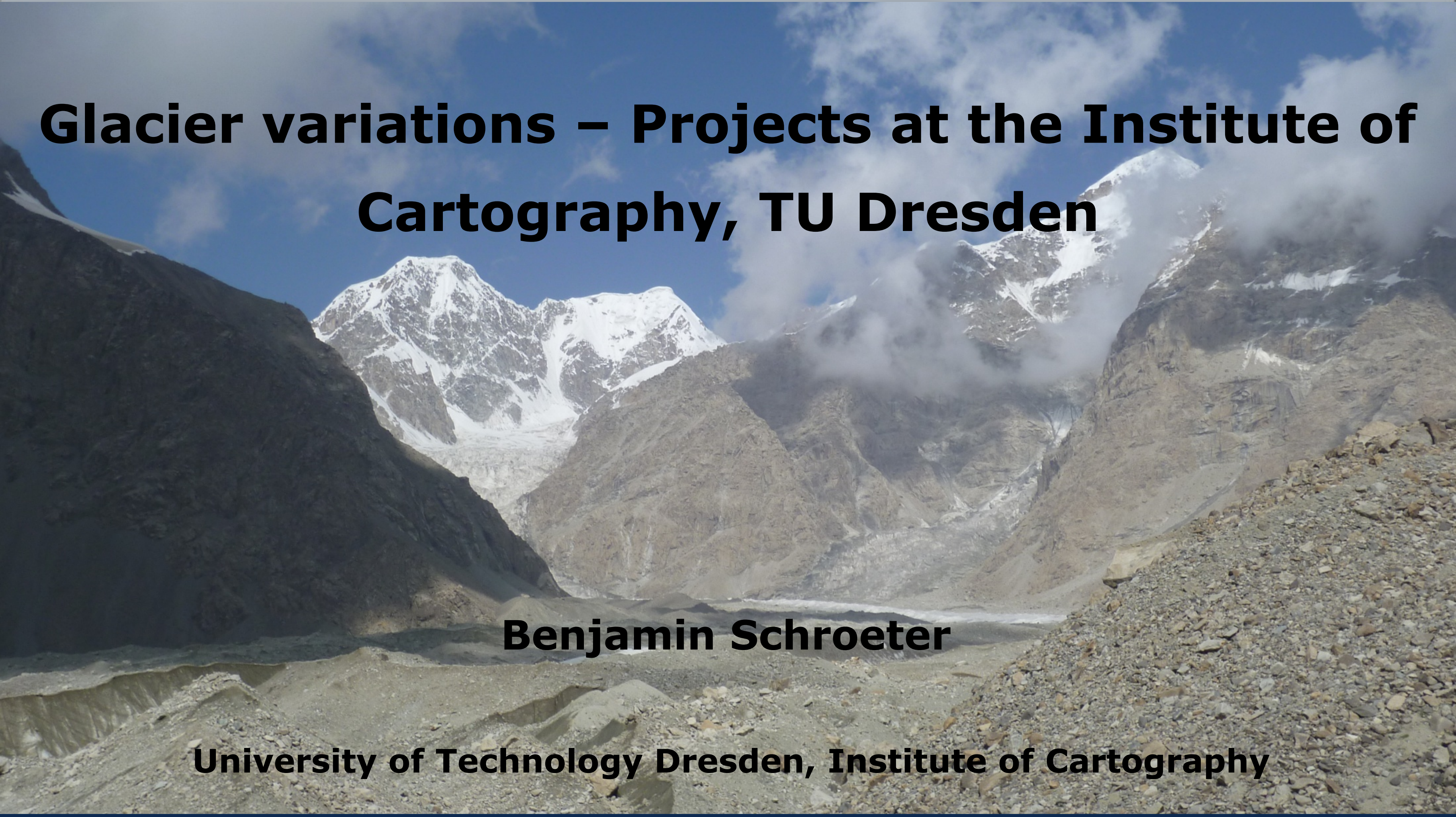
TU Dresden >> Faculty of Forest, Geo and Hydro Sciences >> Institute of Cartography



Glacier variations – Projects at the Institute of Cartography, TU Dresden

Benjamin Schroeter

University of Technology Dresden, Institute of Cartography

8th ICA Mountain Cartography Workshop, Tongariro National Park (NZ), 1-5 September 2012

Glaciers and Glacier variation

Remote Sensing

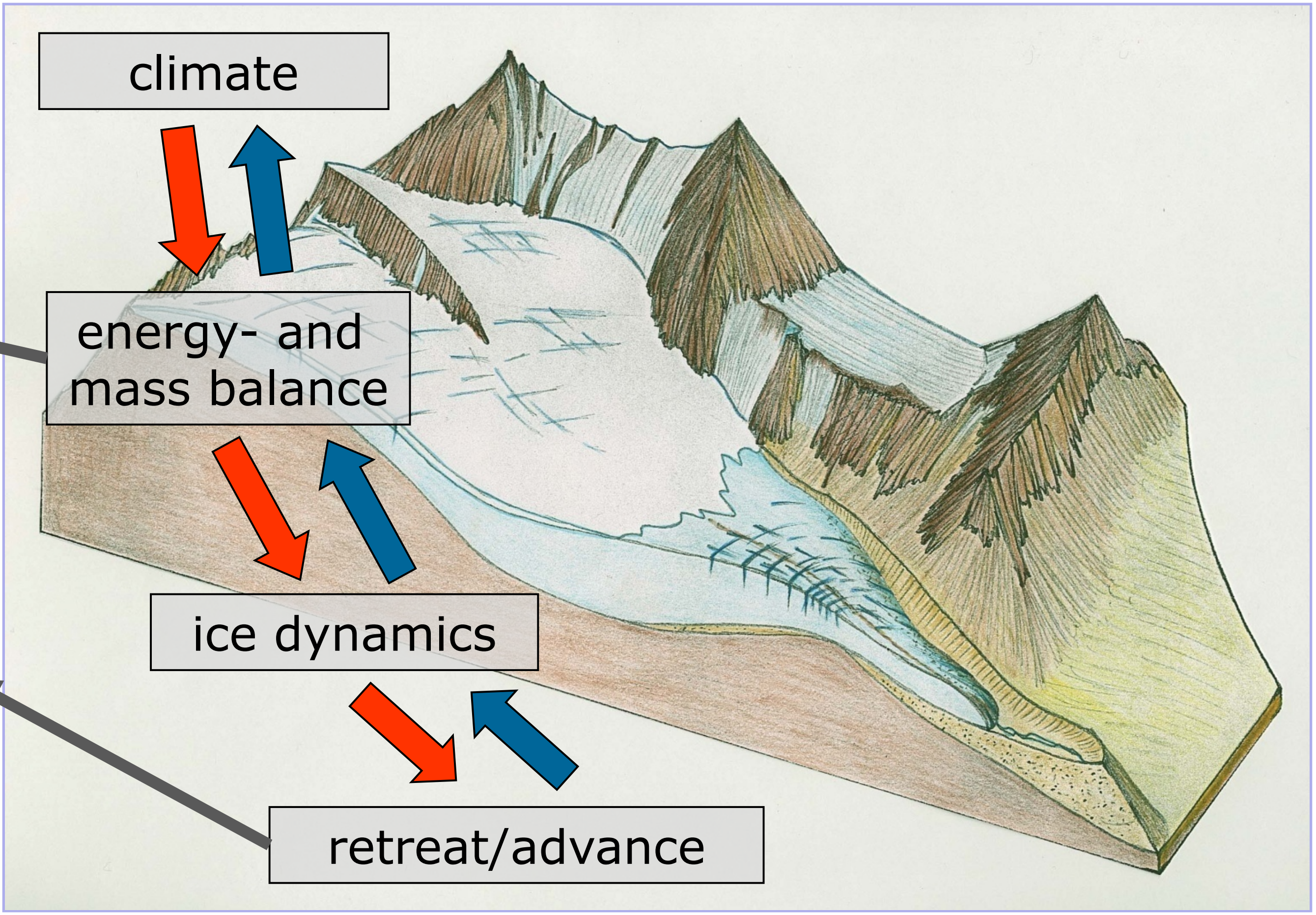
TU Dresden projects in benchmark areas focusing on Nepal and Tibet (Zhadang)

Glacier response to climate change

Modified after Häberli (2003)

Direct signals

Indirect, time-delayed, filtered, sometimes enhanced or even reversed signals



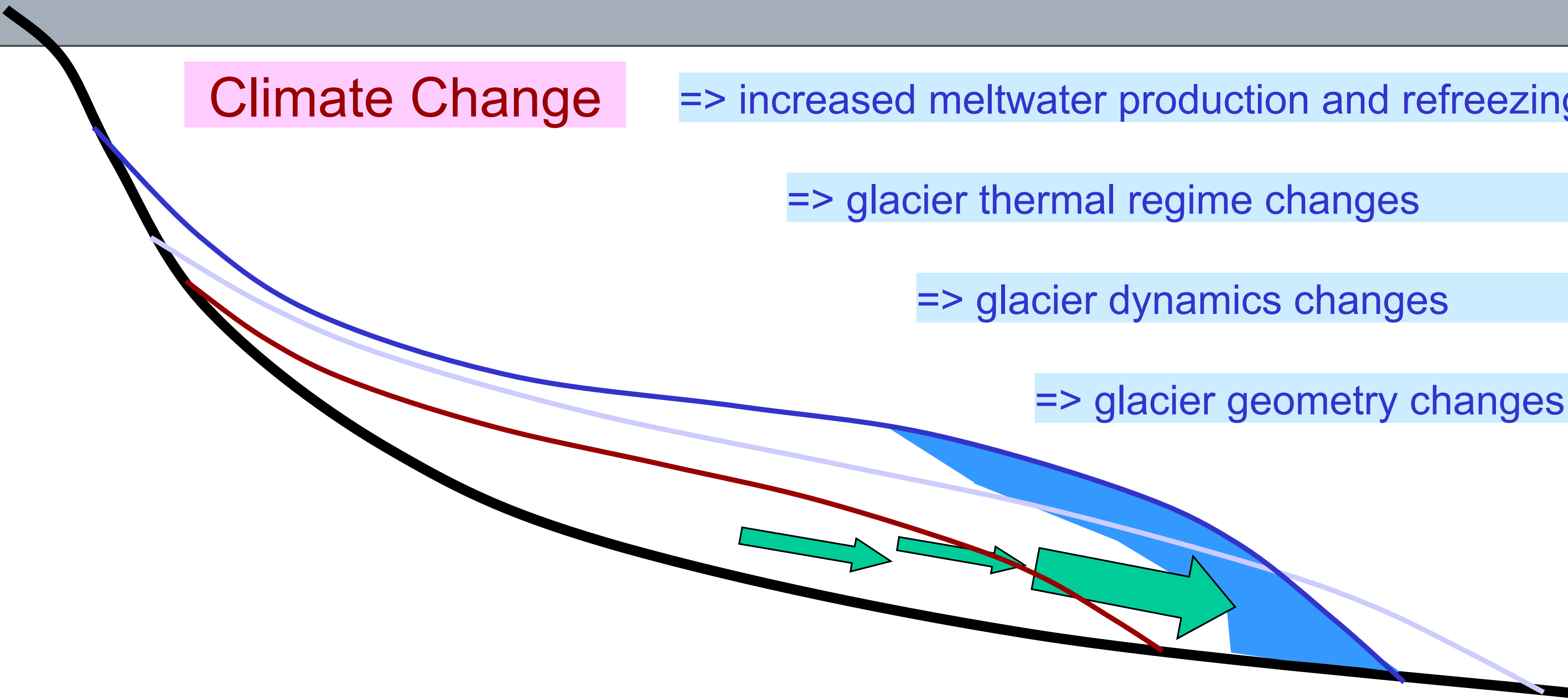
Climate Change

=> increased meltwater production and refreezing

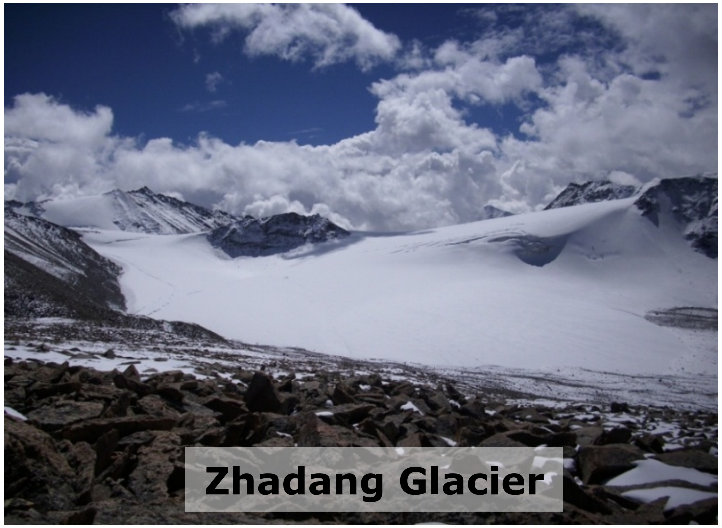
=> glacier thermal regime changes

=> glacier dynamics changes

=> glacier geometry changes

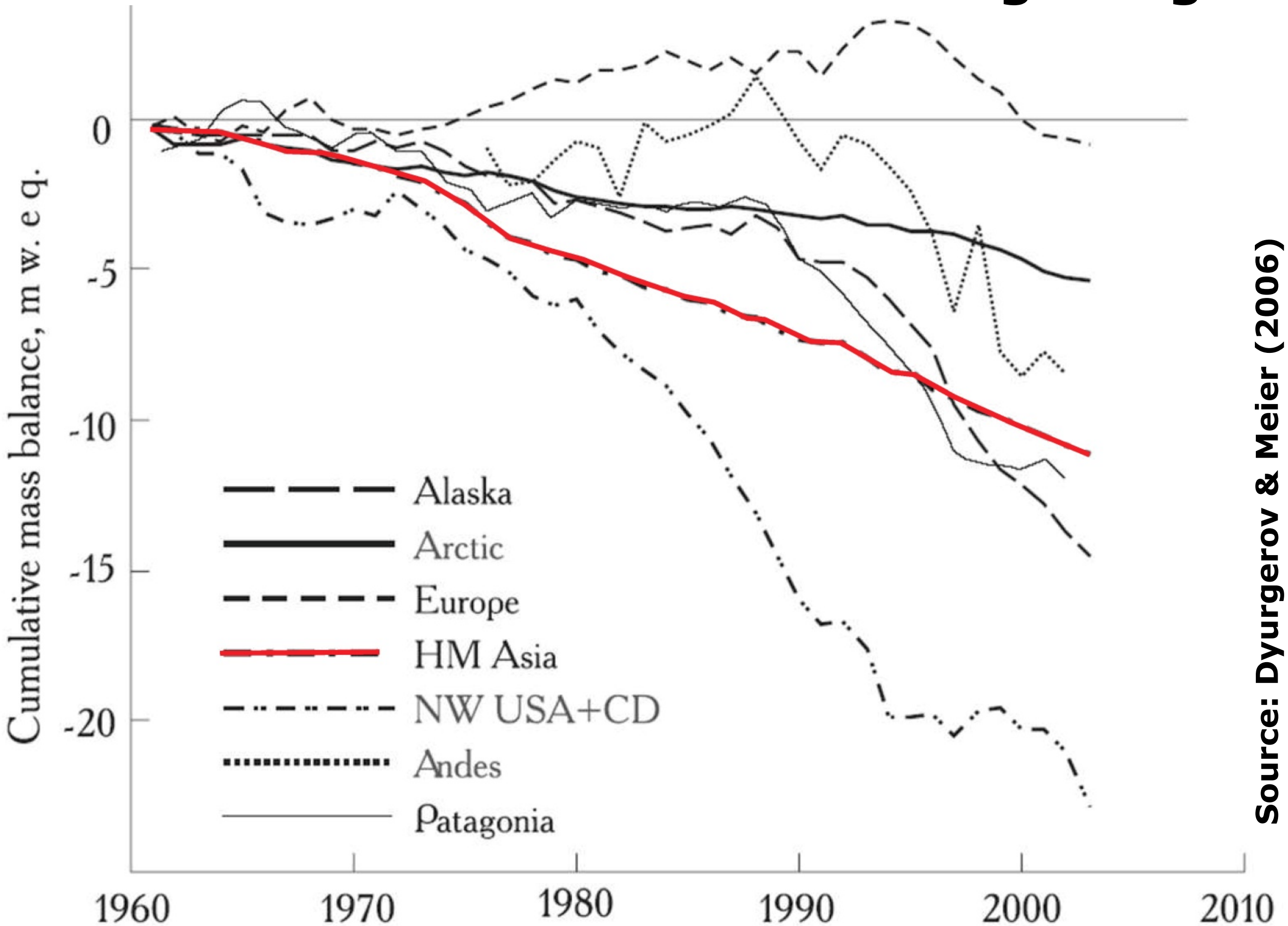


Interpretation of geomorphic features
in respect to paleo-climate reconstruction



Photos: T. Pieczonka 2009

Cumulative mass balance calculated for larger regions



Source: Dyurgerov & Meier (2006)

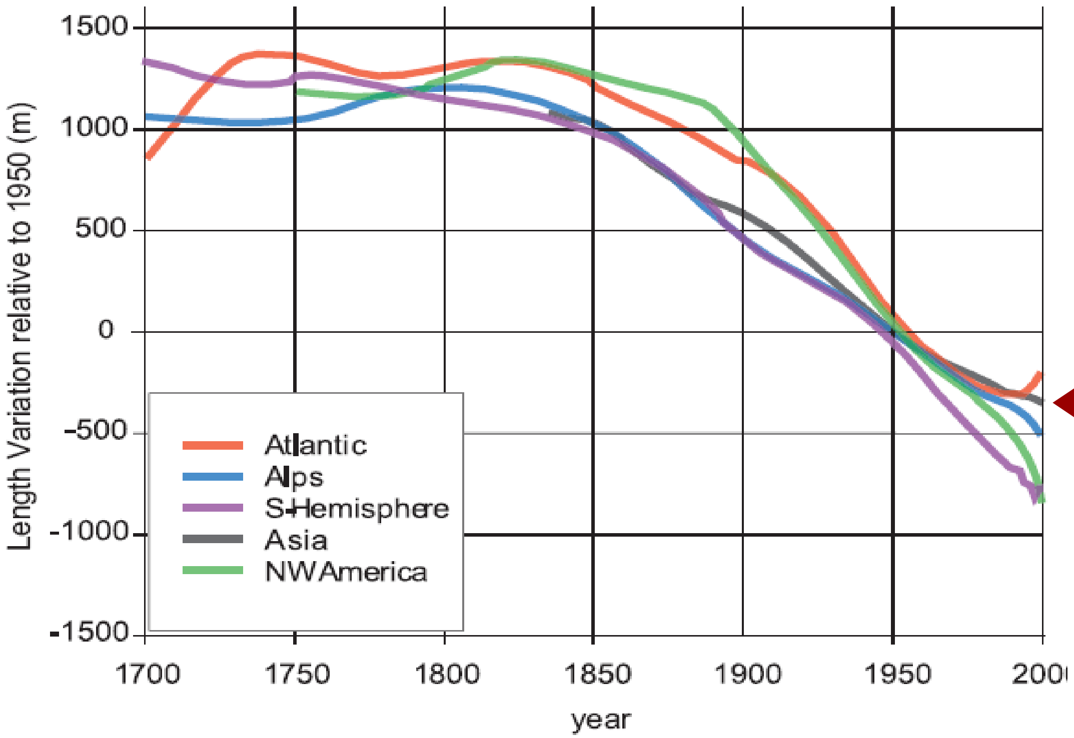


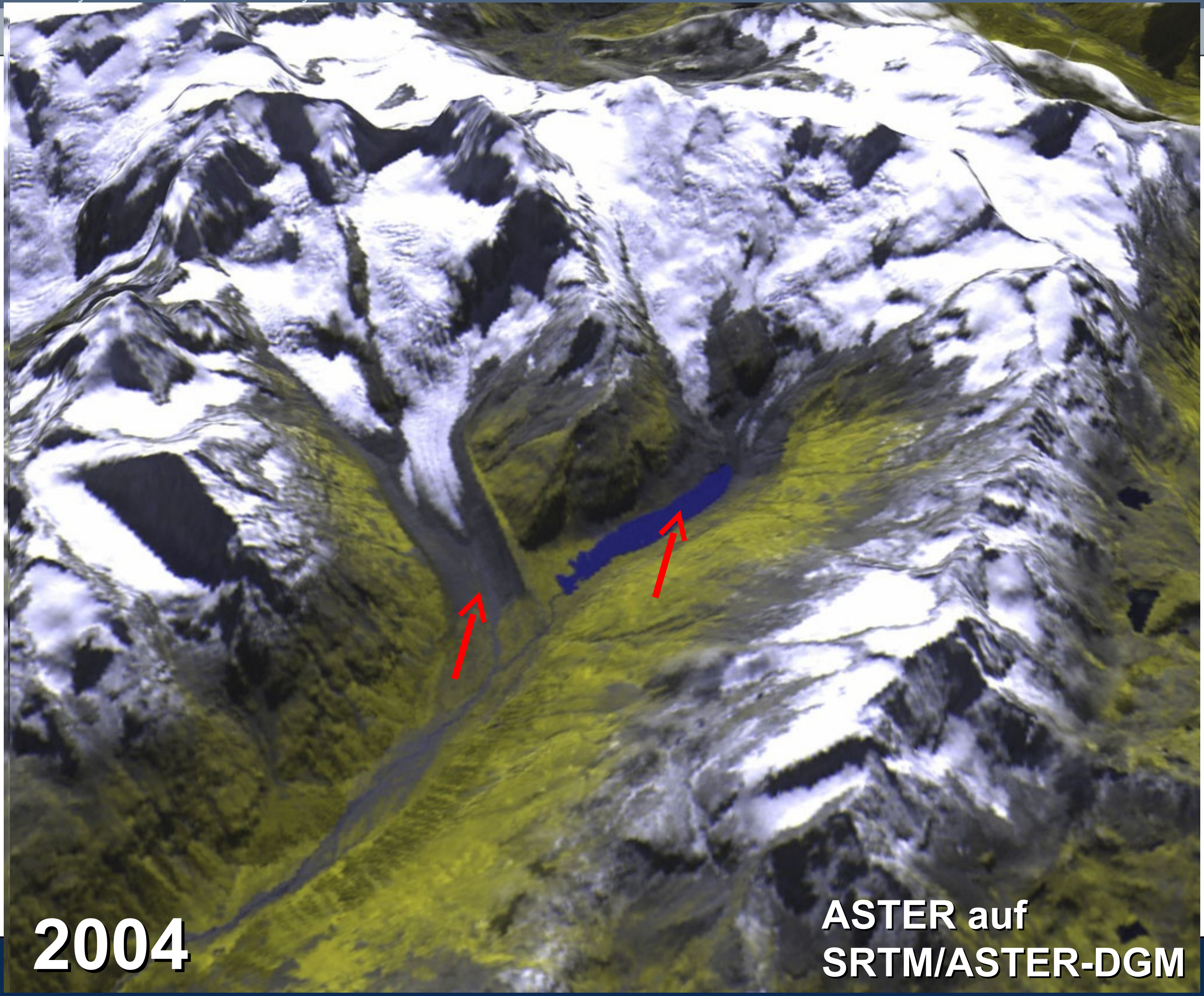
Figure 4.13. *Large-scale regional mean length variations of glacier tongues (Oerlemans, 2005). The raw data are all constrained to pass through zero in 1950. The curves shown are smoothed with the Stineman (1980) method and approximate this. Glaciers are grouped into the following regional classes: SH (tropics, New Zealand, Patagonia), northwest North America (mainly Canadian Rockies), Atlantic (South Greenland, Iceland, Jan Mayen, Svalbard, Scandinavia), European Alps and Asia (Caucasus and central Asia).*

Regional mean length variations of glaciers

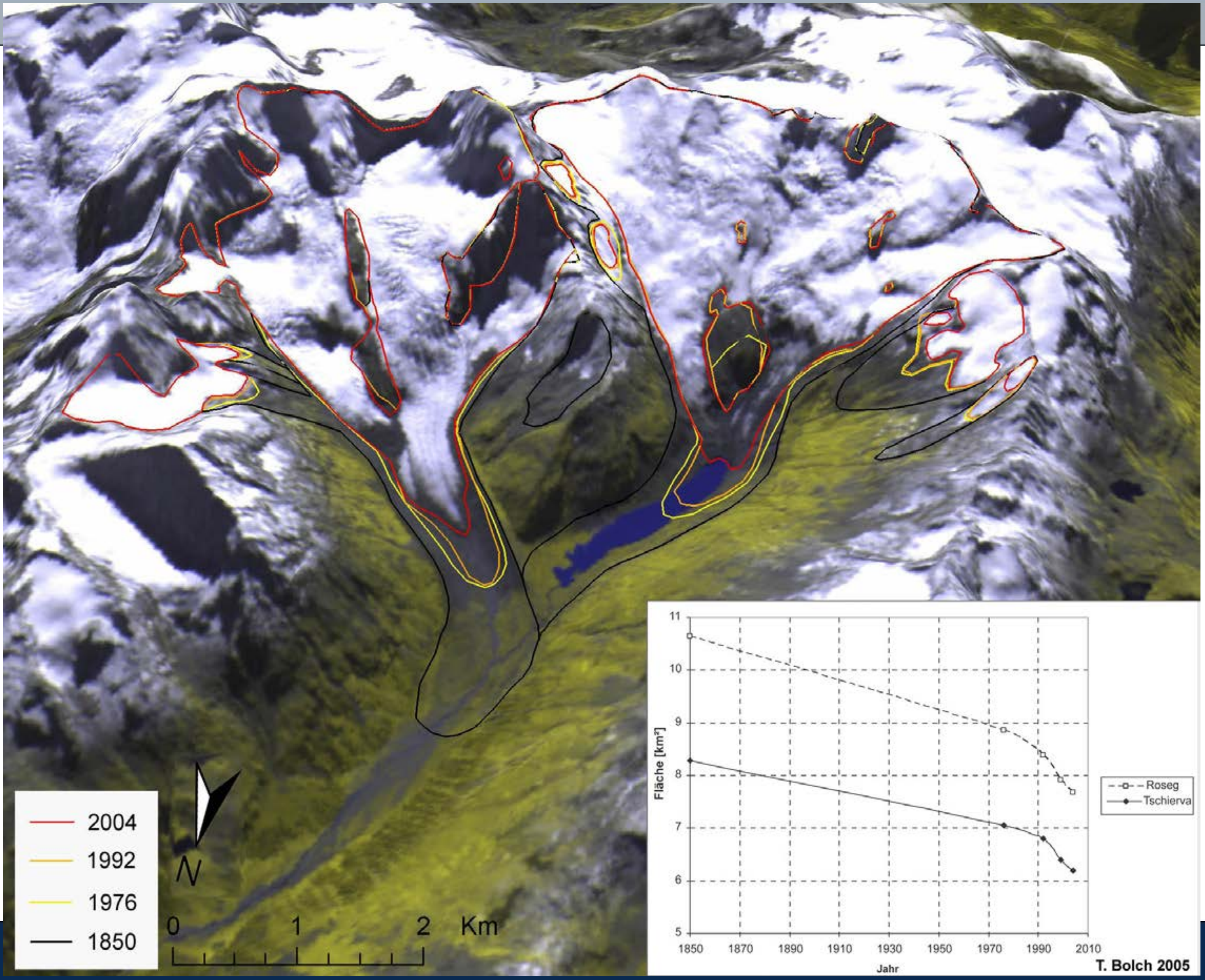
Since 1950 Asian glaciers retreated about 300 m in average

Complex spatio-temporal patterns: retreating, advancing and even surging glaciers

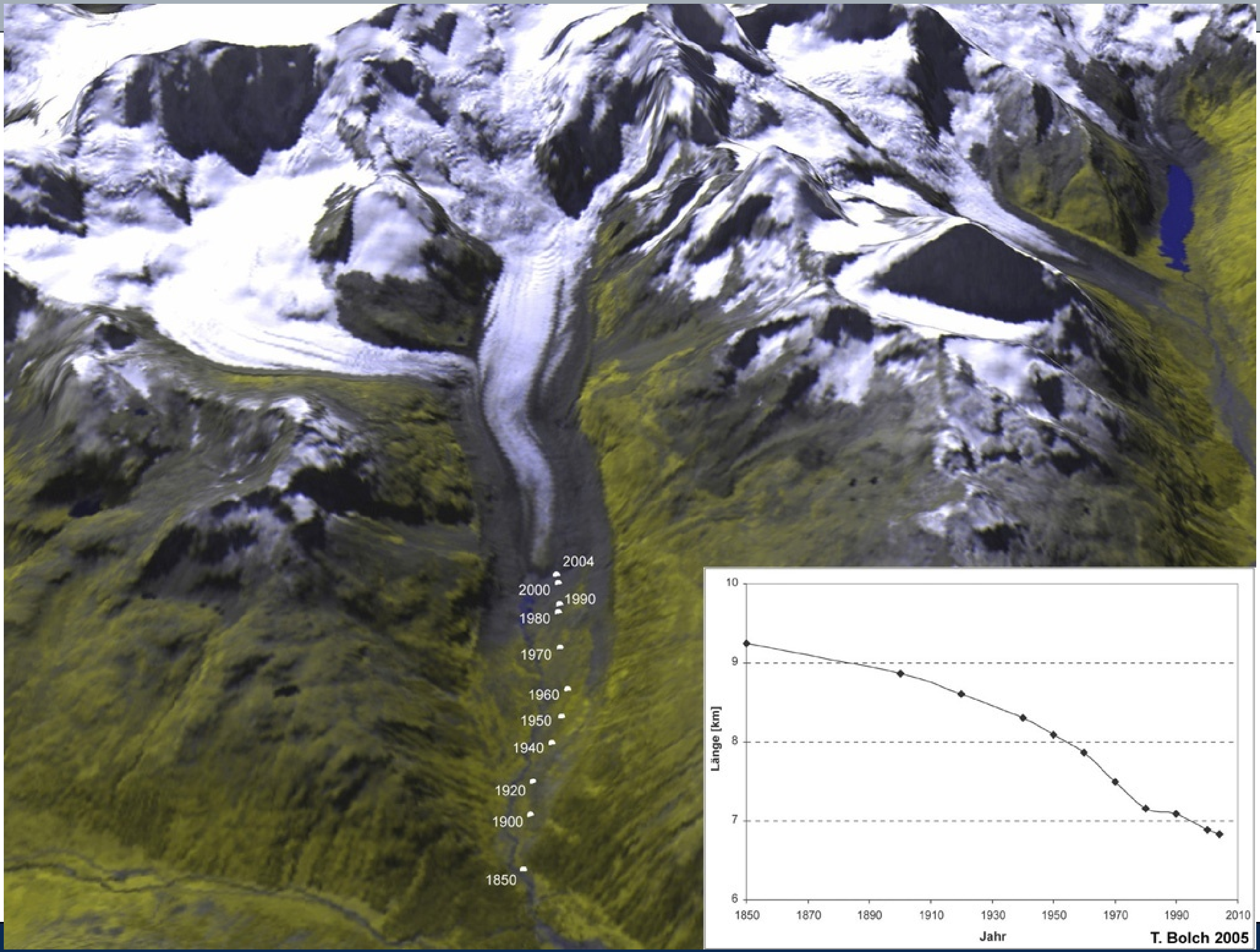
Glacier Change
Bernina/CH



Glacier Change
Bernina/CH



Glacier Change
Bernina/CH



Glaciers are important to study for several reasons:

1. They are the ‘chameleons’ of climate change.
2. They are an important water source in dry areas.
3. They are a source of hydro-power.
4. They are a tourist attraction.

But…

glaciers are difficult to study - they are mostly located in remote areas

➢ remote sensing technology

Remote Sensing Imagery can be used to

a. Extract glacier extents

b. Identify surface characteristics

c. Determine volume losses

d. Determine glacier velocities

These characteristics can be obtained

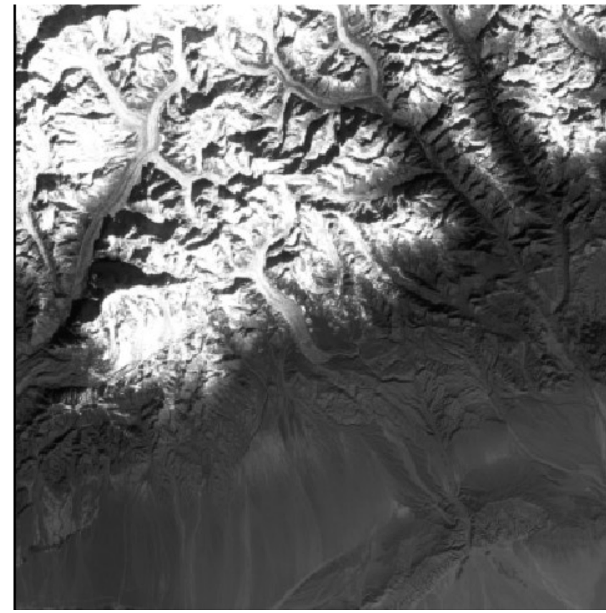
- manually (time consuming, but usually more accurate)
- automated (faster, but usually with errors)

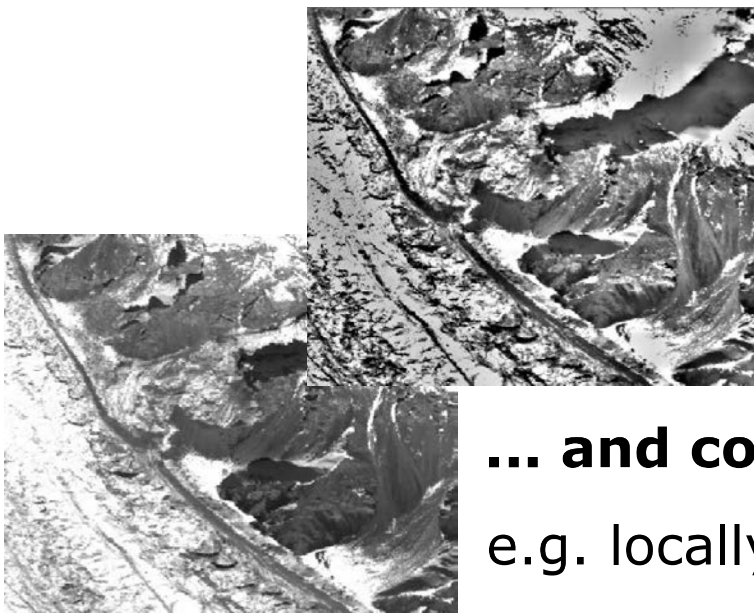
Sensor	Organisation	Operation	Spatial Resolution	Stereo
Corona KH-4/-4A/-4B	CIA Dir. Technol. Sci.	1962 – 1972	4 – 8 m	Yes
Hexagon KH-9	CIA Dir. Technol. Sci.	1971 – 1986	7.6 m	Yes
Landsat MSS	NASA	1972 – 1983	80 m	No
KFA 1000 (Resurs-F1)	Russian Space Agency	1979 – 1987	5-7 m	Yes
Landsat TM	NASA	since 1982	30 m	No
Metric Camera System (MC)	ESA	1983	40 lp/mm	Yes
Large Format Camera (LFC)	NASA/ESA	1984	70 lp/mm	Yes
MK4 (Resurs-F2)	Russian Space Agency	1987 – 1995	8 m	Yes
IRS-1C	ISRO	1995 – 1996	5.8 m	Yes
Landsat ETM+	NASA	since 1999	30 m (15 m panchrom)	No
ASTER	NASA	since 1999	15 m	Yes
IKONOS	GeoEye	since 1999	3.2 m (0.8 m panchrom)	Yes
Quickbird 2	DigitalGlobe	since 2001	2.4 m (0.6 m panchrom)	No
Spot 5	CNES	since 2002	10 m (2.5 m panchrom)	Yes
Cartosat 1 (IRS P5)	ISRO	since 2005	2.5 m	Yes
RapidEye	RapidEye Germany	since 2008	6.5 m	Yes

Visual assessment of Input data …

Problems: Clouds, snow cover,

shadows





… and contrast enhancement

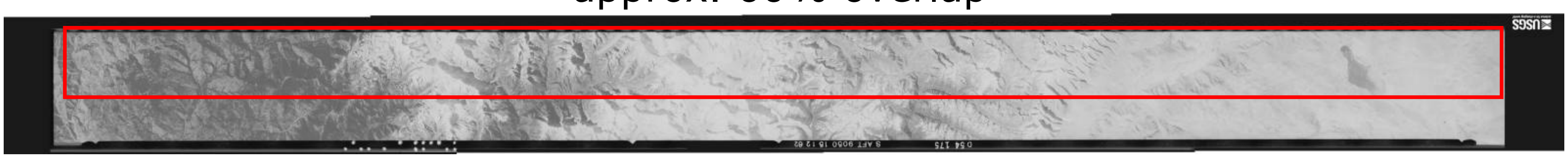
e.g. locally adaptive Wallis Filter

Excursus: Corona KH-4 (1960-1972, declassified 1995)

- First reconnaissance satellite -> Problem: Panoramic distortion plus motion
- Initial objectives: Gathering information about the military strenght of the former Soviet Union

Forward (FWD)

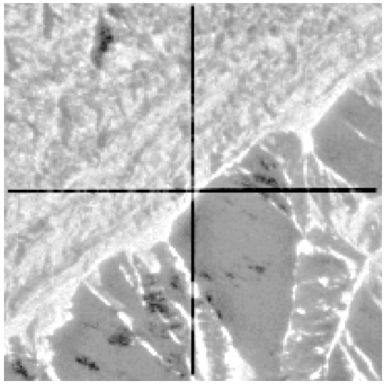
approx. 60% overlap



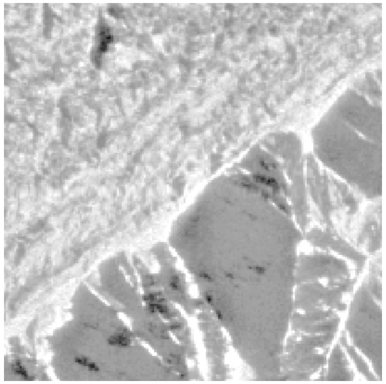
Aft (AFT)

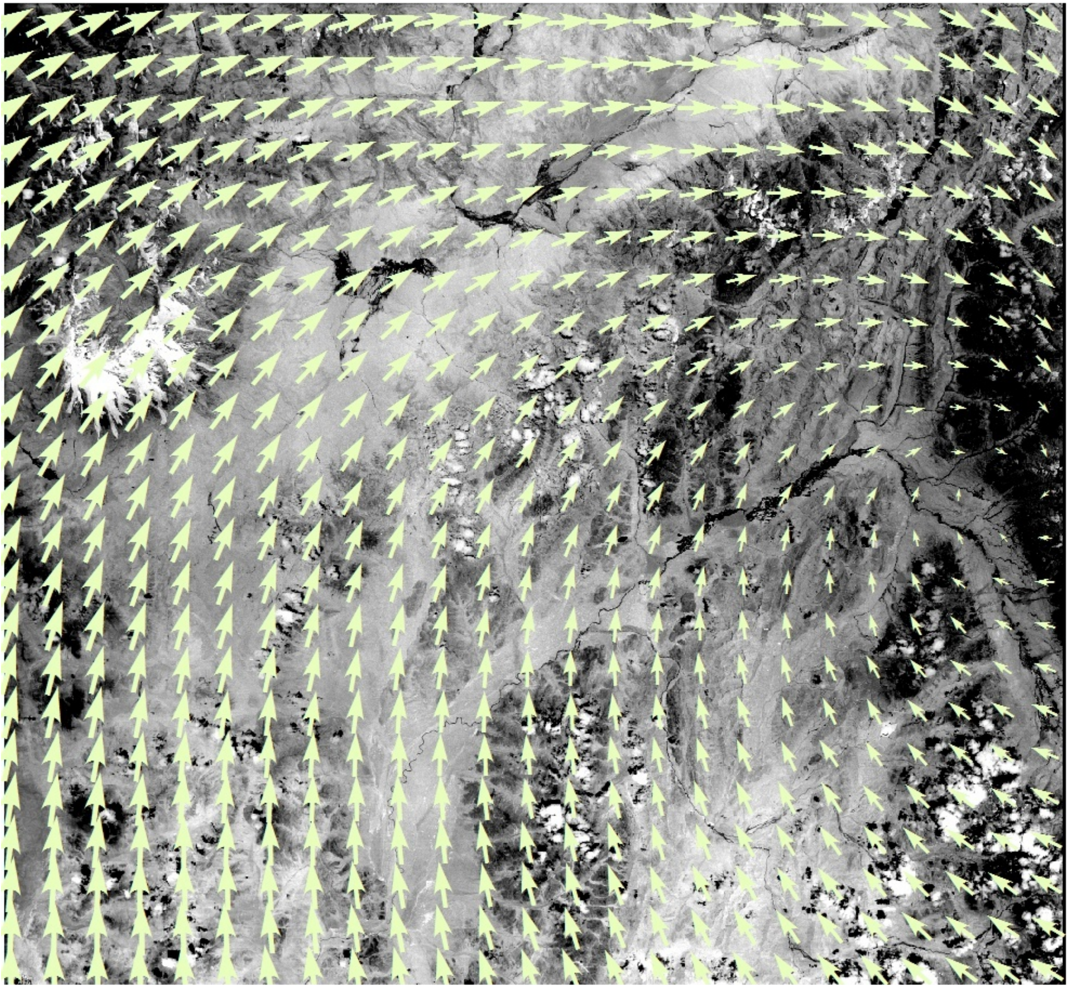
Excursus: Hexagon KH9

Reseau Cross

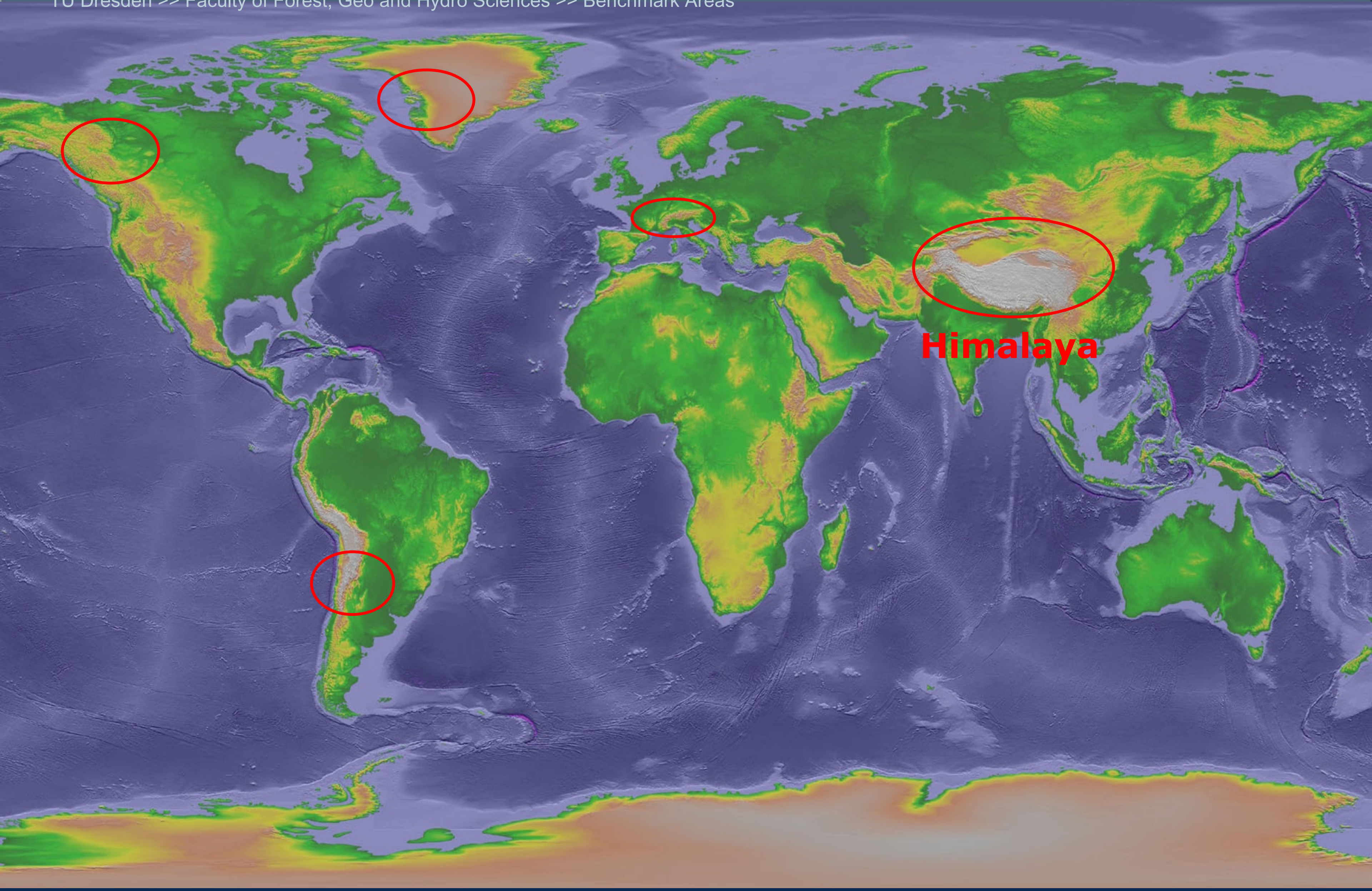


Bicubic interpolation



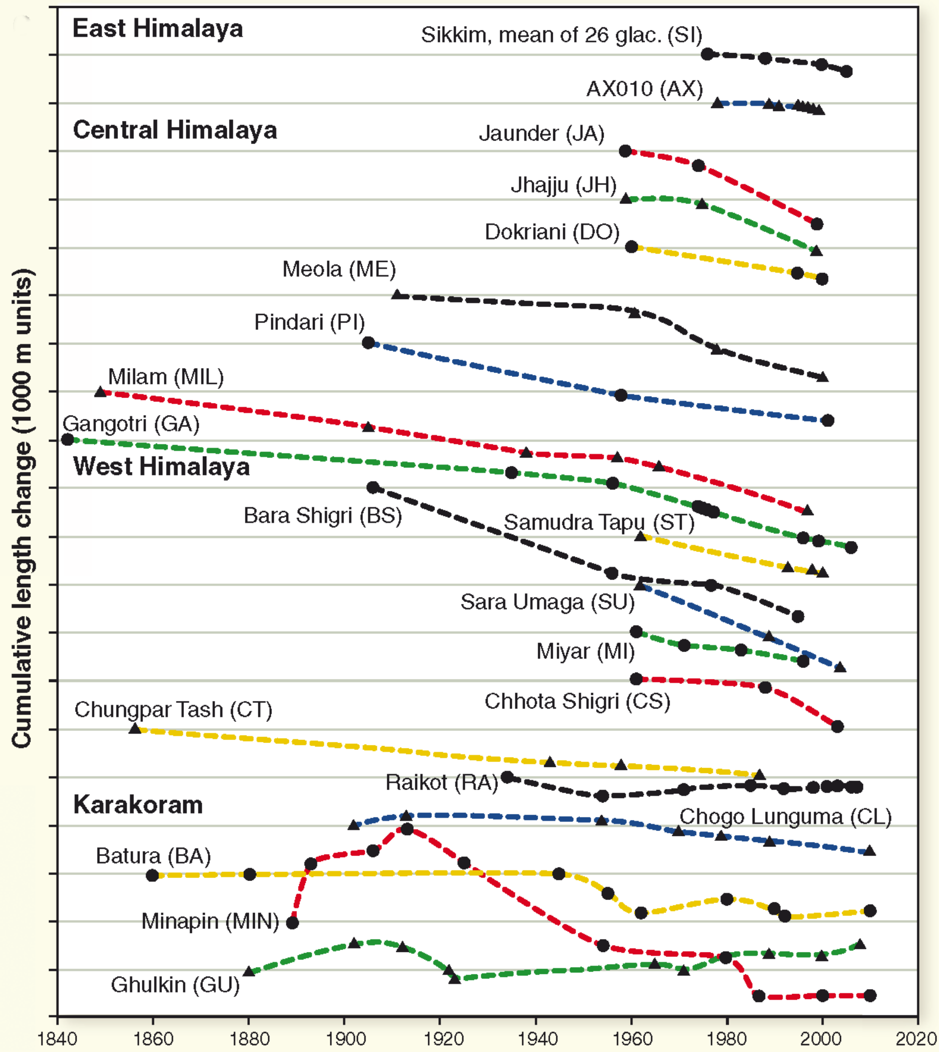


Benchmark Areas
Himalaya

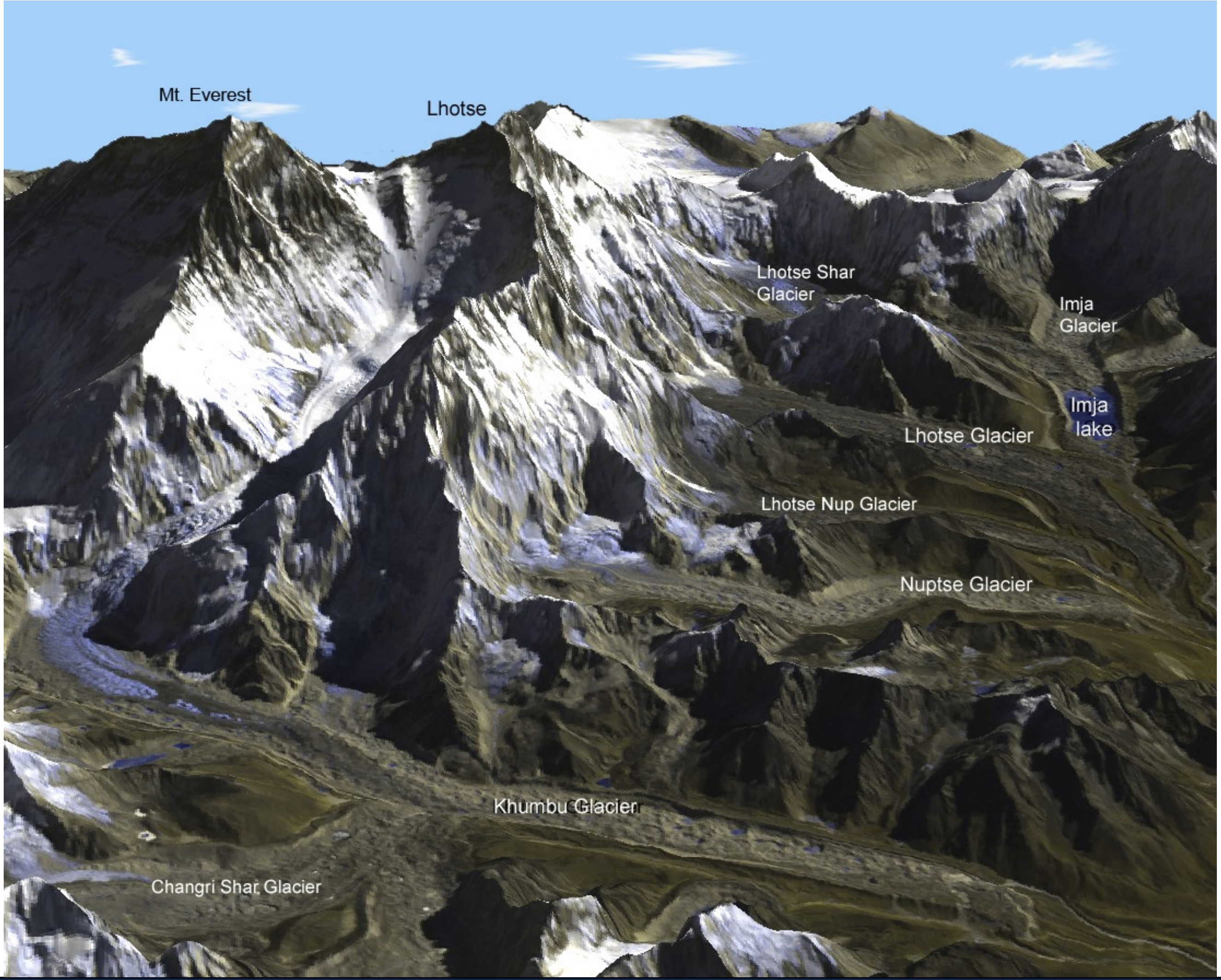


Cumulative length change for the HKH region

- Significant glacier retreat since the mid-19th century
- Complex behavior in the Karakoram (glacier retreat is interrupted by short periods of glacier advance)



Bolch et al. (2012)



Khumbu Himal

ASTER 3-3-1

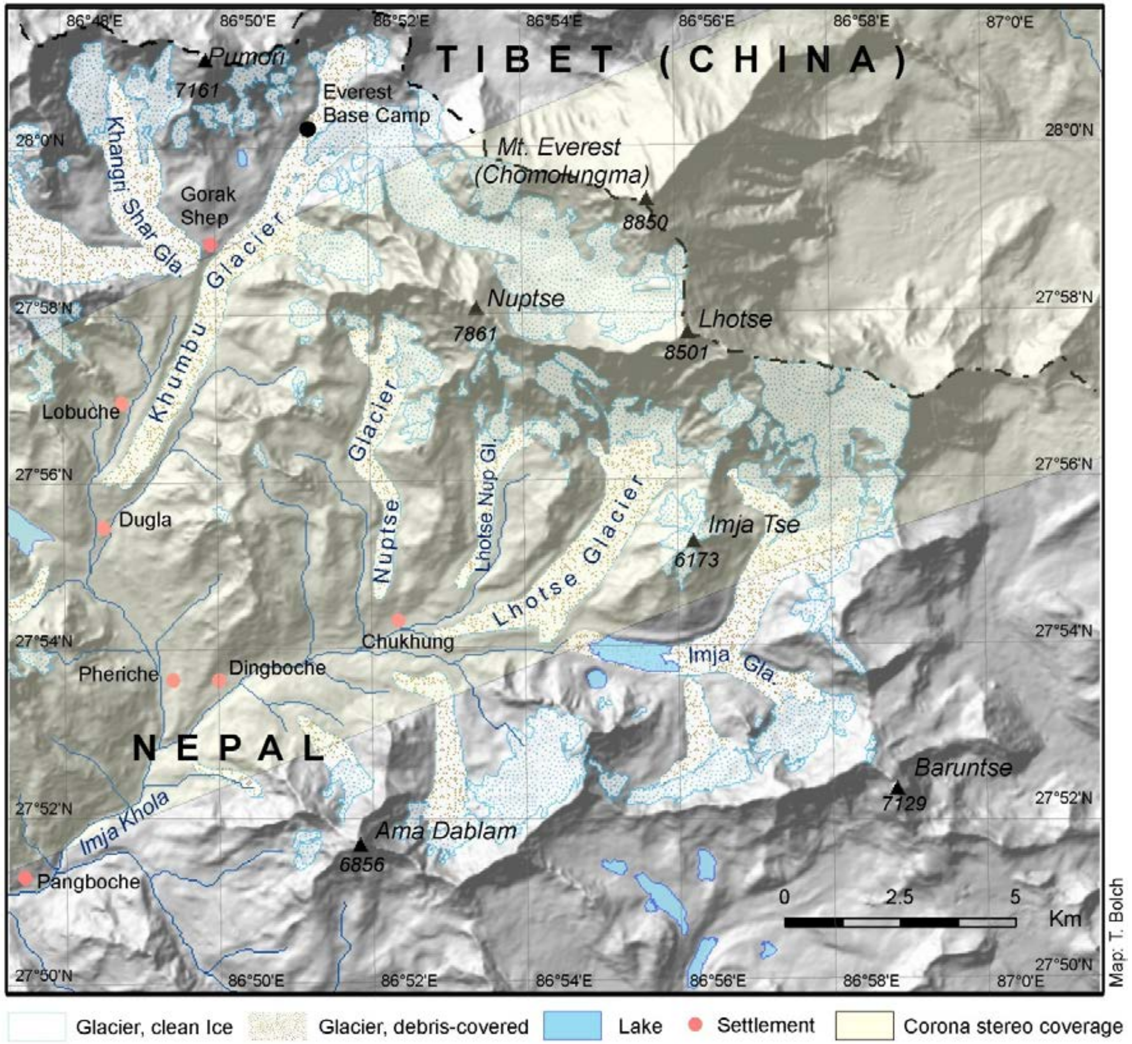
on ASTER-DEM

Khumbu Himal

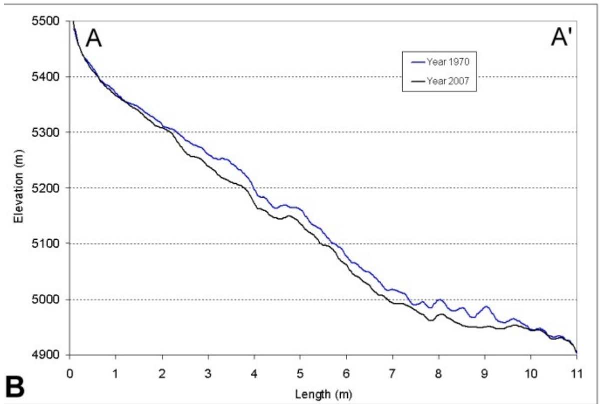
86°80‘ – 87°00‘ E
27°80‘ – 28°00‘ N

Area: 21x24 km

Glacier area lost ~5% between 1962-2002 (Bolch et al. (2008), JoG)



Glacier mass changes 1970 – 2007



Glacier mass loss:

almost 0.6 km³

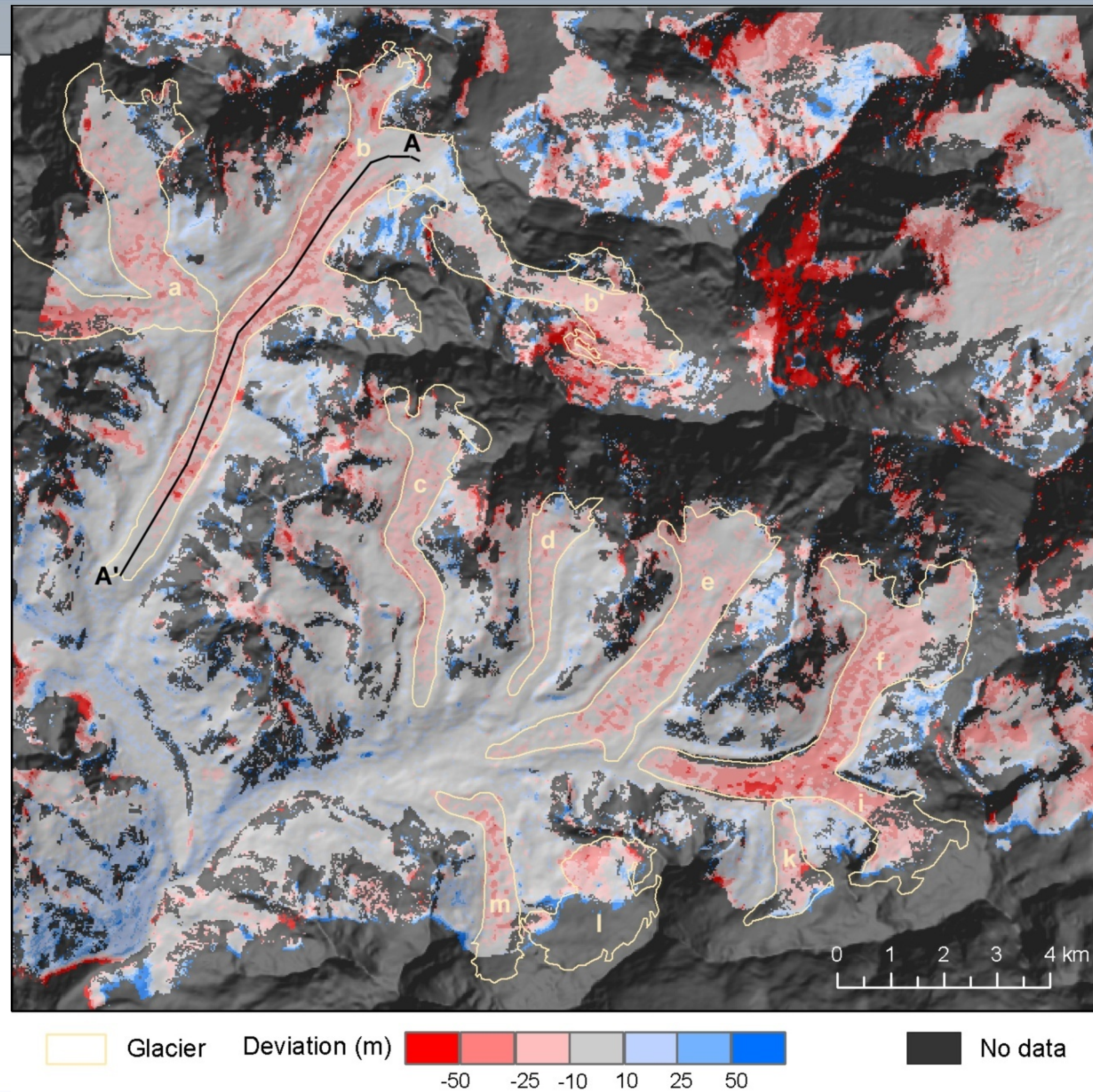
Glacier thinning:

0.37 ± 0.27 m a^{-1}

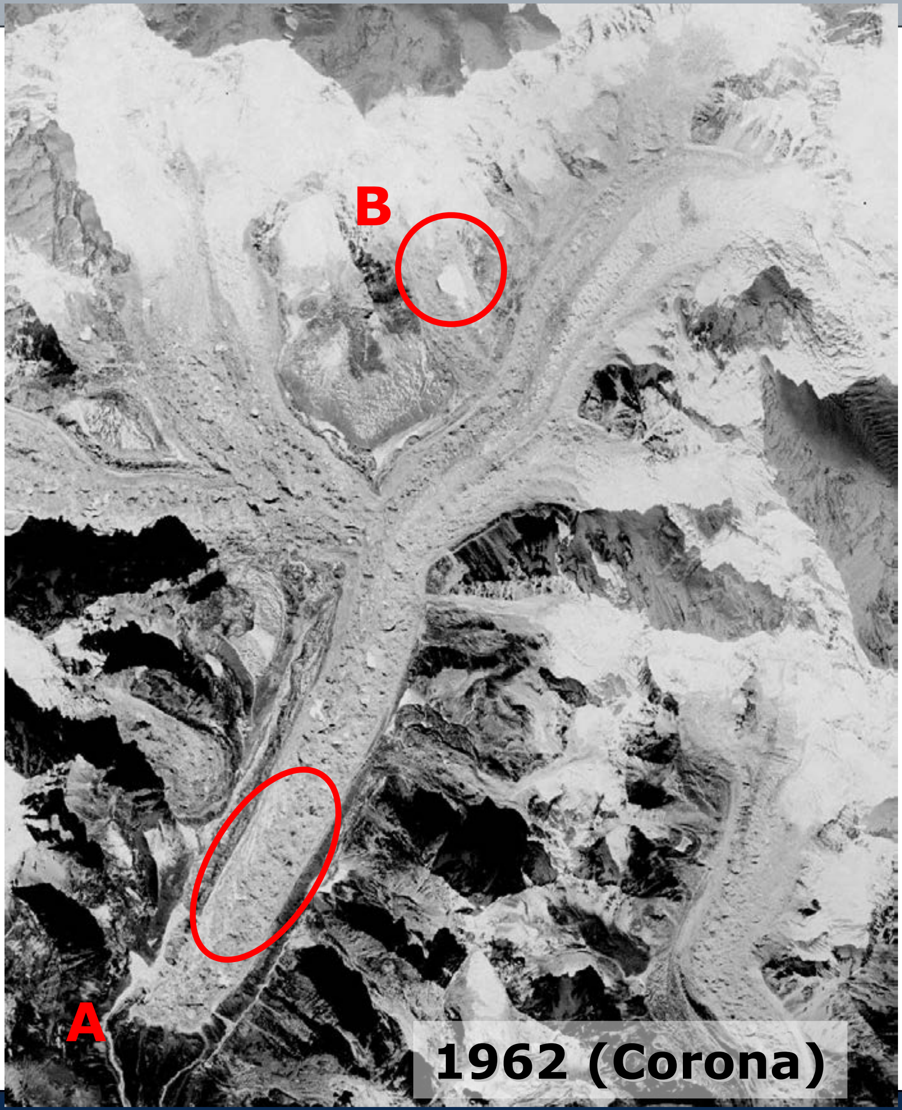
Specific mass balance:

-0.32 ± 0.23 m w.e.a^{-1}

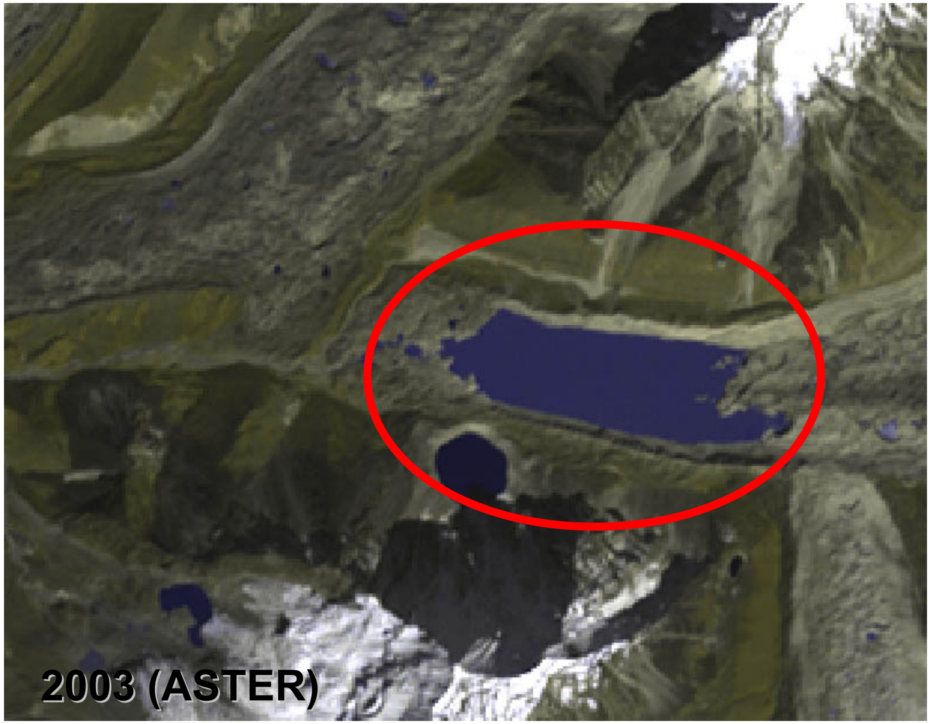
Bolch et al. (2011)



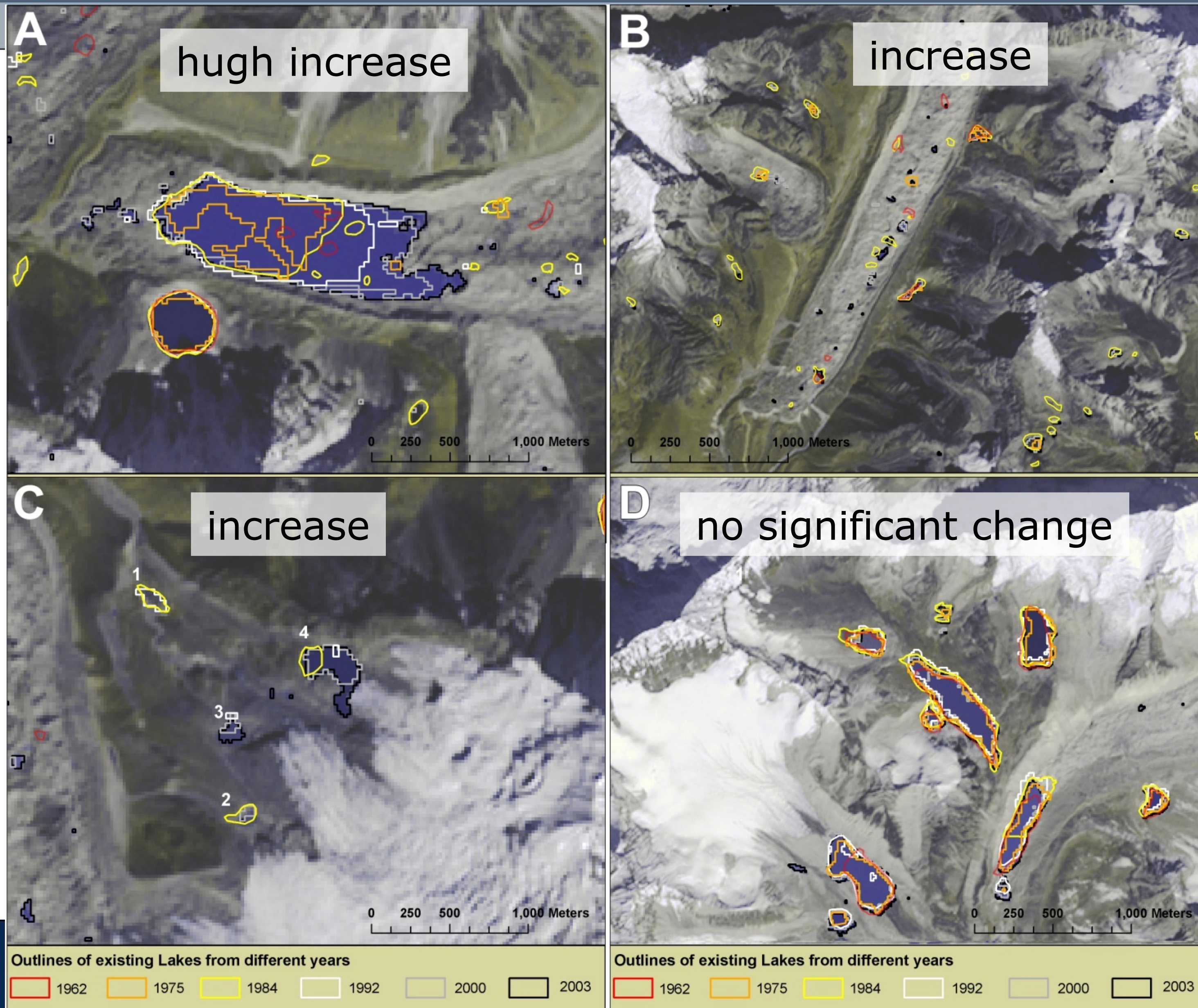
Khumbu Himal
Glacier Area Change



Formation of Imja Lake

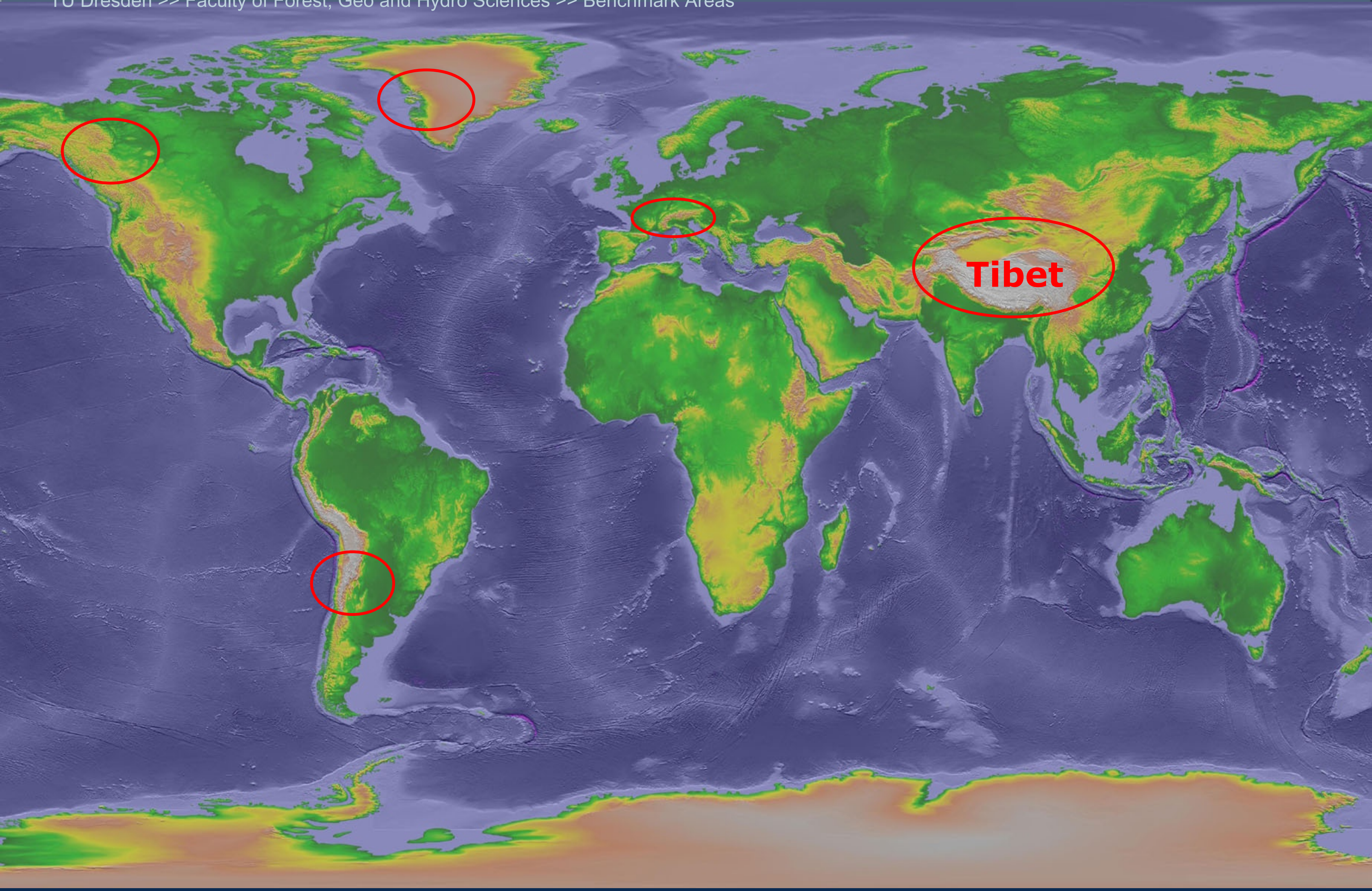


Khumbu Himal
Glacier Lakes



Bolch et al. (2008)

Benchmark Areas
Tibet



Projects at TU Dresden

TECHNISCHE UNIVERSITÄT DRESDEN

Bundesministerium für Bildung und Forschung

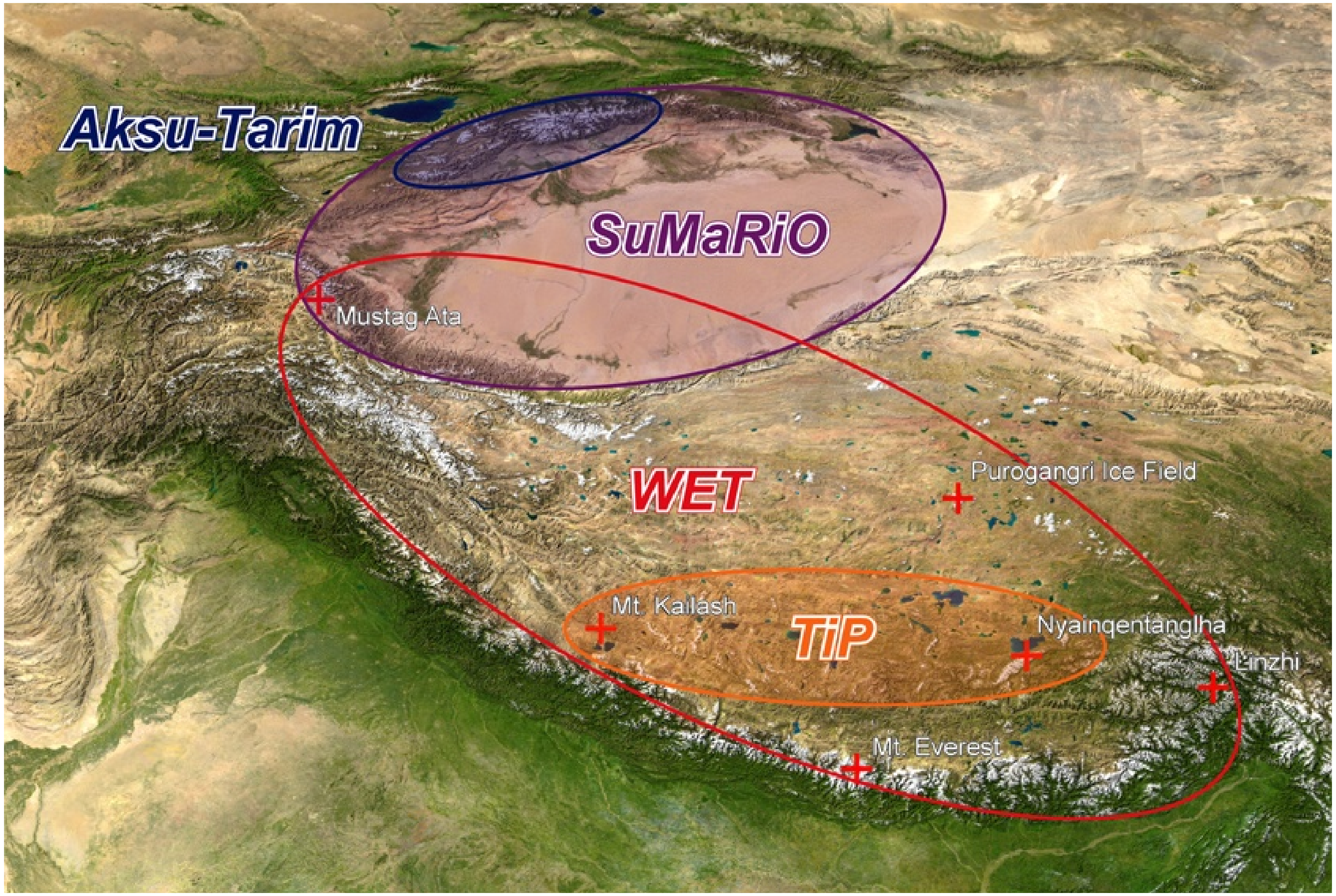
WET

SuMaRiO

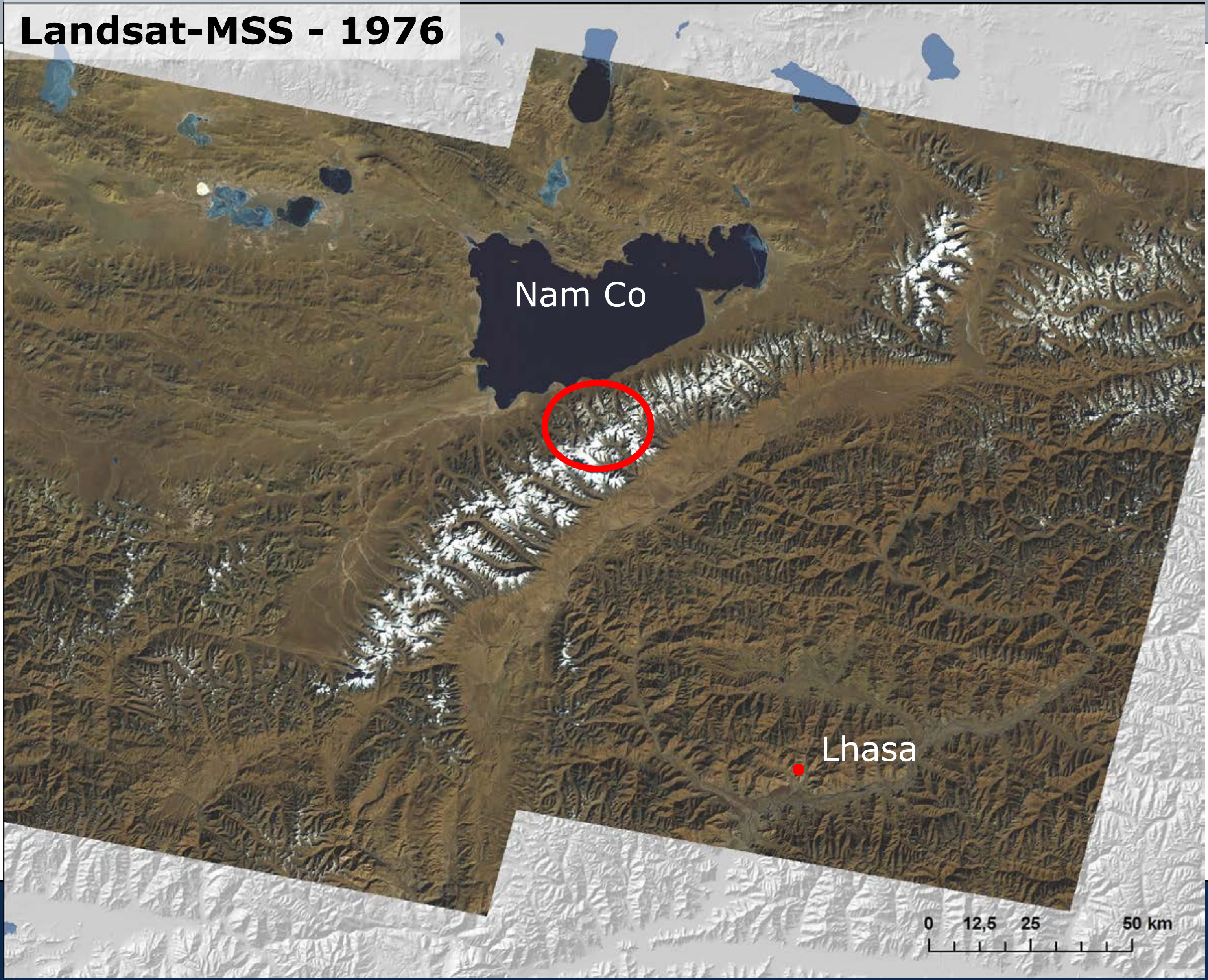
DFG Deutsche Forschungsgemeinschaft

AKSU-TARIM

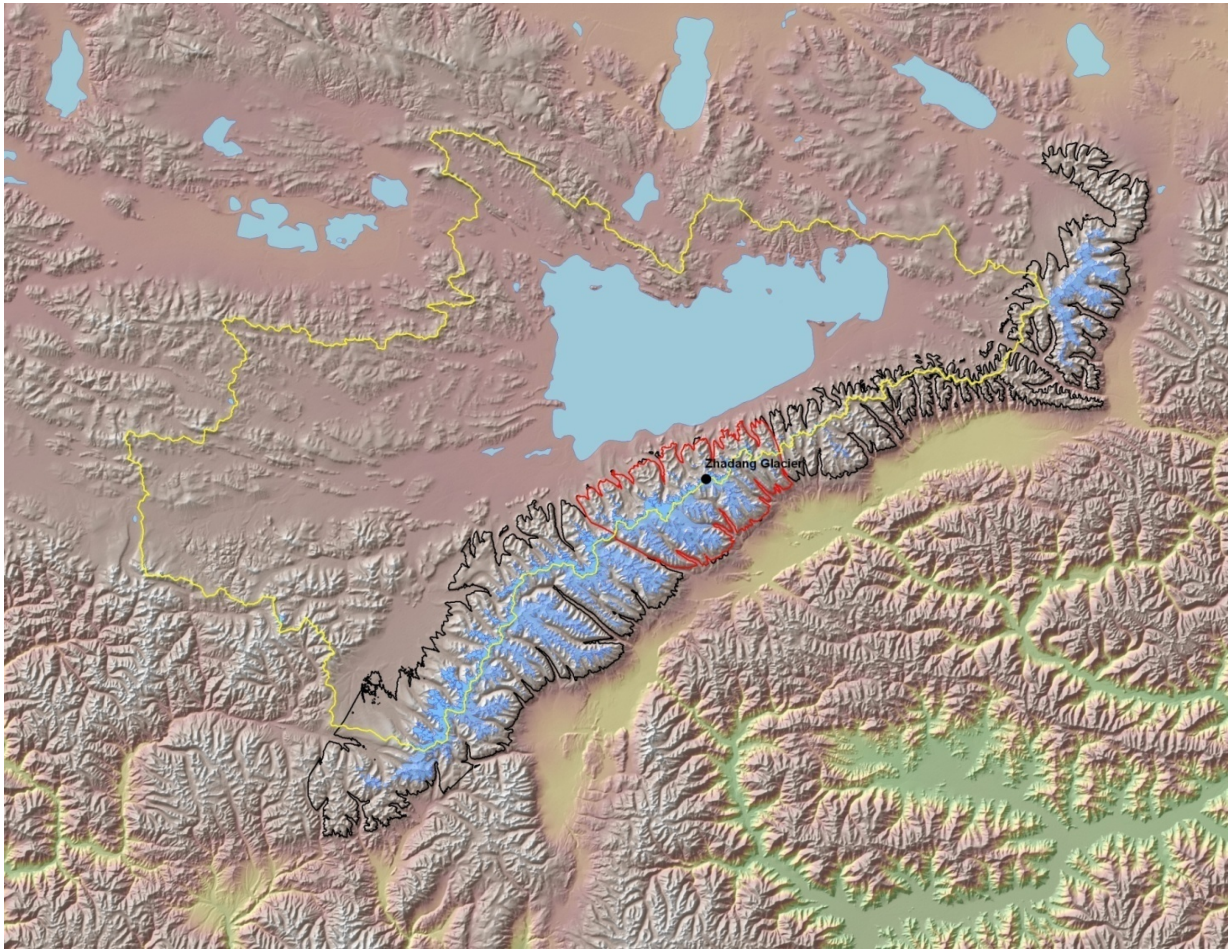
TiP



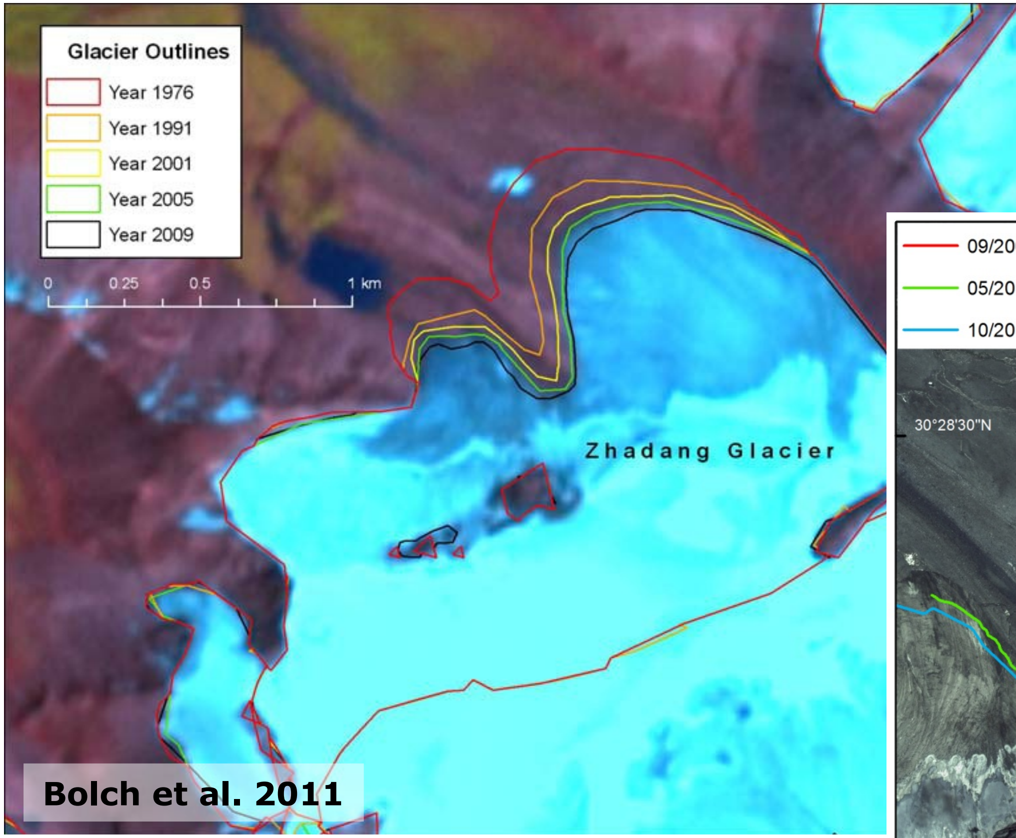
Nyainqêntanglha Study Area



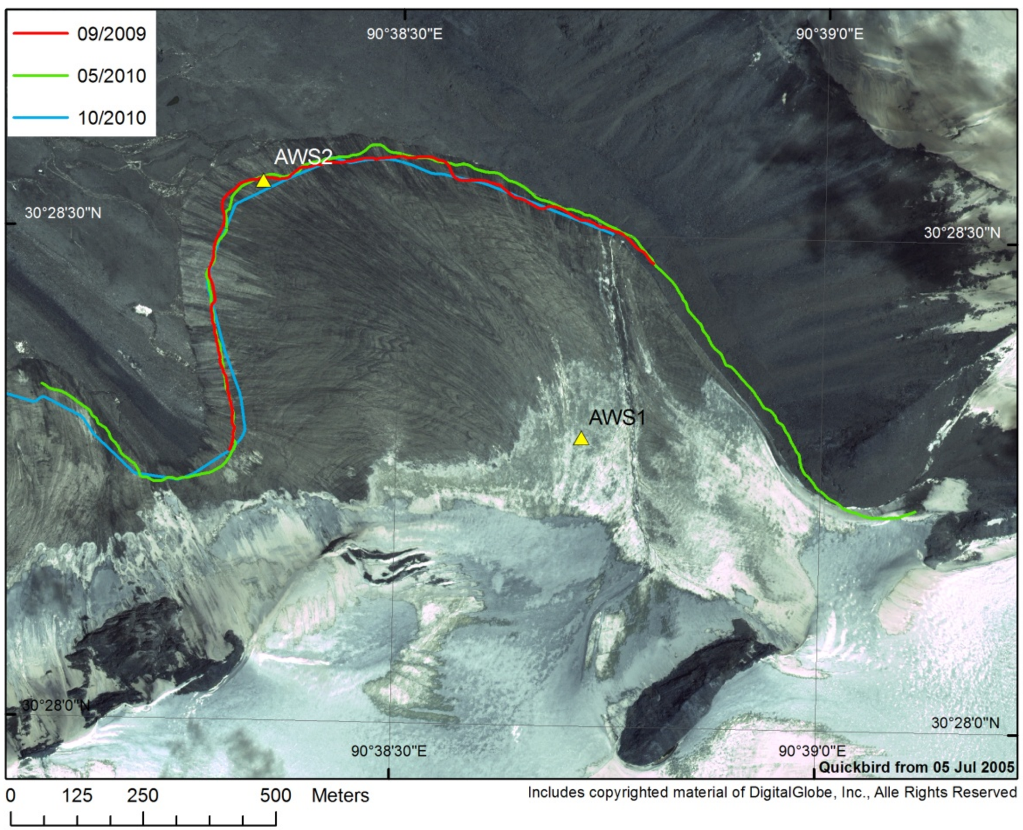
Nyainqêntanglha Study Area



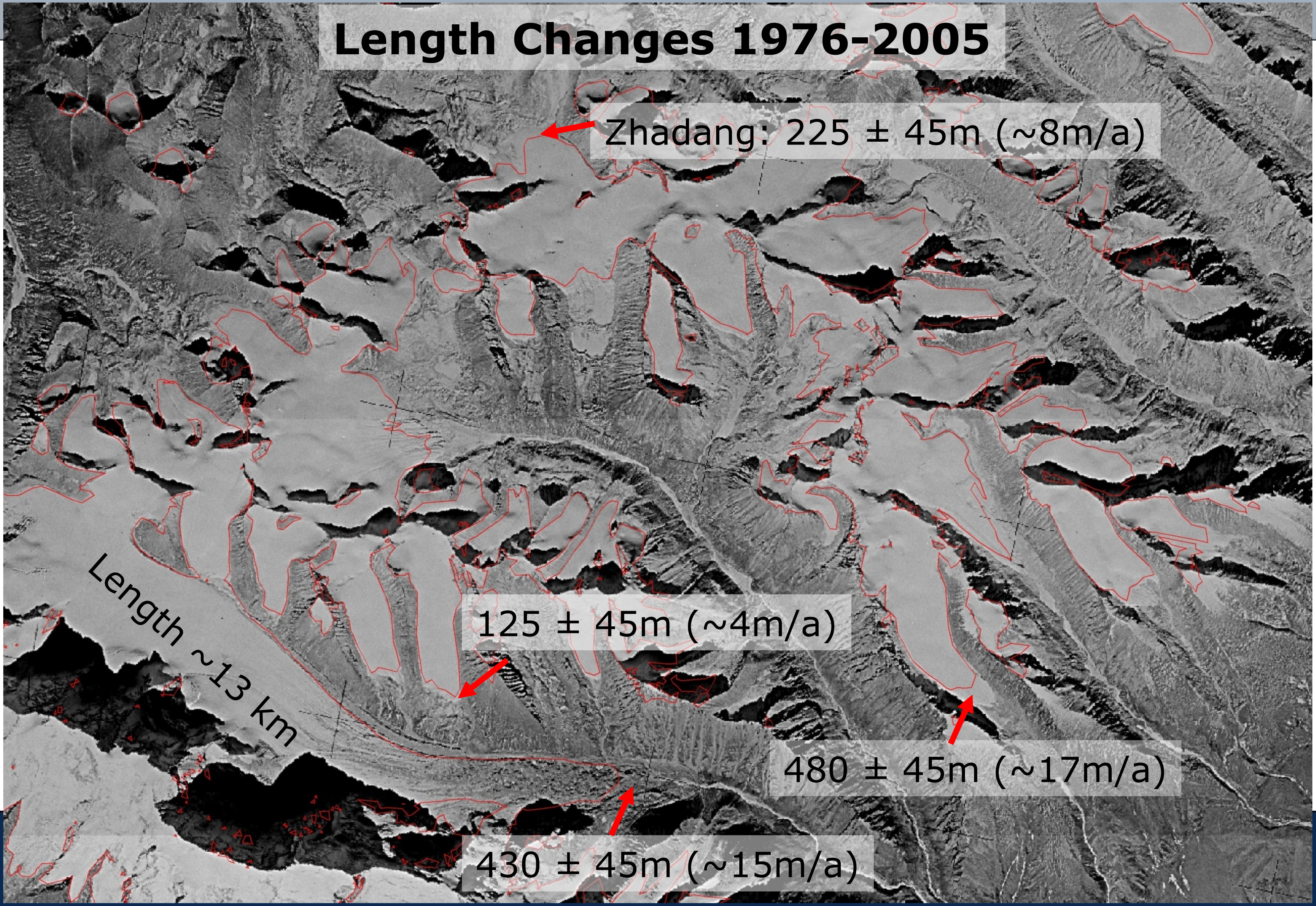

Zhadang Glacier
Photo: T. Pieczonka 2009



Zhadang-Glacier



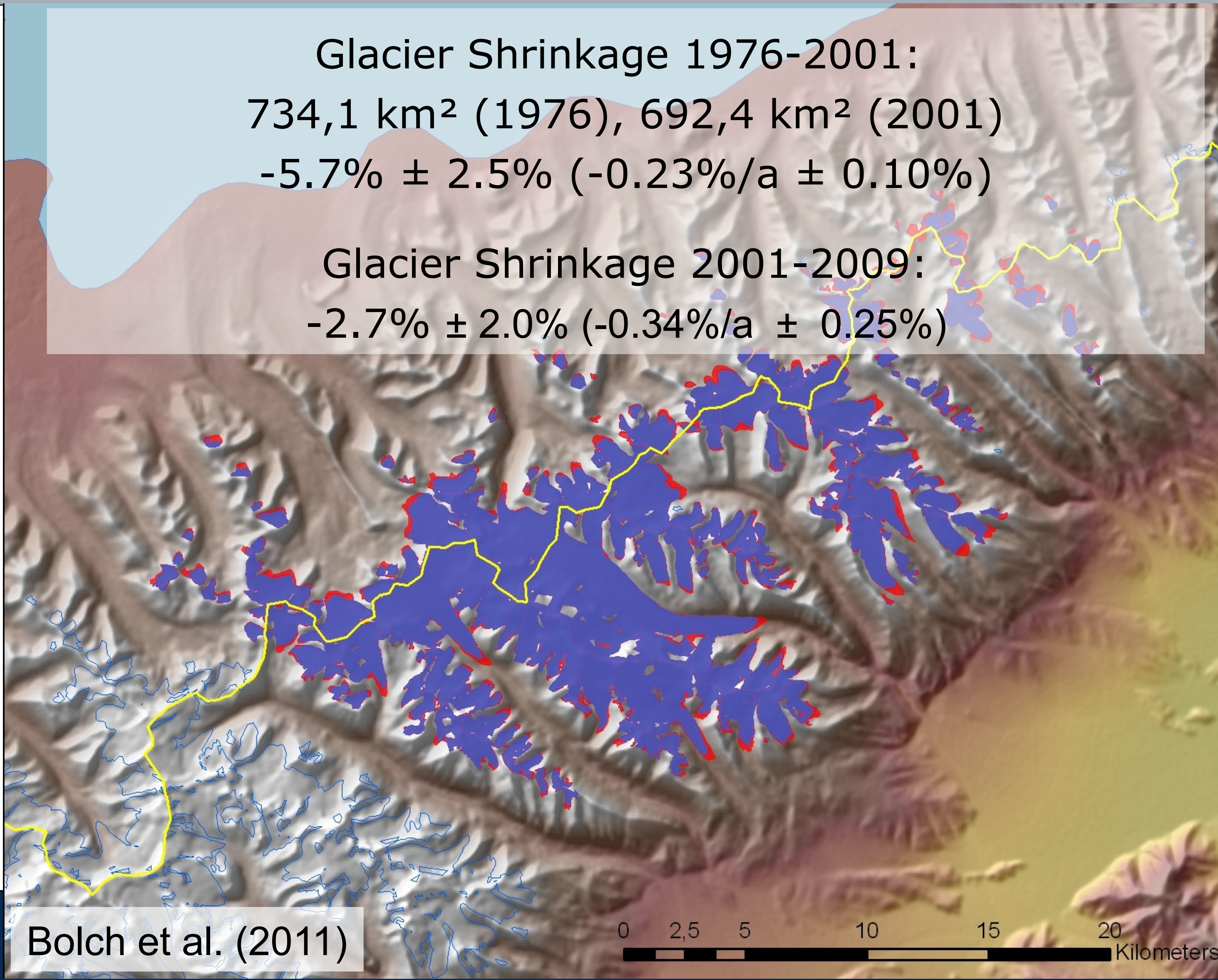
Glacier Area Change Nyanchentangla:
1976 – 2009: -16,0 km² (-7,7 %)


Length Changes 1976-2005
Zhadang: 225 ± 45m (~8m/a)
Length ~13 km
125 ± 45m (~4m/a)
480 ± 45m (~17m/a)
430 ± 45m (~15m/a)

Nyainqêntanglha
Glacier Area Change

Glacier Shrinkage 1976-2001:
734,1 km² (1976), 692,4 km² (2001)
-5.7% ± 2.5% (-0.23%/a ± 0.10%)

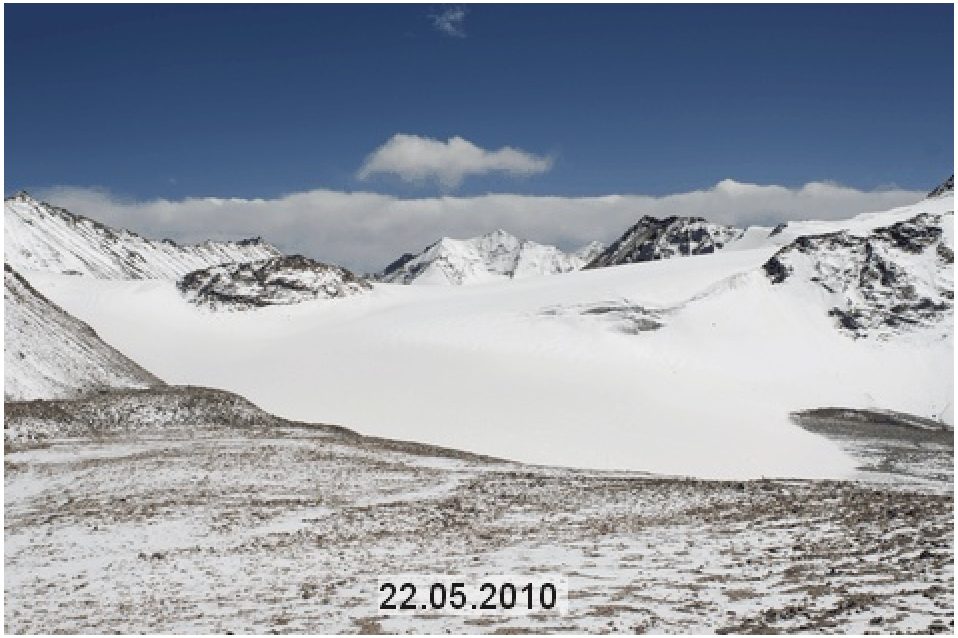
Glacier Shrinkage 2001-2009:
-2.7% ± 2.0% (-0.34%/a ± 0.25%)



Bolch et al. (2011)


Camera Zhadang Glacier
Photo: T. Pieczonka 2009

Terrestrial camera system, Zhadang Glacier



left camera: picture series from 2010

right camera: picture series from 2011

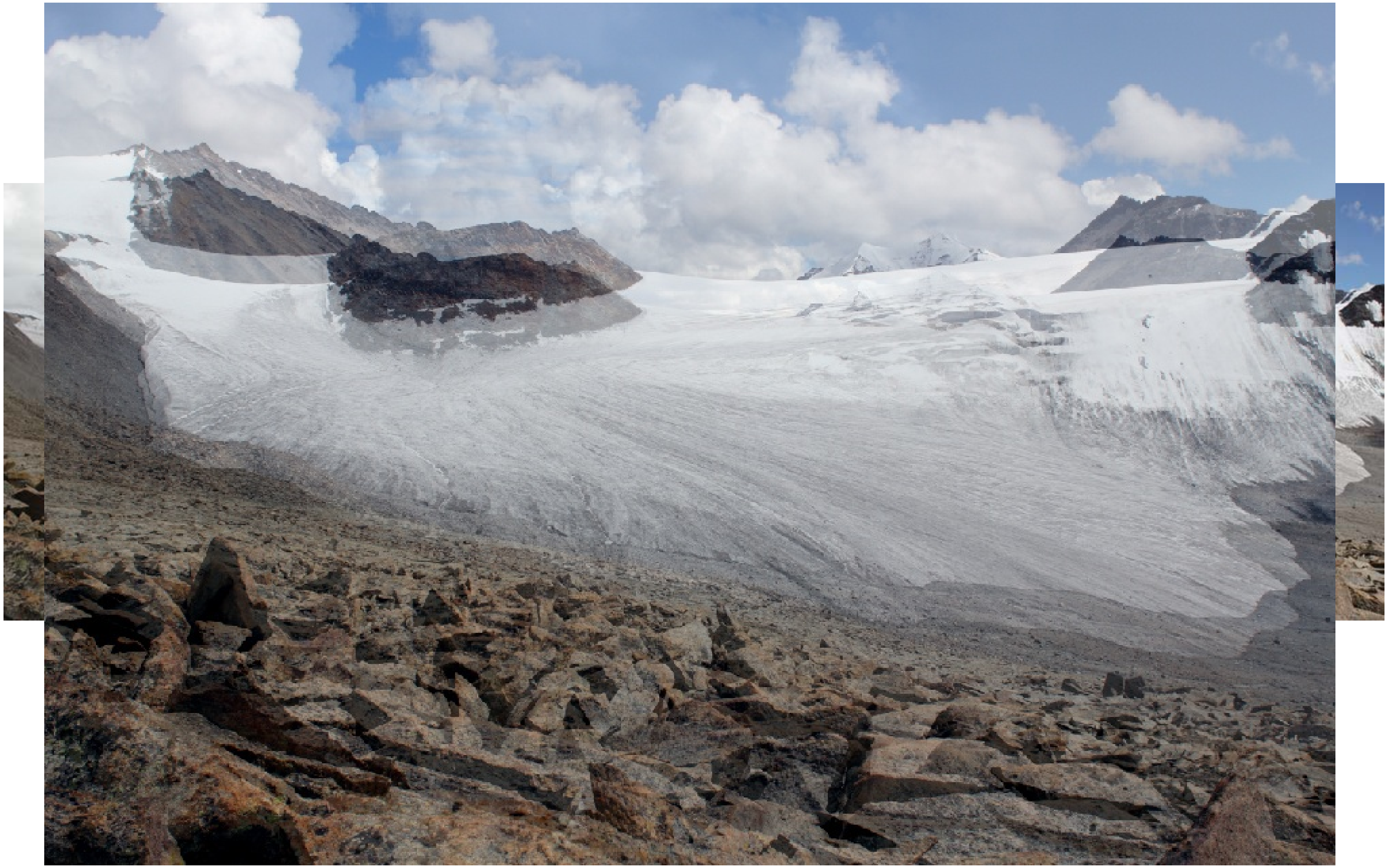
Problems with DEM generation

Accuracy insufficient (basic GPS, no differential in Tibet)

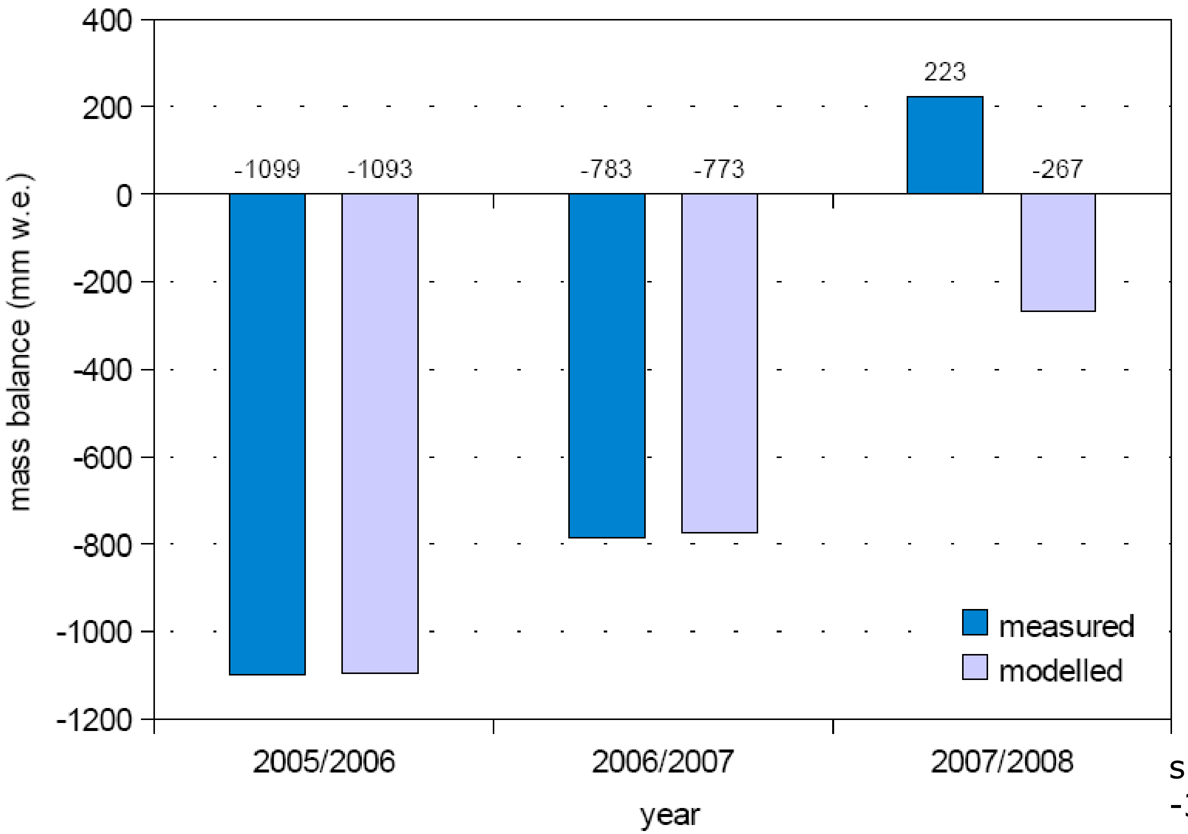
Surface consists of permafrost soil → movement, determined position invalid

Not enough GCPs (basic GPS only), not well balanced

Theft

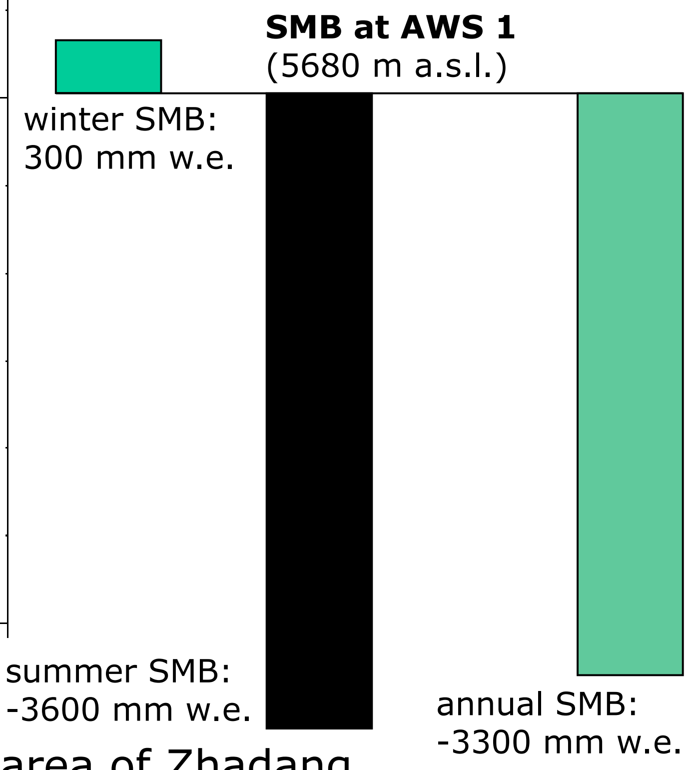


Surface Mass Balance Zhadang Glacier



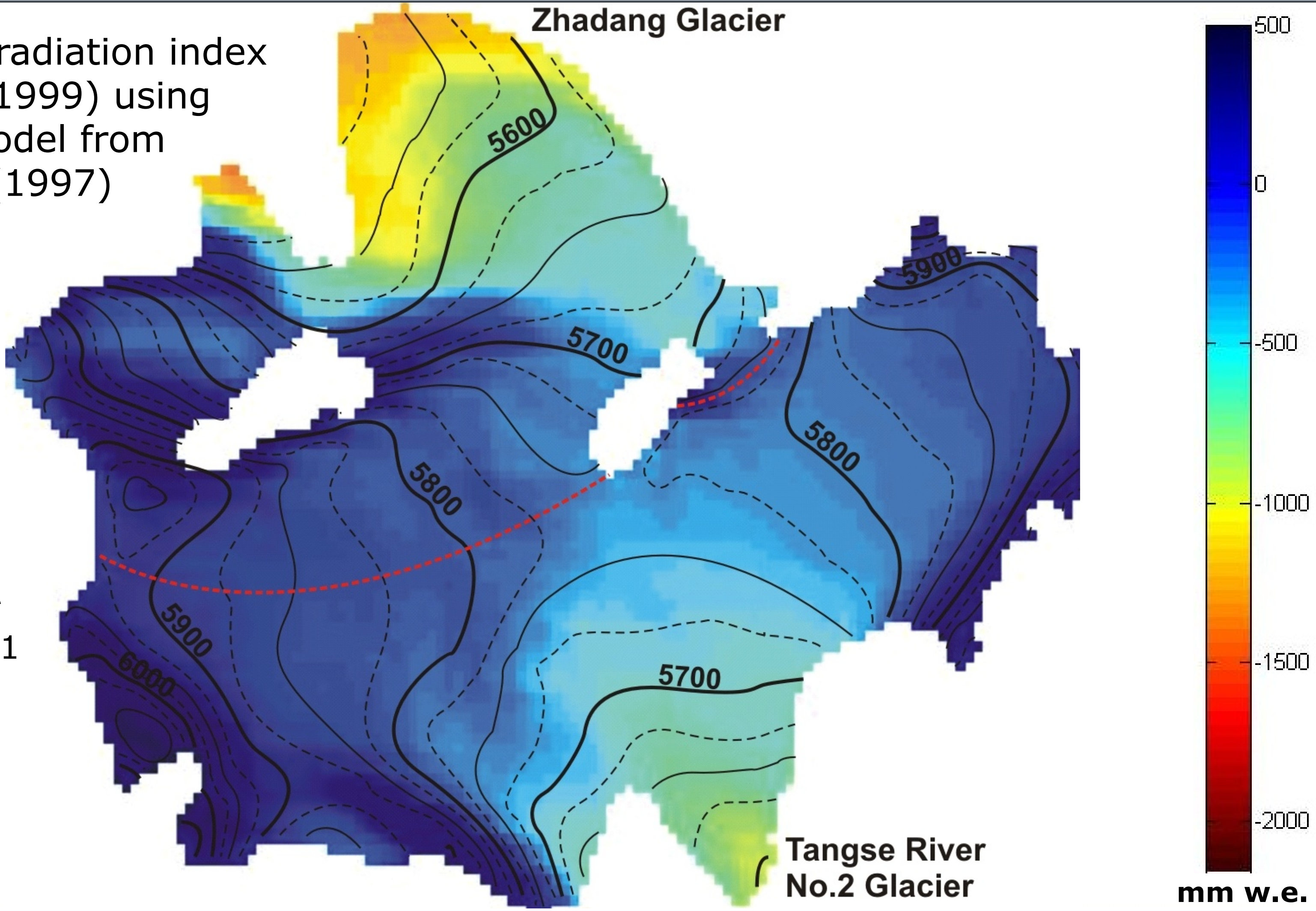
Measured vs. modelled surface mass balances for the area of Zhadang Glacier (measured mass balance values after Kang et al. 2009)

A first glimpse on the mass-balance year 2008/2009



Modelled annual mean surface mass balance 2007/08

Temperature-radiation index model (Hock 1999) using a radiation model from Kumar et al. (1997)

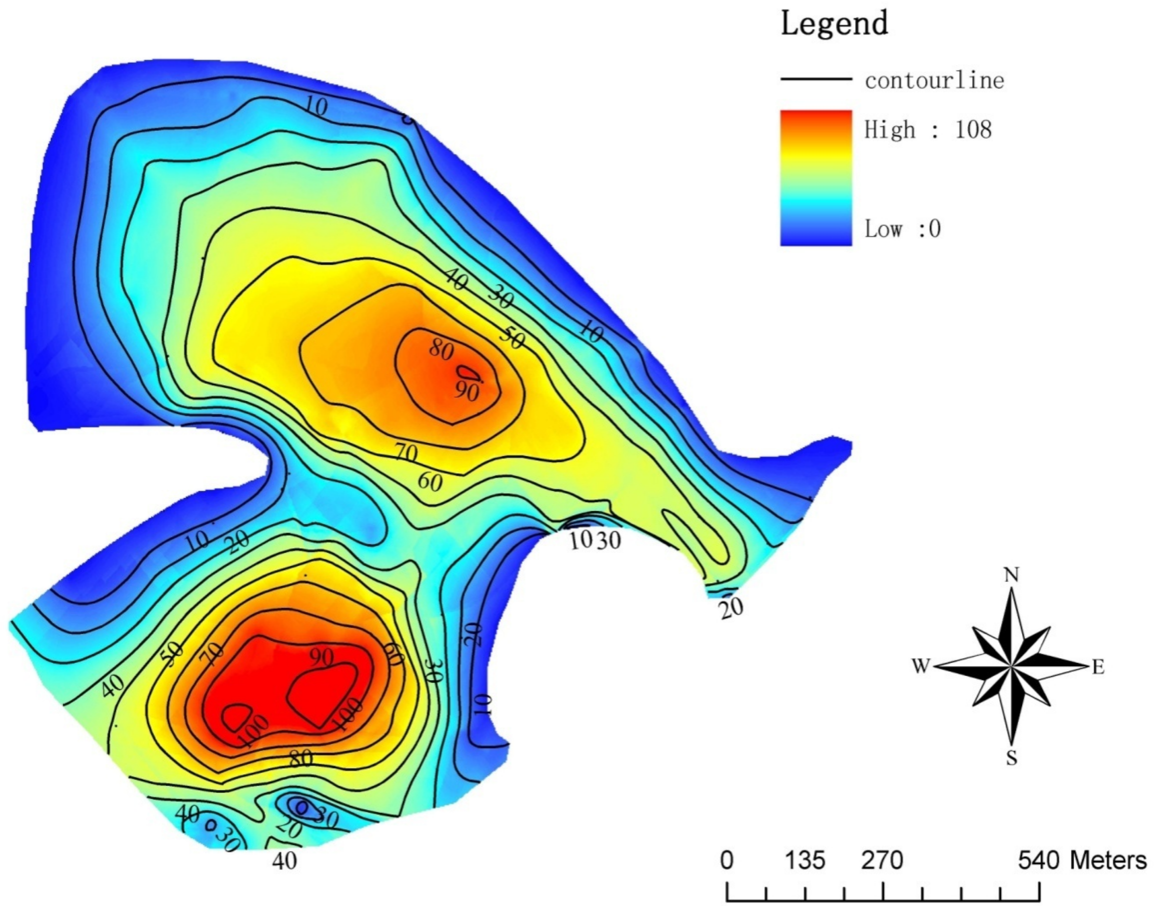


Daily air temperature and precipitation values from Baingoin station (31°22' N, 90°01' E 4701 m a.s.l.), adapted to Zhadang Glacier

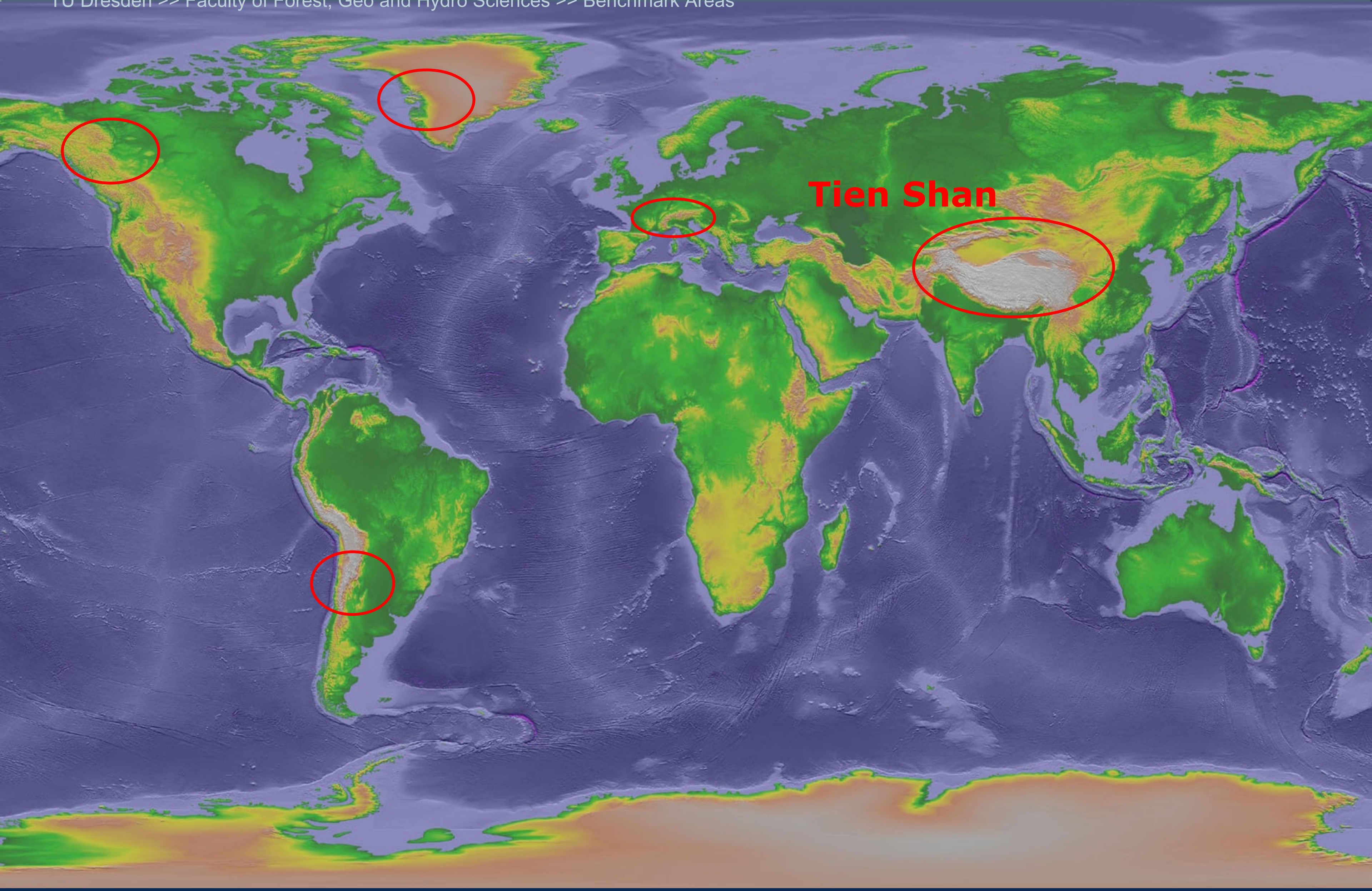
E. Huintjes

Nyainqêntanglha Glacier Thickness

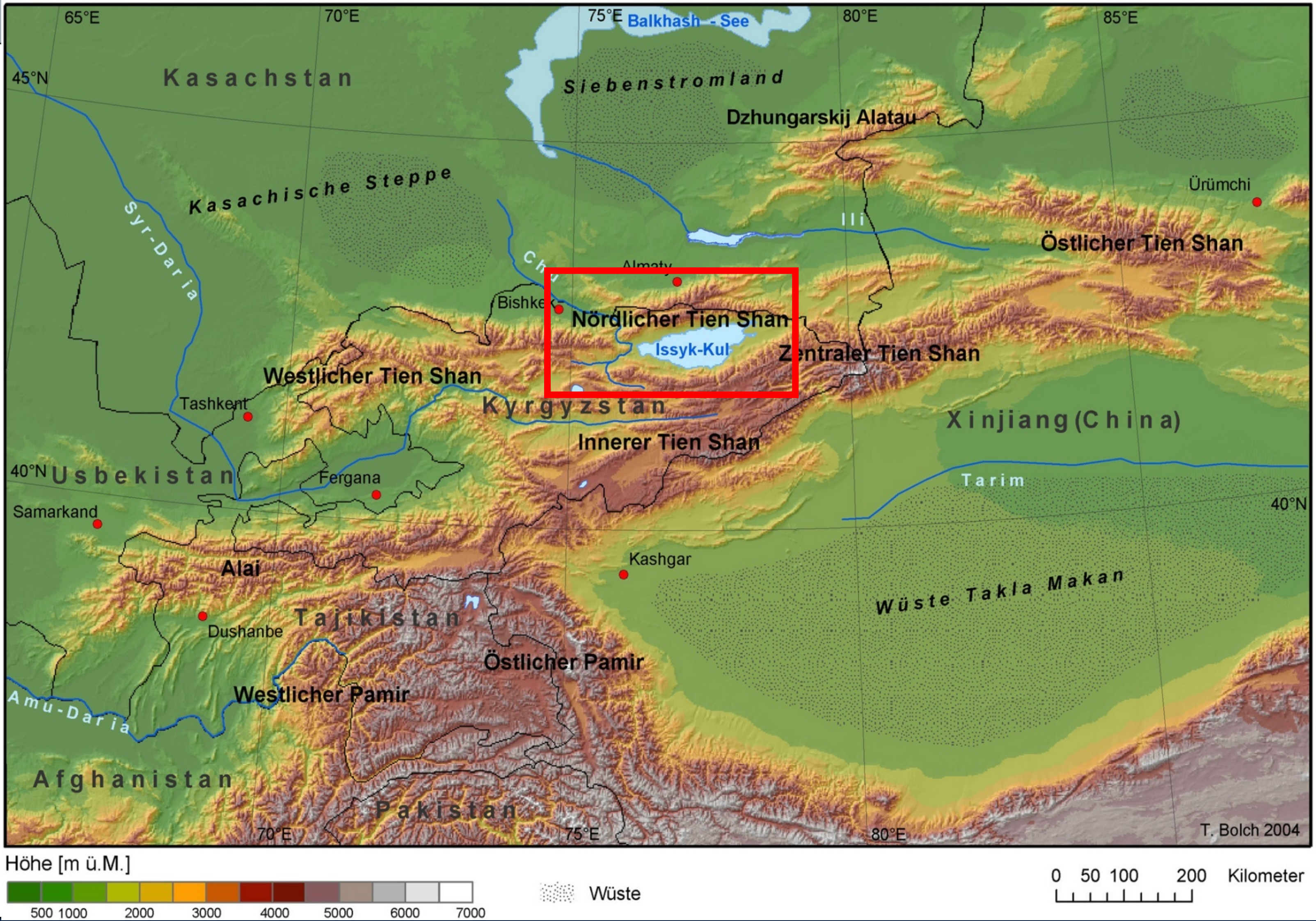
- Calculation of glacier thickness based on glacier branch lines (approach of Linsbauer, Univ. Zürich)
- First results show a good correlation with GPR measurements carried out by the ITP (Yang Wei)



Benchmark Areas
Tien Shan



Northern Tien Shan
Study Area



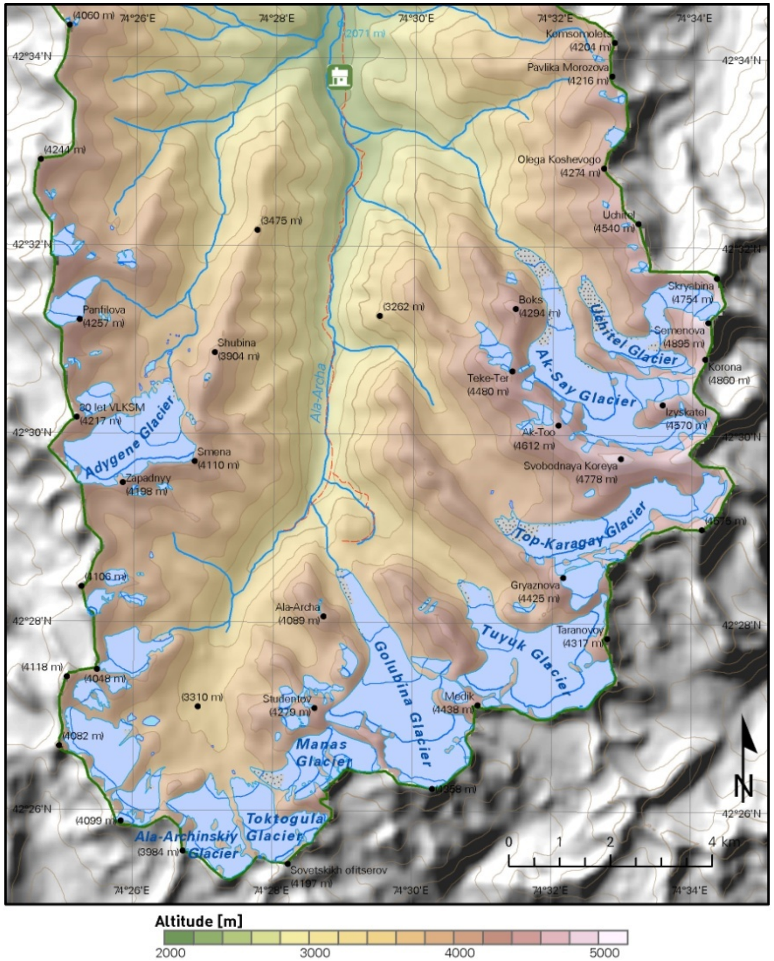
Ala-Archa National Park

74°24‘ – 74°34‘ E

42°24‘ – 42°36‘ N

Area: 194 km²

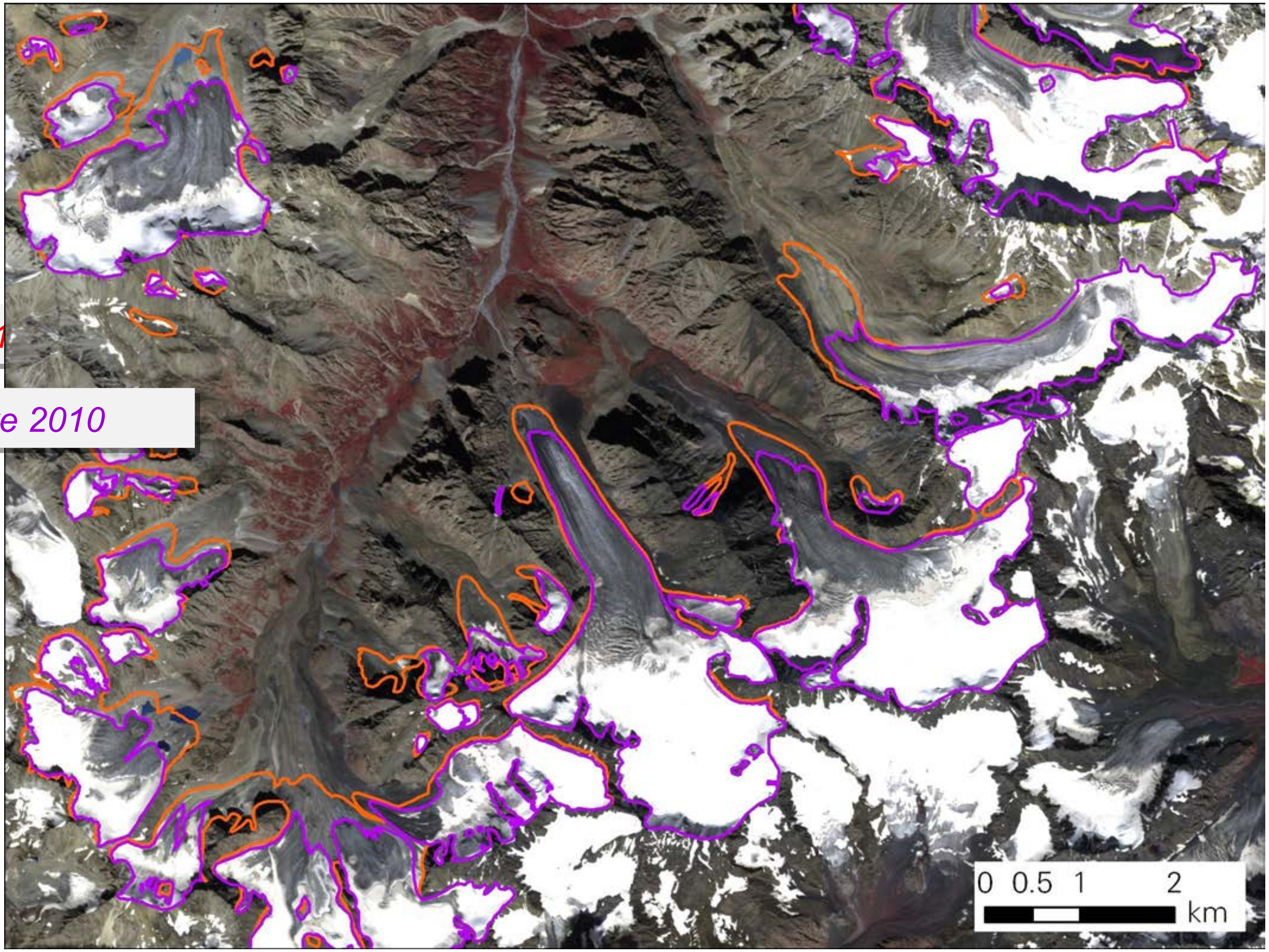
Glacier: 33 km² (~17%)



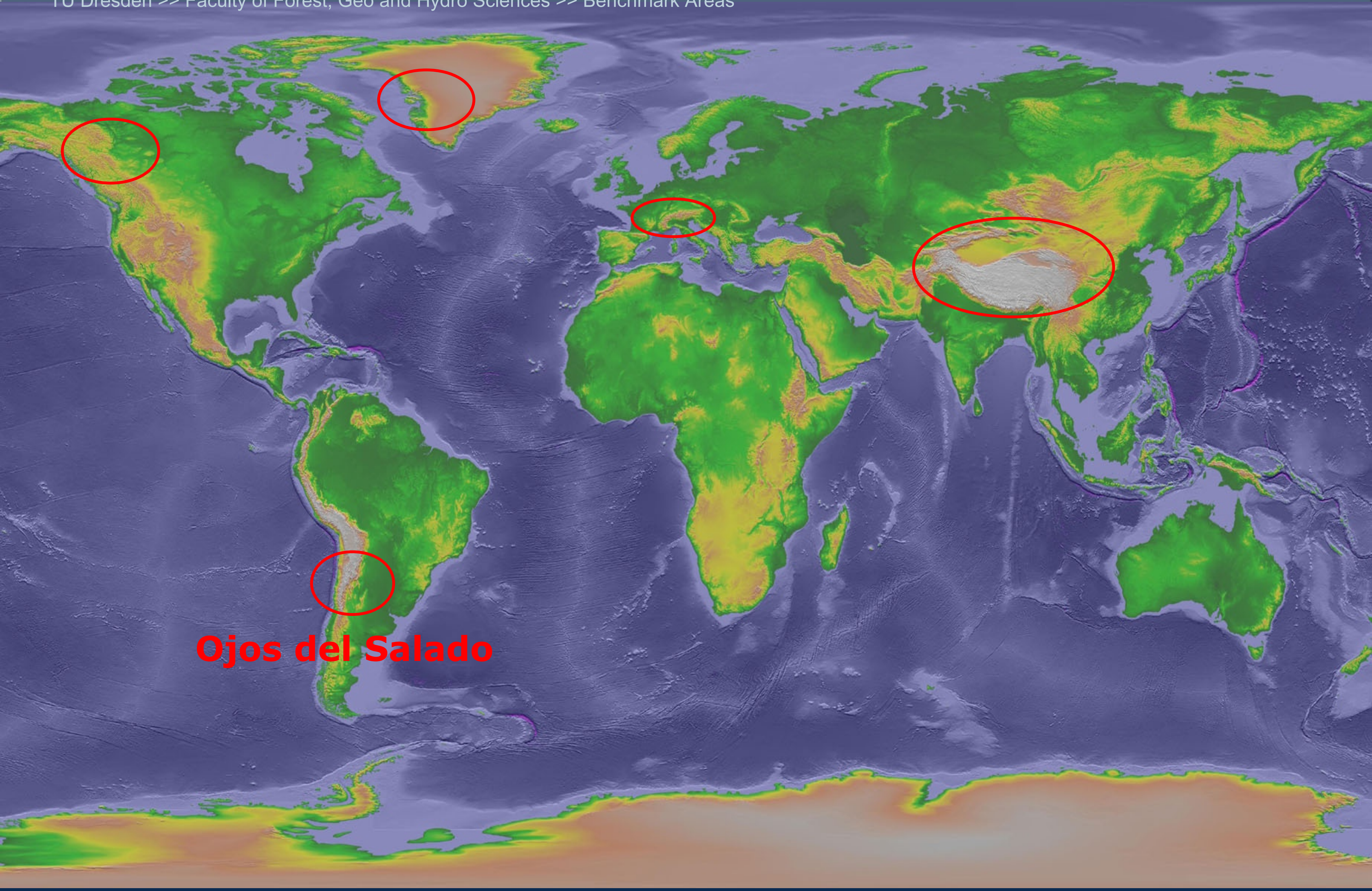
Ala-Archa Glacier Area Change

Corona 1

RapidEye 2010



Benchmark Areas
Canadian Cordillera

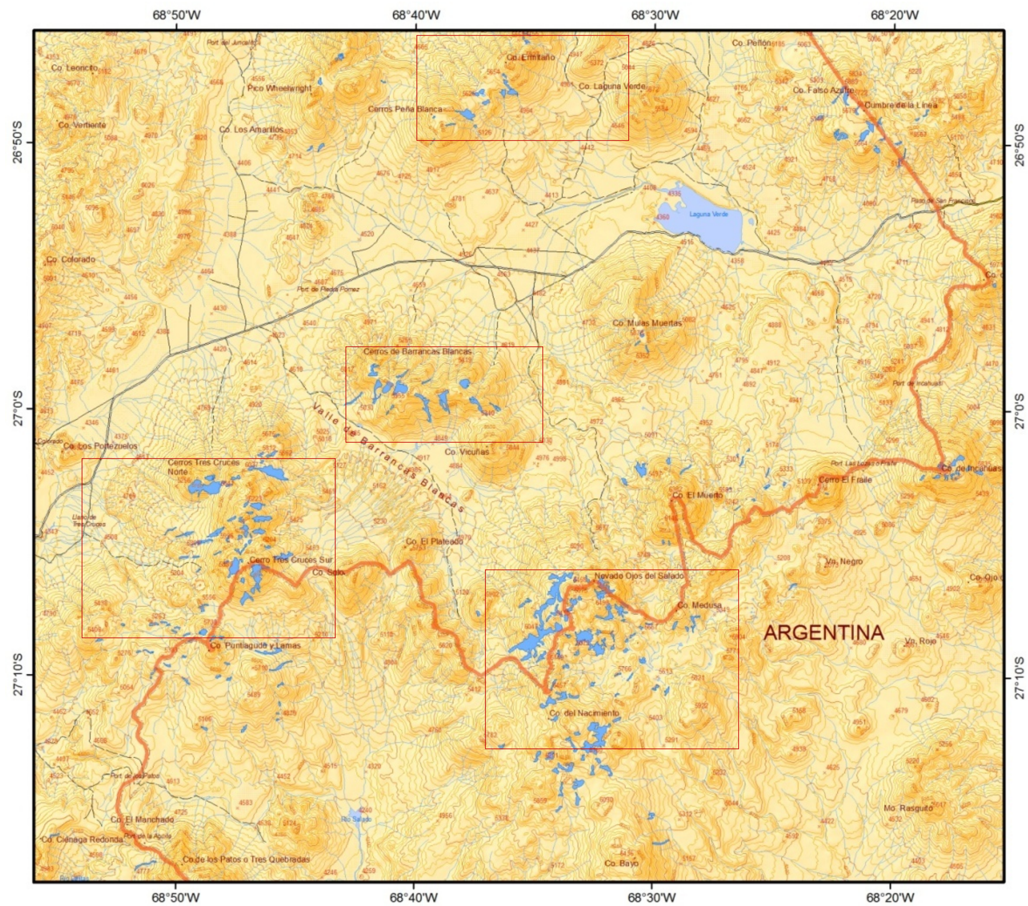


Nevado Ojos del Salado

(Chile)

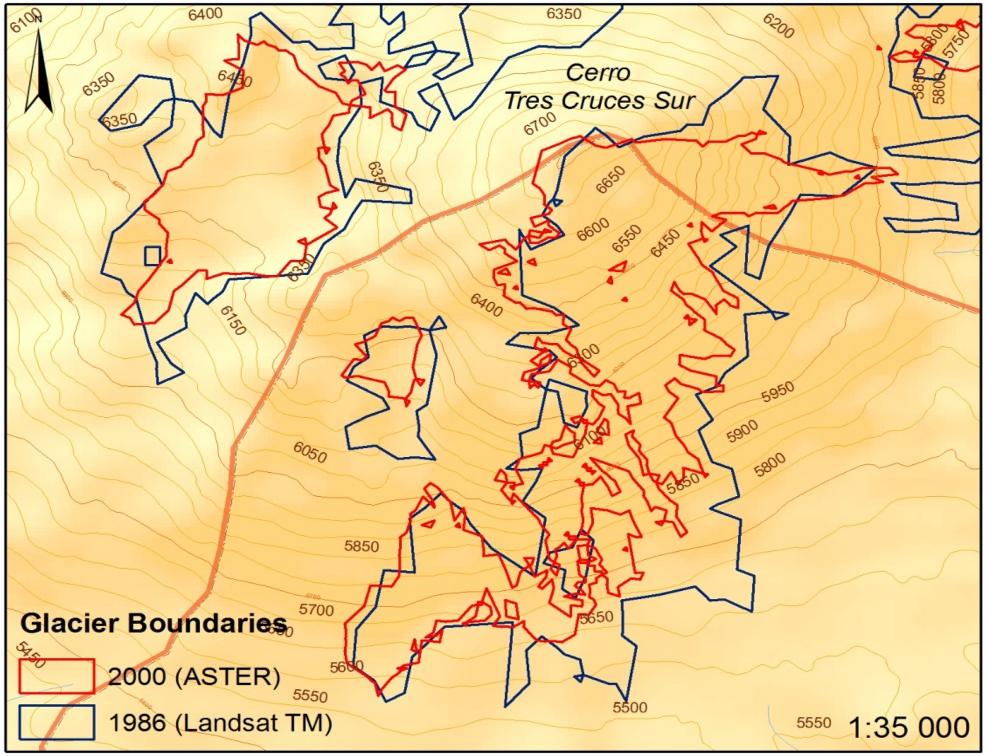
68°20‵ – 68°50‵ W

26°50‵ – 27°10‵ S



Glacier retreat between 1986-2000

- Total Glacierised Area: 56.80 km² (1986) to 34.04 km² (2000): -40%
- Accumulation Area: 16,67 km² (1986) to 16,98 km² (2000)



Glacier retreat: -38%

Conclusions

- Remote sensing technologies can be used to determine glacier variations in regard of mass balance, kinematics and extend in a cheap and efficient way, in particular for remote areas.
- Glaciological research employed with remote sensing technologies has a high relevance for the global society in regard of climate change, water supply and human impact.

Outlook

- Further glacial and periglacial research, with a special focus on debris-covered glaciers and permafrost modelling, is currently employed at the Institute of Cartography.
- The overall goal is to determine glacier properties in benchmark areas on the Tibetan Plateau and the Aksu-Tarim catchment and to link these results with climatic / spatial as well as temporal variables to obtain further conclusions on glacier variations.

My thanks for the kind support go to
Tino Pieczonka, Nicolai Holzer and Juliane Peters!

For further questions please contact:
benjamin.schroeter@tu-dresden.de


2013
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TO
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26th International Cartographic Conference
August 25 - 30, 2013 | Dresden, Germany

Thank you for your attention!!!