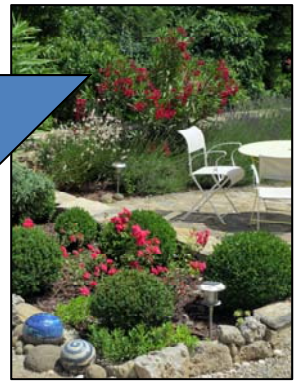
Mernild

*feed-back imbalance*

indirect,
delayed,
filtered and
enhanced
signal



# *time and space*



repeat inventory

mass balance
length change
area/volume/thickness change

repeat inventory

mass balance
length change
area/volume/thickness change

base inventory

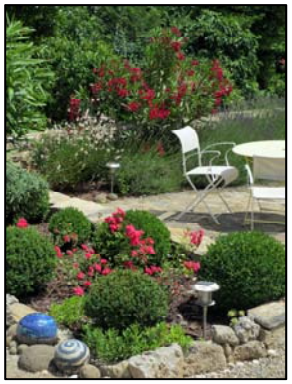
time

space

*fluctuations of glaciers*

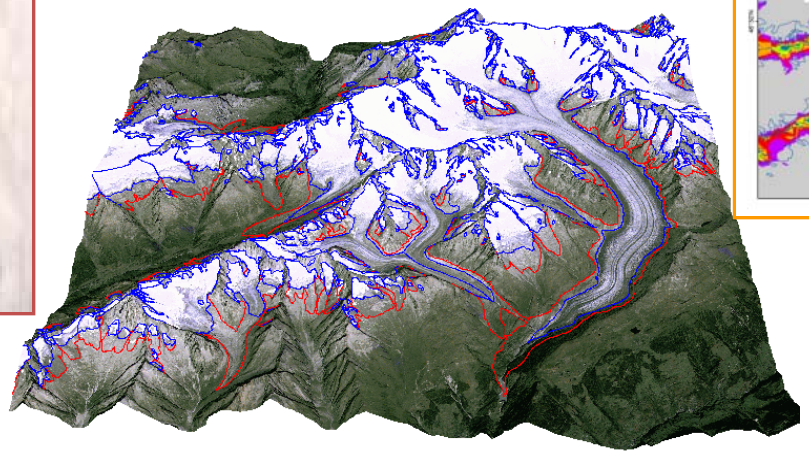
*glacier inventories*

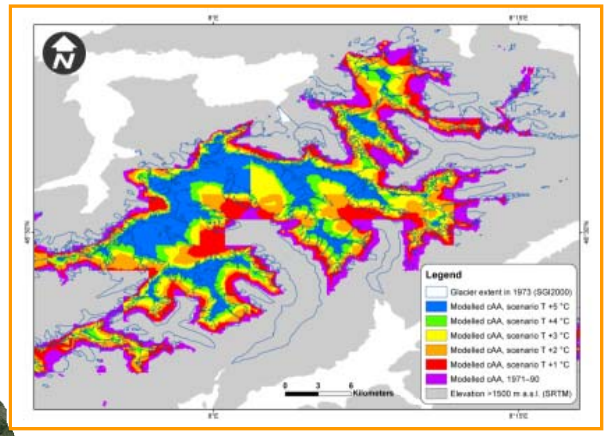
# *integrative monitoring principle*



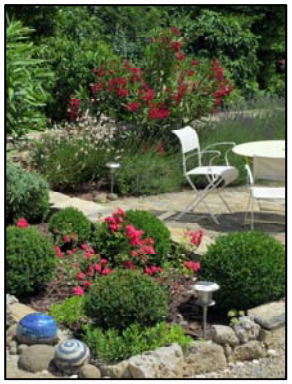
**Integration of**

**in-situ measurements, remote sensing and numerical modelling**





# *GTOS/GTN-G observing strategy*



**main goals of long-term observations:**

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

**change detection:**

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

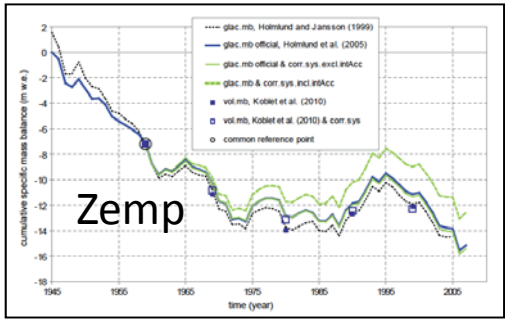
***integrated /tiered observing strategy***

**process understanding and model calibration**
=> extensive energy/mass balance, flow, etc.
**representativeness in space and time**
=> cumulative length change, DEM differencing
**global coverage**
=> inventories (remote sensing/geoinformatics)

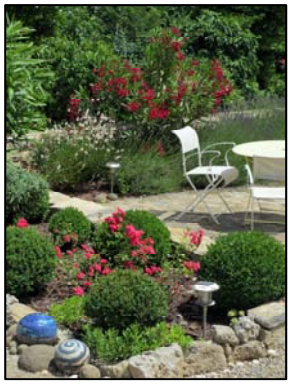
**regional, global:**

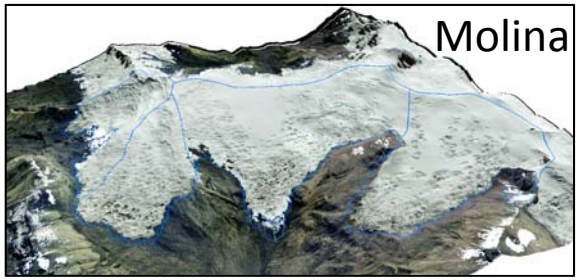
- water supply, sea level
- hazards, risks
- landscape change
- tourism, etc.

# *mass balance*

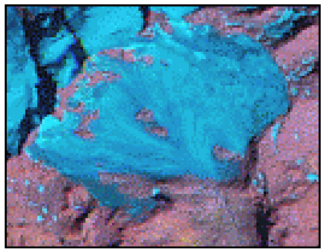


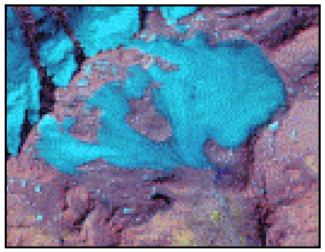

**calibration** –
process understanding
volume/mass change

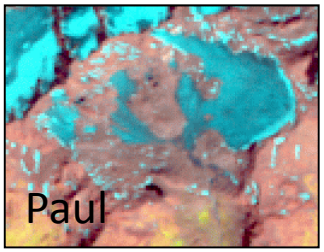




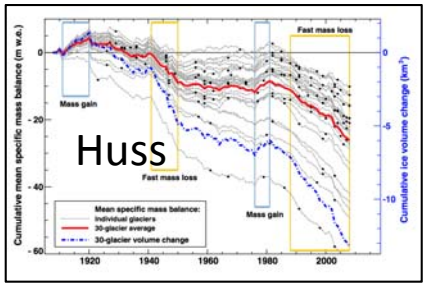

**new methods** – lidar
drones





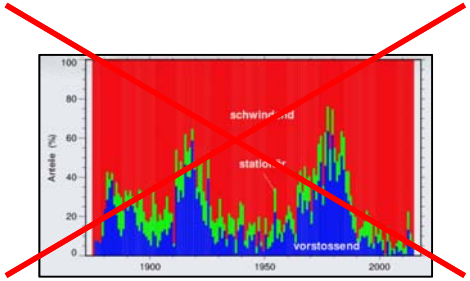


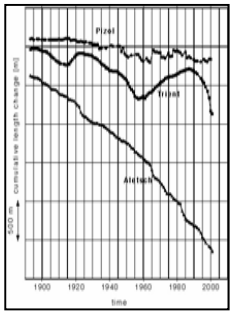

**vanishing glaciers** –
replacement
homogenization



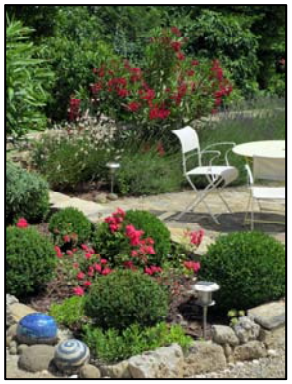

**measured/modelled data** –
independent climate indicator
applications

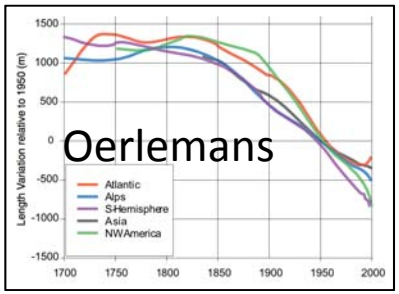
# *length change ...*



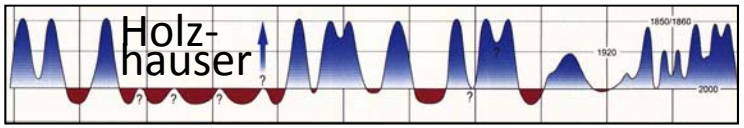



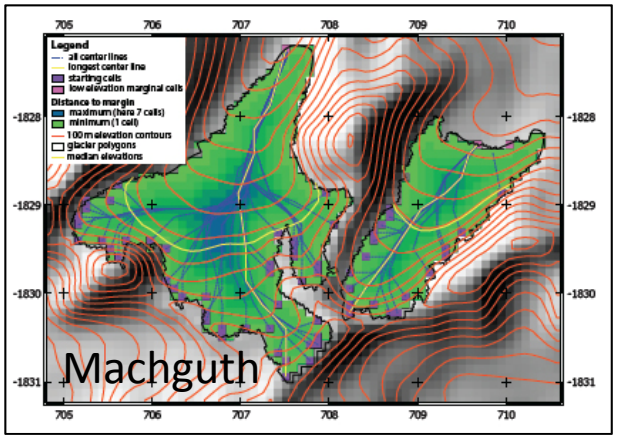

**signal** – cumulative effect



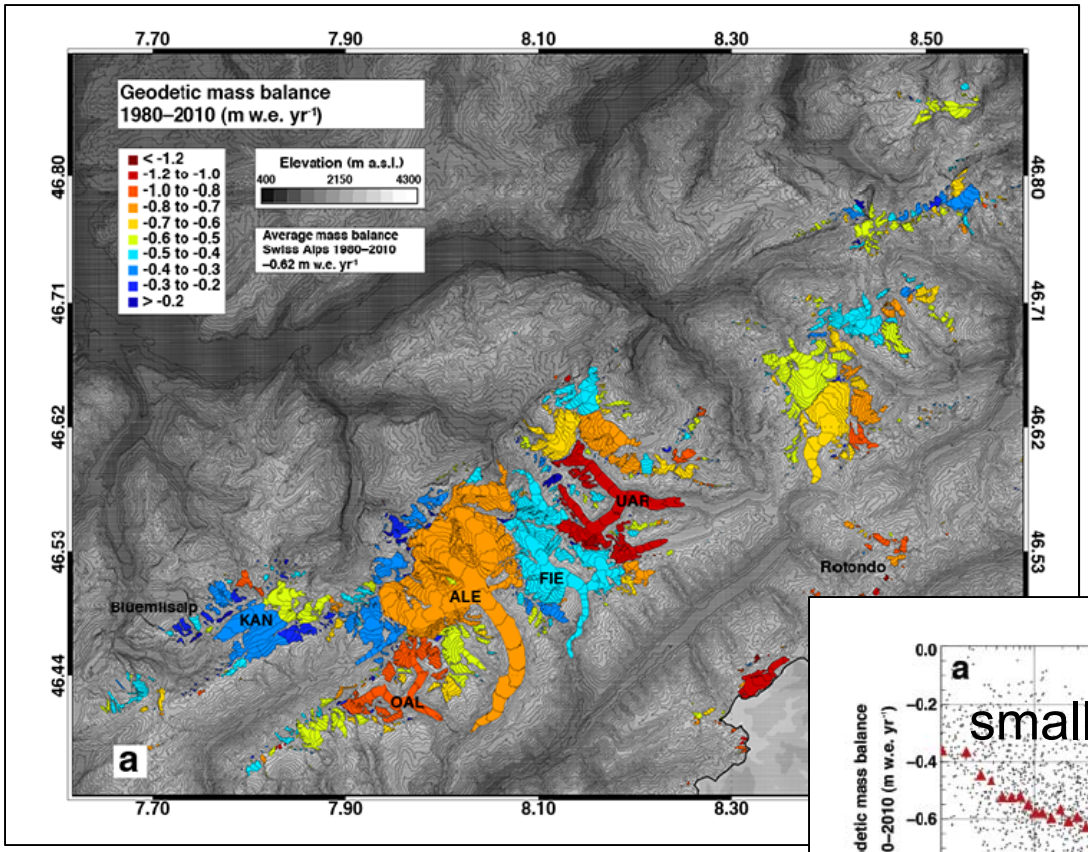


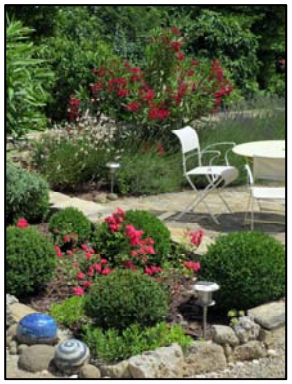

**space and time** – global trend
visibility
key to the past



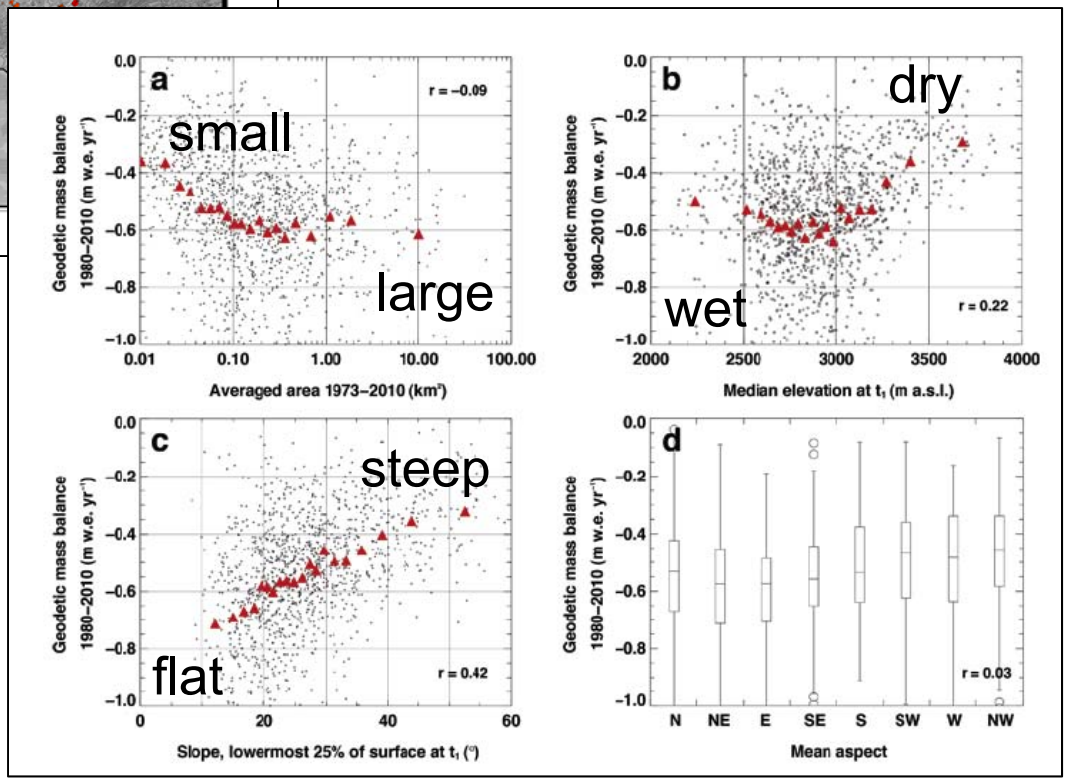

**new formats** – data flood
added value?



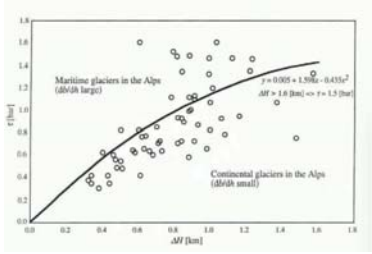
## ... and DEM differencing

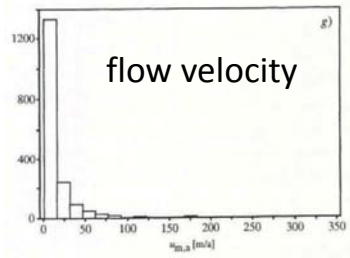
*Fischer et al. (2014)*

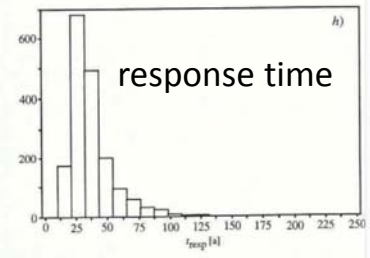


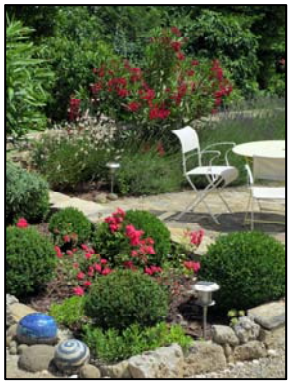

## *glacier inventories ...*

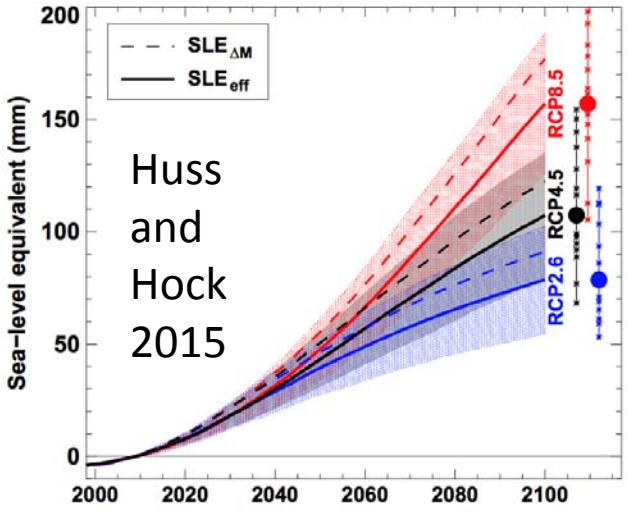
# *... with their applications*



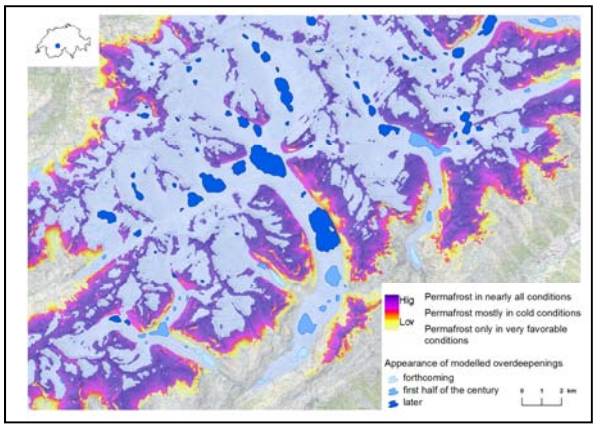



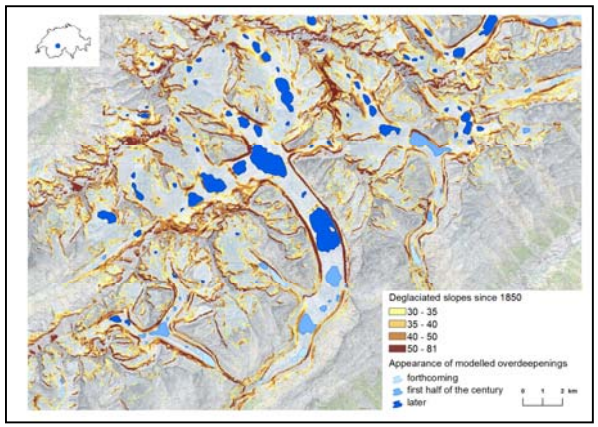



Huss and Hock 2015

**inventory analysis 1995**

**global modeling** – sea level rise




**regional modeling** –
new landscapes
new dynamics


30 years
World Glacier Monitoring Service
a fascinating
and important
responsibility
thanks to the
many friends and
colleagues
who contribute …
… and keep going!