Fenomén „GLOF“ jako projev změny klimatu

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Vybrané kapitoly z fyzické geografie

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CZECH DEVELOPMENT AGENCY

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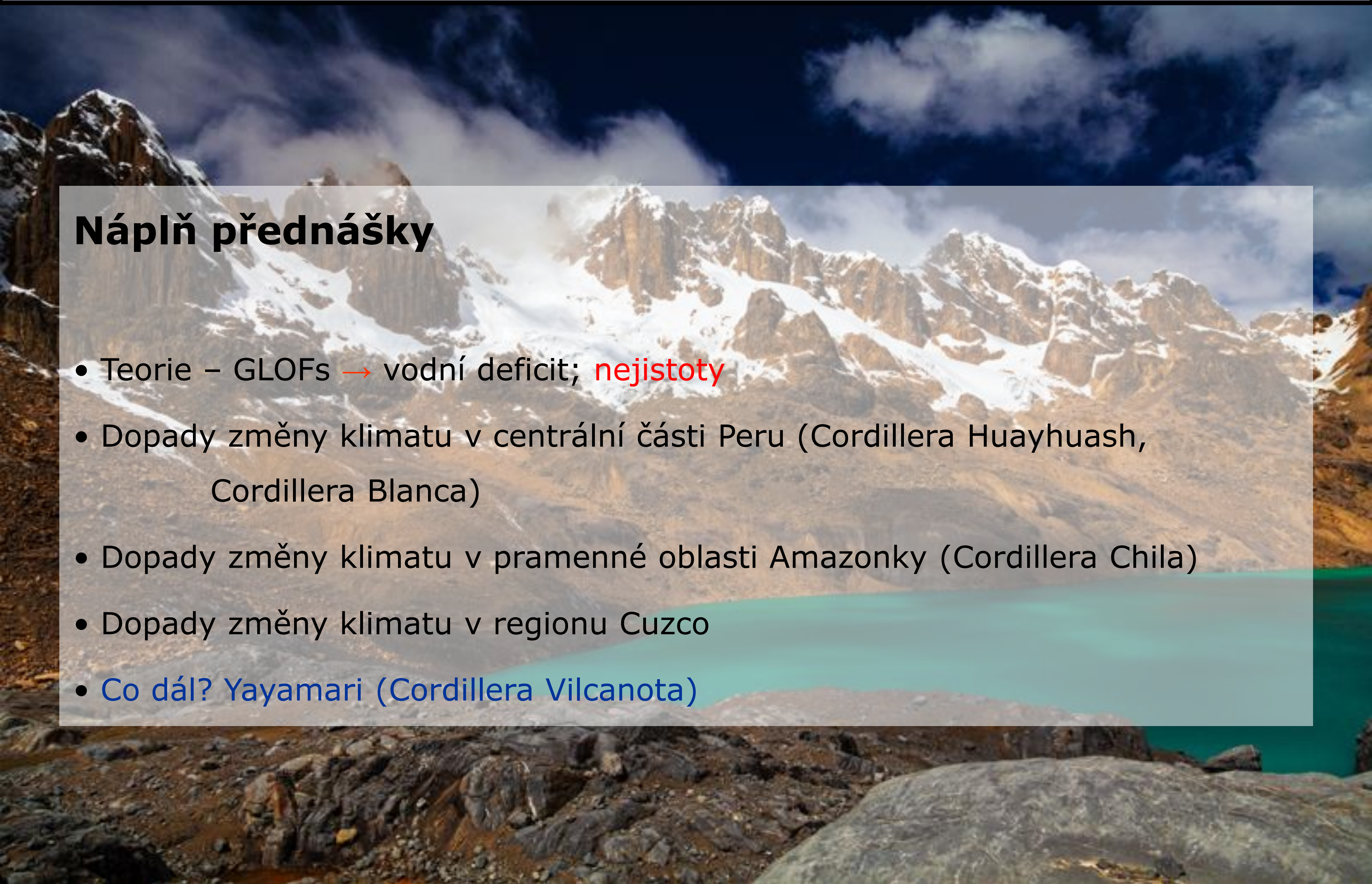
Motto

Rivers in headwaters are the architects of their own future ...



Náplň přednášky

- Teorie – GLOFs → vodní deficit; nejistoty
- Dopady změny klimatu v centrální části Peru (Cordillera Huayhuash, Cordillera Blanca)
- Dopady změny klimatu v pramenné oblasti Amazonky (Cordillera Chila)
- Dopady změny klimatu v regionu Cuzco
- Co dál? Yayamari (Cordillera Vilcanota)

Cali
Kolumbie
Quito
Puerto Ayora
Ekvádor
Guayaquil
Cuenca
Trujillo
Peru
Lima
Cuzco
Arequipa
La Paz
Cochabamba
Sucre
Antofagasta
JUJUY
Guyana
Francouzská Guyana
Boa Vista
RORAIMA
AMAPÁ
Macapá
Belém
Manaus
Santarém
São Luís
AMAZONAS
PARÁ
MARANHÃO
CEARÁ
Imperatriz
ACRE
Porto Velho
Brazílie
PIAUÍ
João Pessoa
PERNAMBUCO
Palmas
RONDÔNIA
TOCANTINS
ALAGOAS
Cat Hill
Salvador
MATO GROSSO
Cuiabá
Brasília
Bolívie
Goiânia
Santa Cruz de la Sierra
Uberlândia
Belo Horizonte
Campo Grande
Ribeirão Preto
MATO GROSSO DO SUL
São Paulo
Rio de Janeiro
Paraguay


QUITO
EKVÁDOR
Guayaquil
Chiclayo
Trujillo
PERU
LIMA
Arequipa
LA PAZ

GLOF = Glacial Lake Outburst Flood

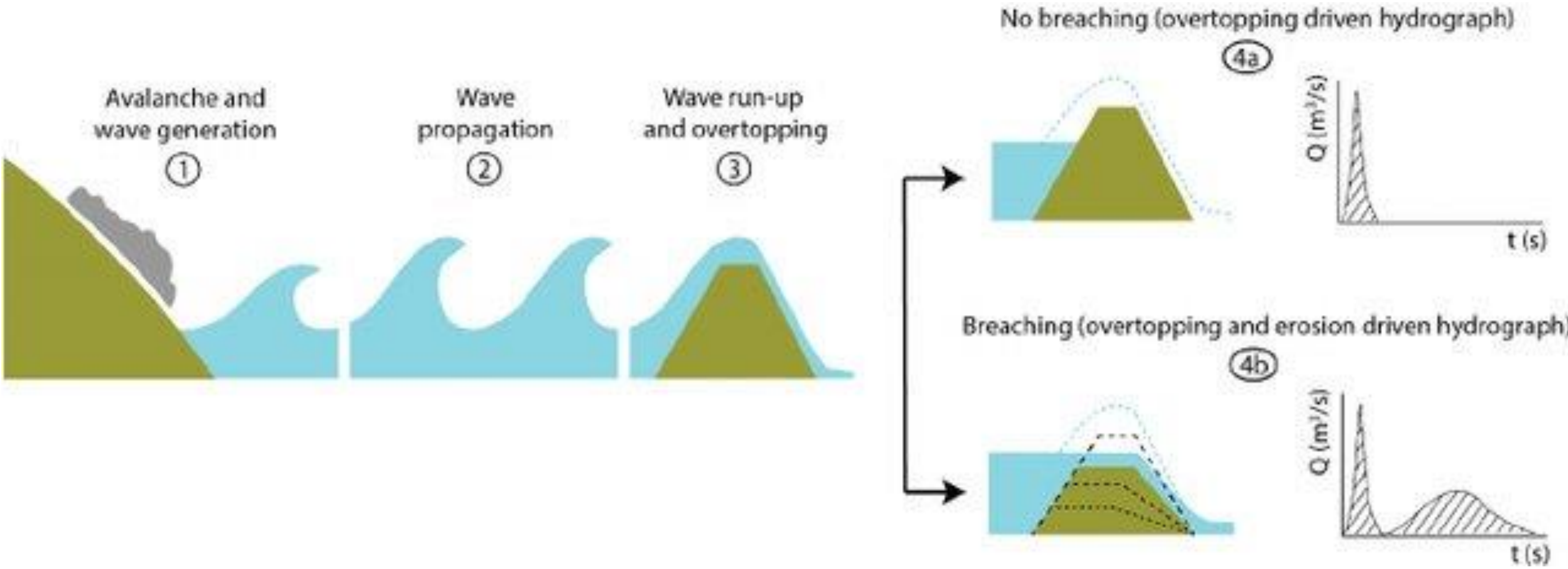
- type of outburst flood caused by the failure of a dam containing a glacial lake (similar to „jökulhlaup“)
- dam can consist of glacier ice or a terminal moraine
- **causes**: erosion, a buildup of water pressure, an avalanche of rock or heavy snow, an earthquake or cryoseism, volcanic eruptions under the ice, or massive displacement of water in a glacial lake when a large portion of an adjacent glacier collapses into it

In this Hubbard Glacier image from 16 July 2002, the glacier has closed off Russell Fjord from Disenchantment Bay. The waters behind the glacier rose 61 feet (19 m) in 10 weeks, creating a short lived Russell Lake.

GLOF = Glacial Lake Outburst Flood

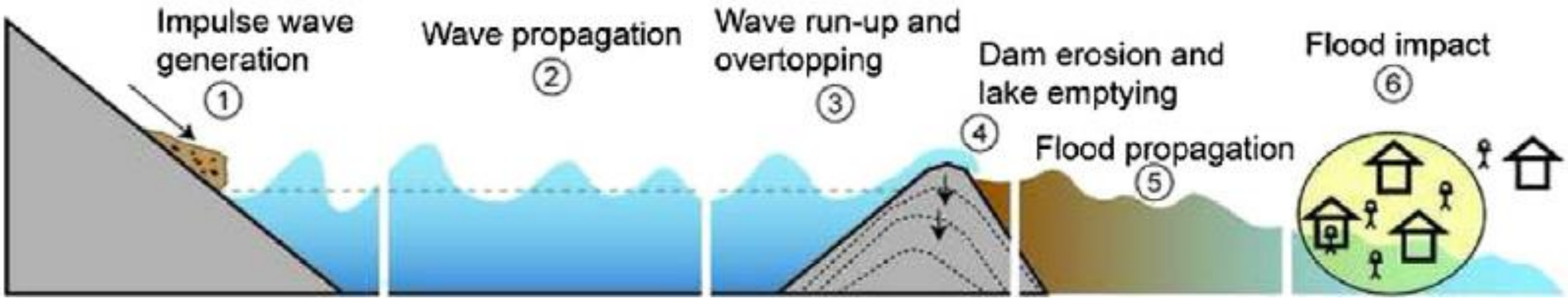
The Hubbard Glacier is overwhelmed on 14 August 2002 in the second largest GLOF in historical times!

Typical GLOF process chain I.

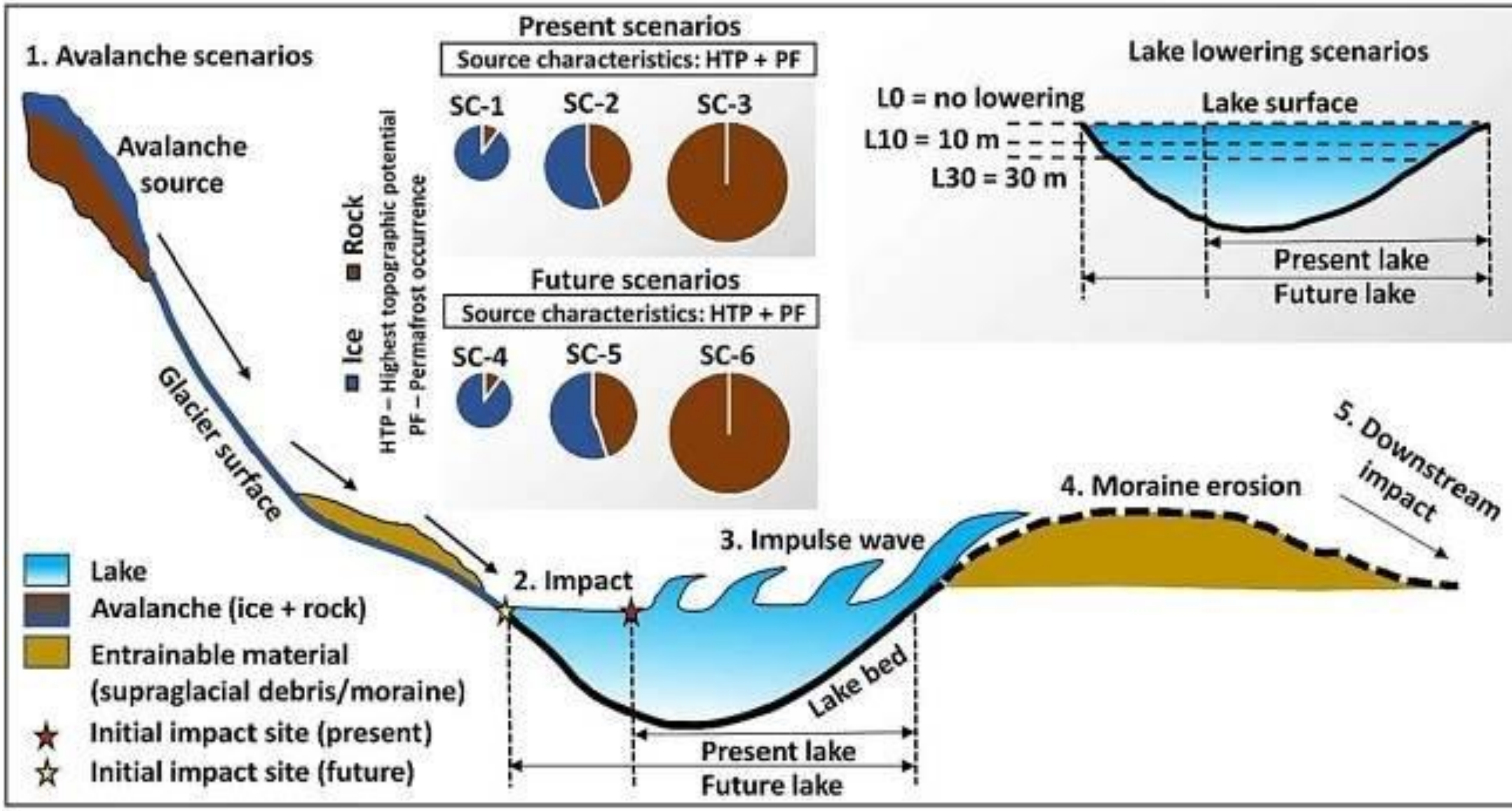


Sketch of a typical GLOF process chain. (1) An avalanche/landslide enters a lake, powering a wave that (2) propagates across the lake and (3) overtops the front dam moraine. As a consequence, either (4a) the waves discharge only their own water volume downstream or (4b) an erosion process starts over the moraine, such that the resulting GLOF drains waves and remaining lake volume throughout two phases, forming an overtopping- and erosion-driven hydrograph (adapted from Worni et al., 2014).

Typical GLOF process chain II.



GLOF and its impact



GLOFs in general
https://youtu.be/BDPbtP-0AW8

ILULISSAT GLACIER, GREENLAND
https://www.youtube.com/watch?v=49bYTMo3Vxw

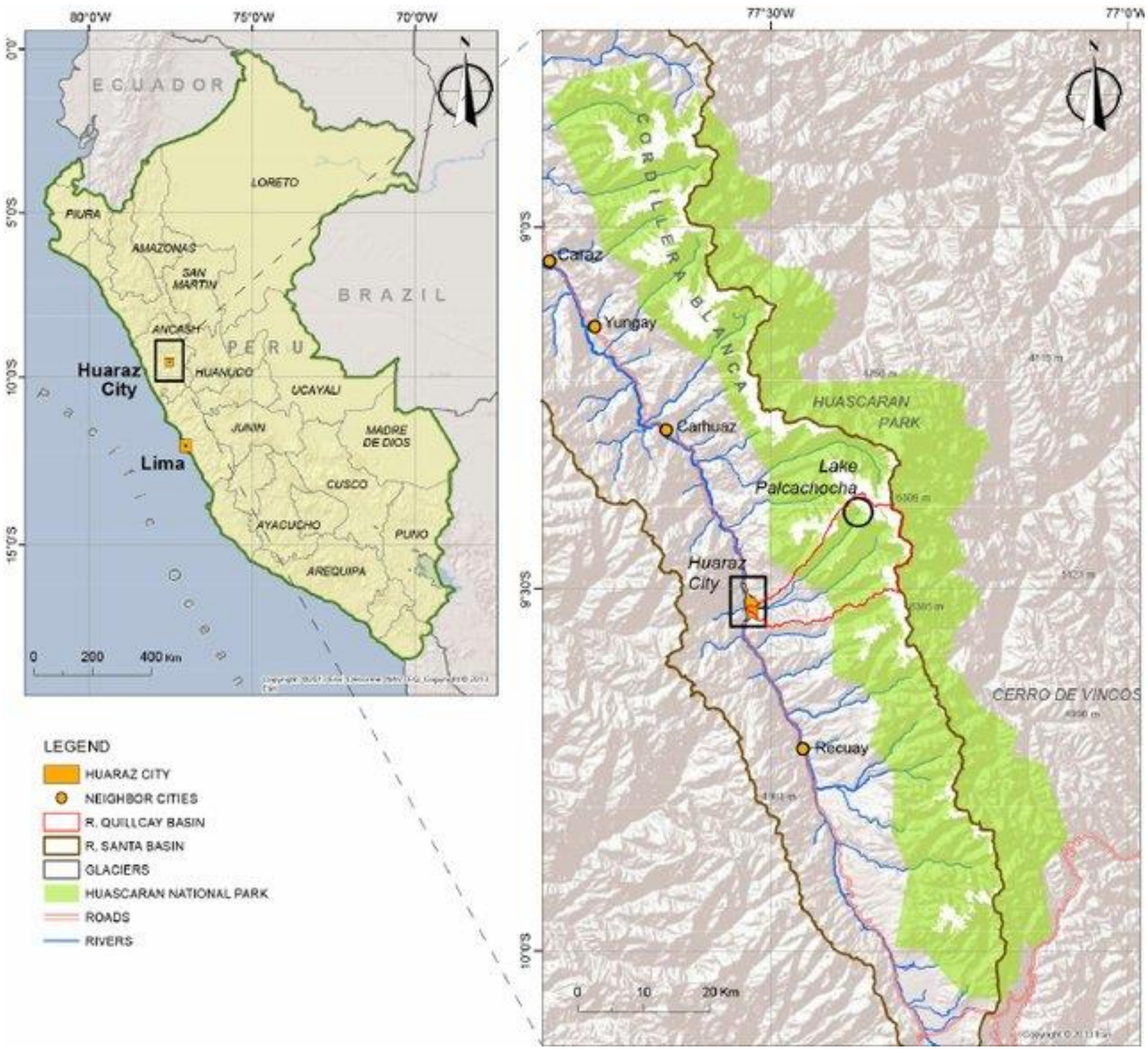
CALVING GLACIER, CHILE
https://www.youtube.com/watch?v=RVwLHX6lgzQ

INDIA

Climate Change Impact on the central part of Andes

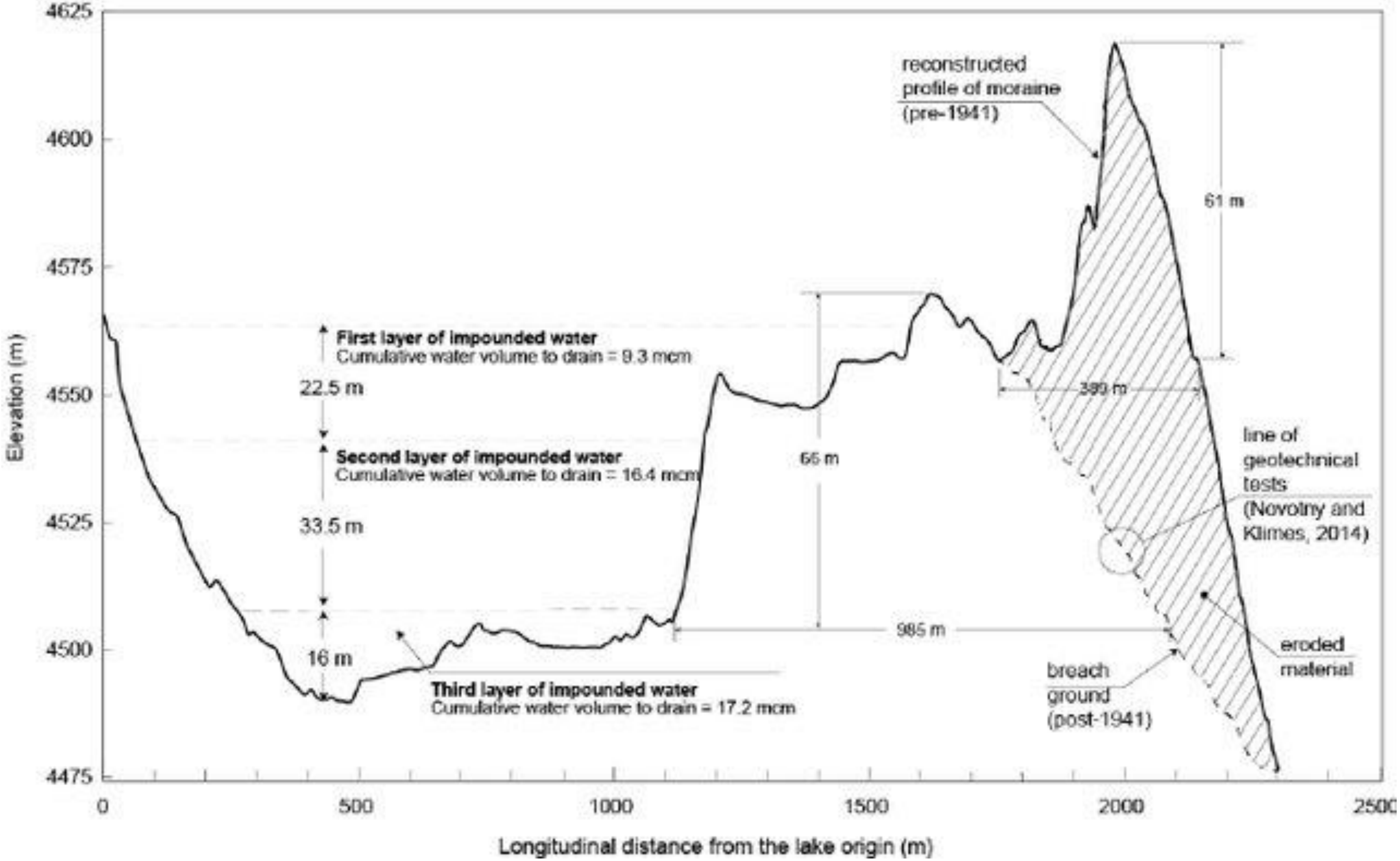
Cordillera Blanca, Peru


Lake Palcacocha,
Cordillera Blanca

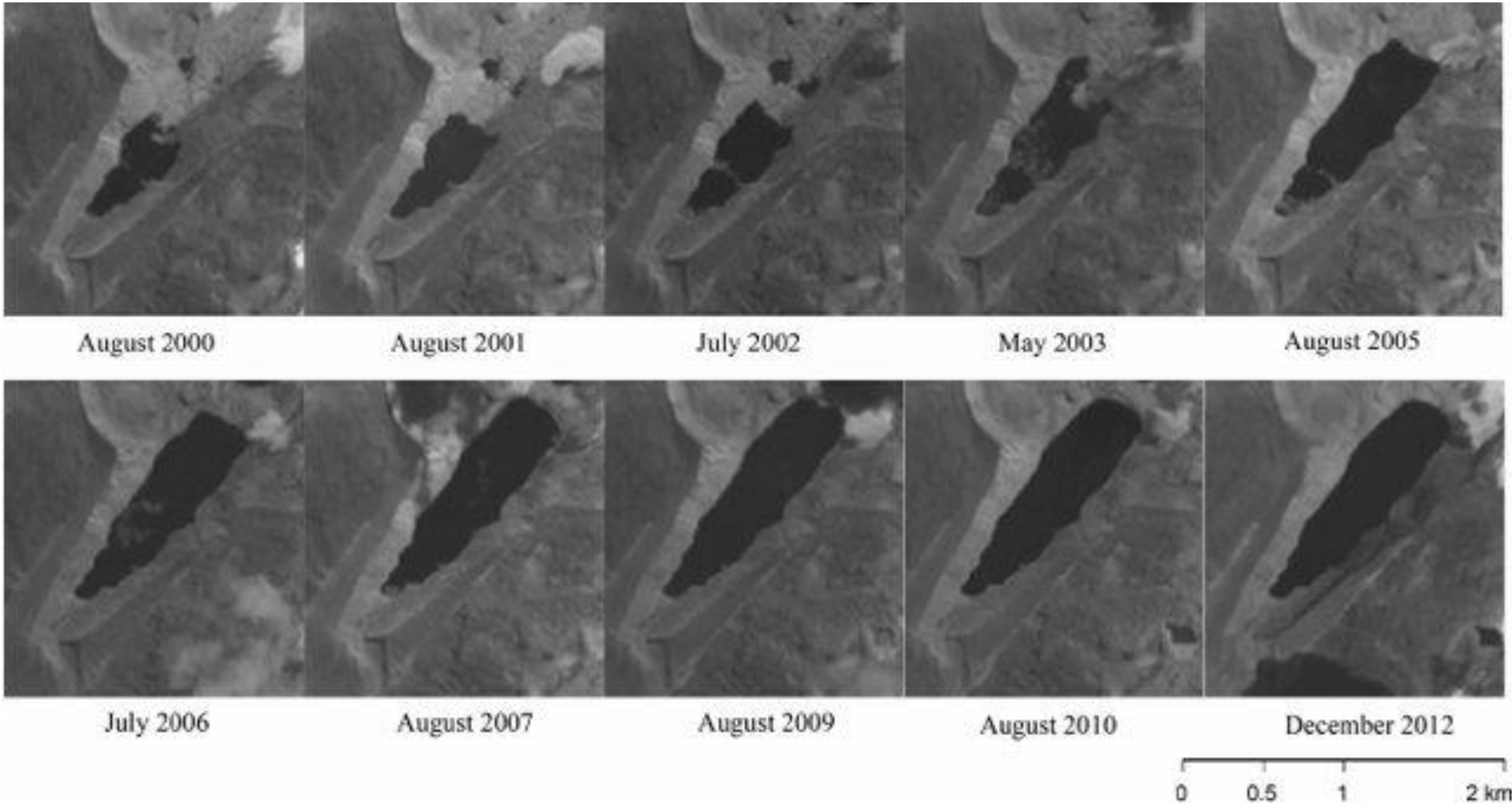


Lake Palcacocha location, upstream from Huaraz city in the Cordillera Blanca in Peru

Front views of Lake Palcacocha and the breach of the 1941 GLOF



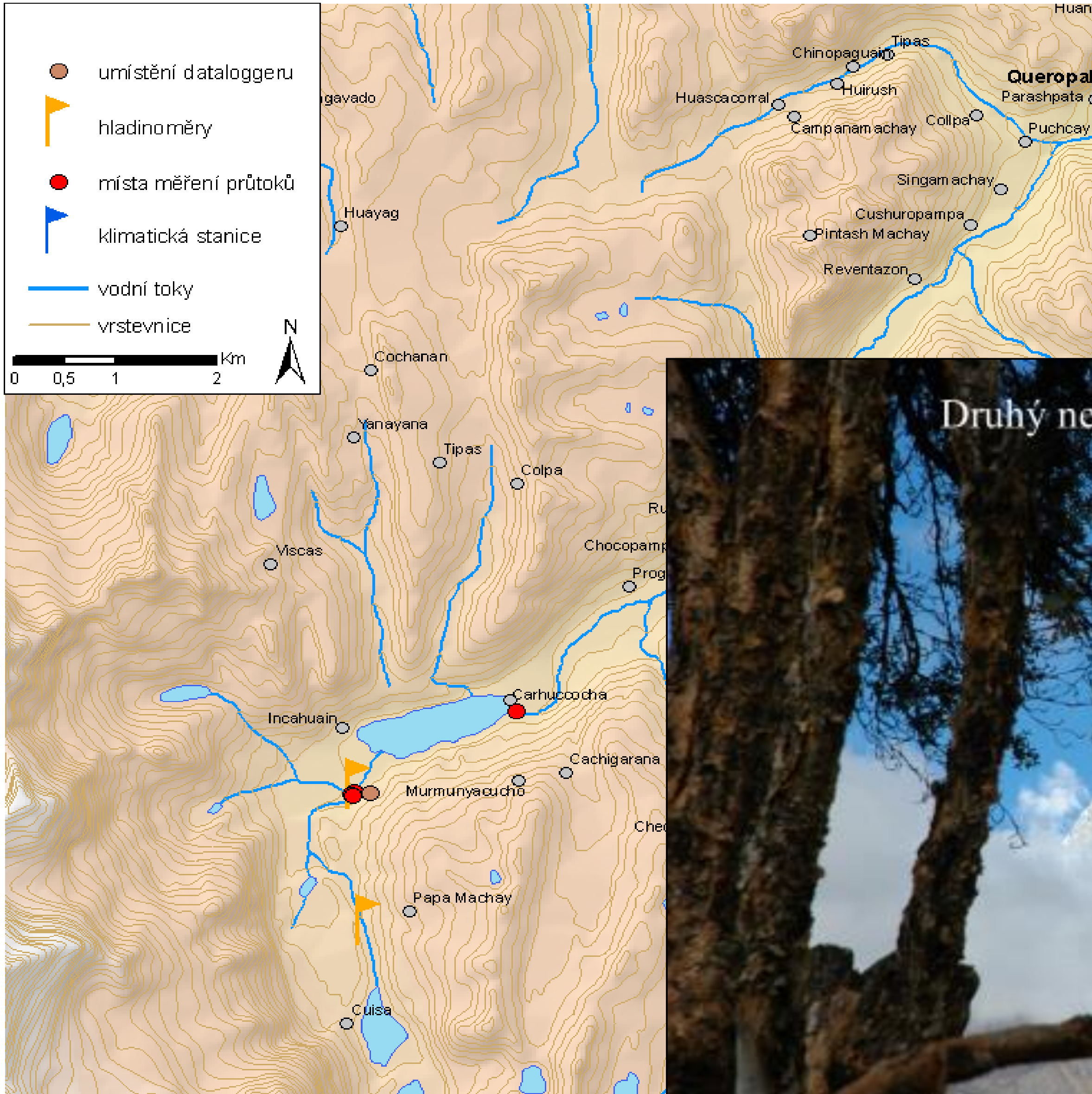
Palcacocha Lake and moraine longitudinal profile revealing differences between the post-1941 current moraine and a reconstruction of the moraine profile before 1941 (projected from non-breached adjacent portions of the end moraine)

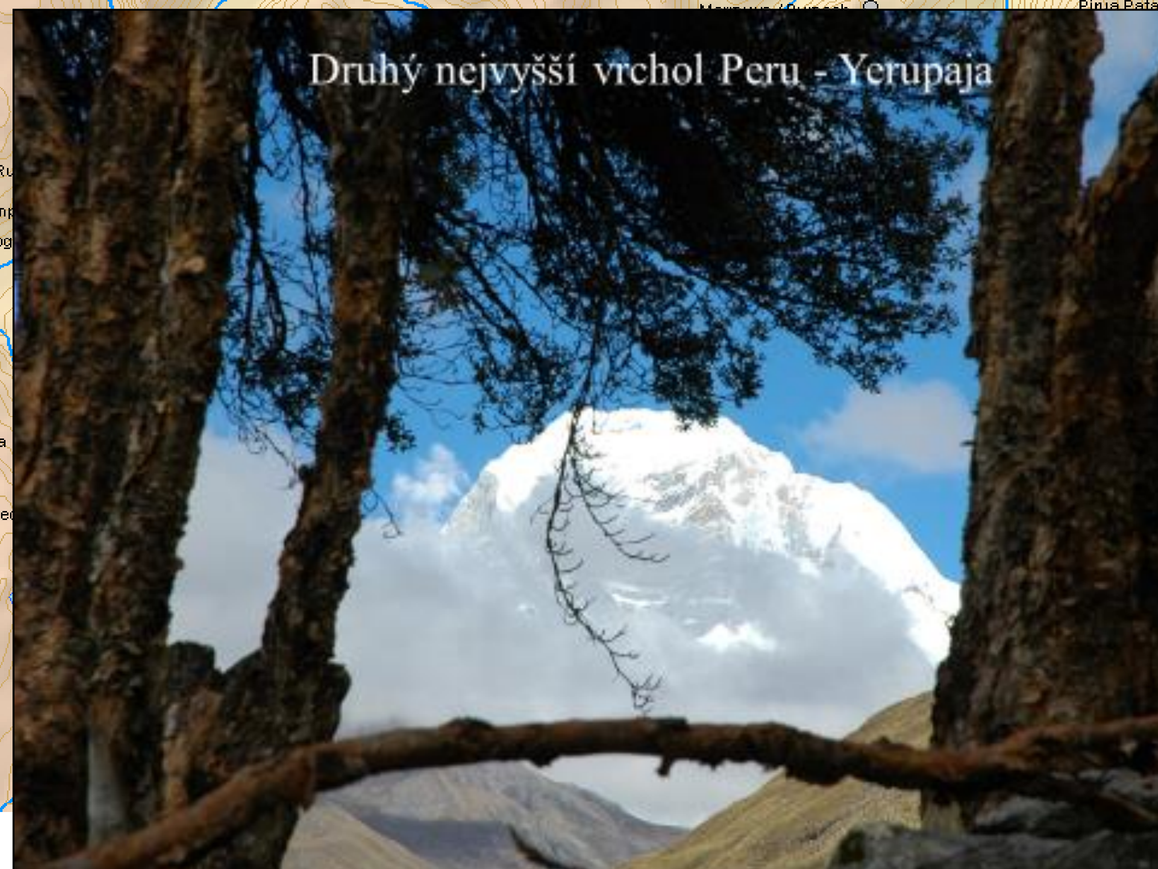


Growth pattern of Lake Palcacocha from 2000 to 2012: a sequence of ASTER satellite images reveal that the lake growth is following the glacier-retreat direction, changing the morphology of the lake's bottom (ASTER data from NASA Land Processes Distributed Active Archive Center).


Climate Change Impact on the central part of Andes
Cordillera Huayhuash, Peru

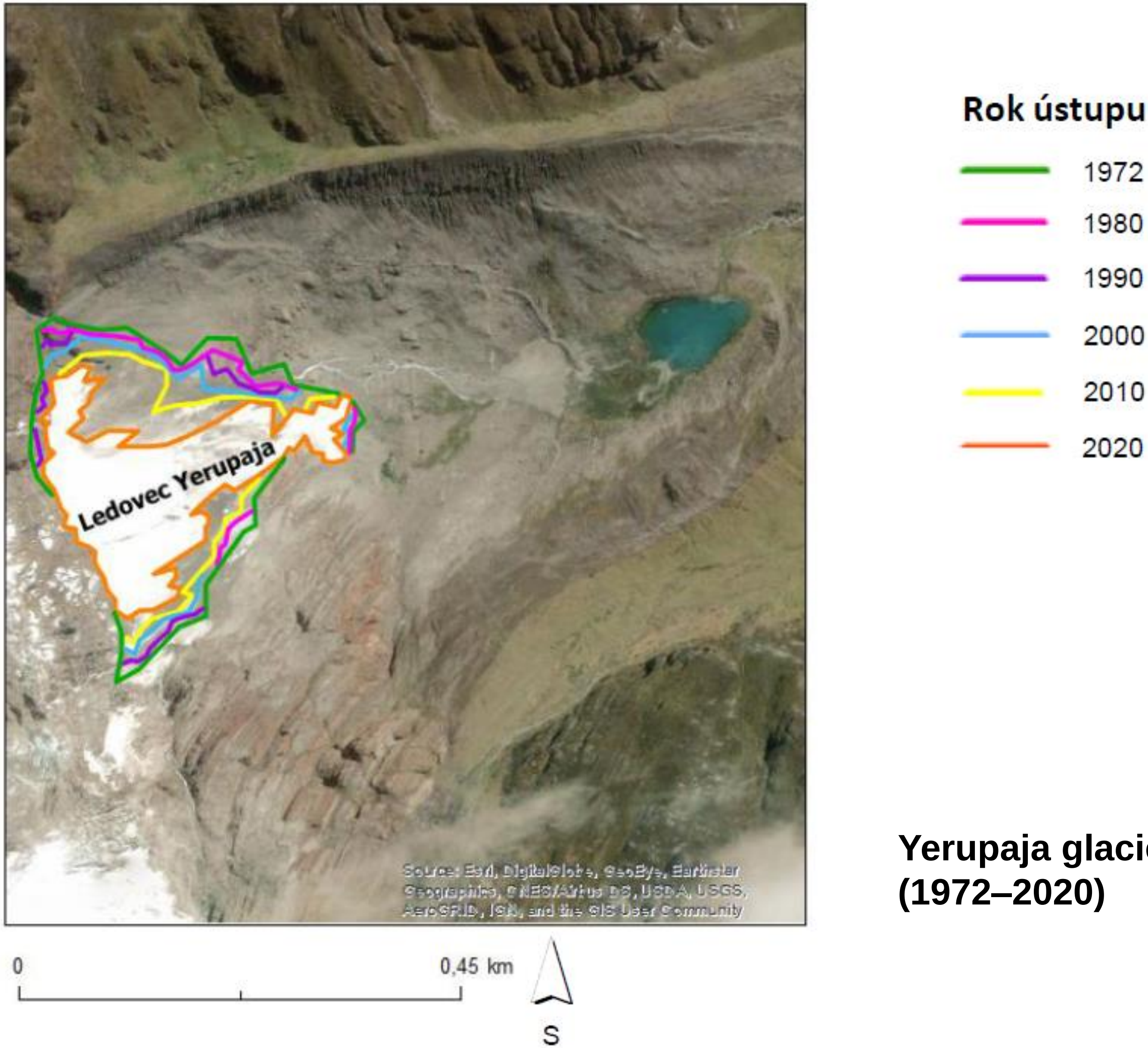
Headwaters territory of Marañon River



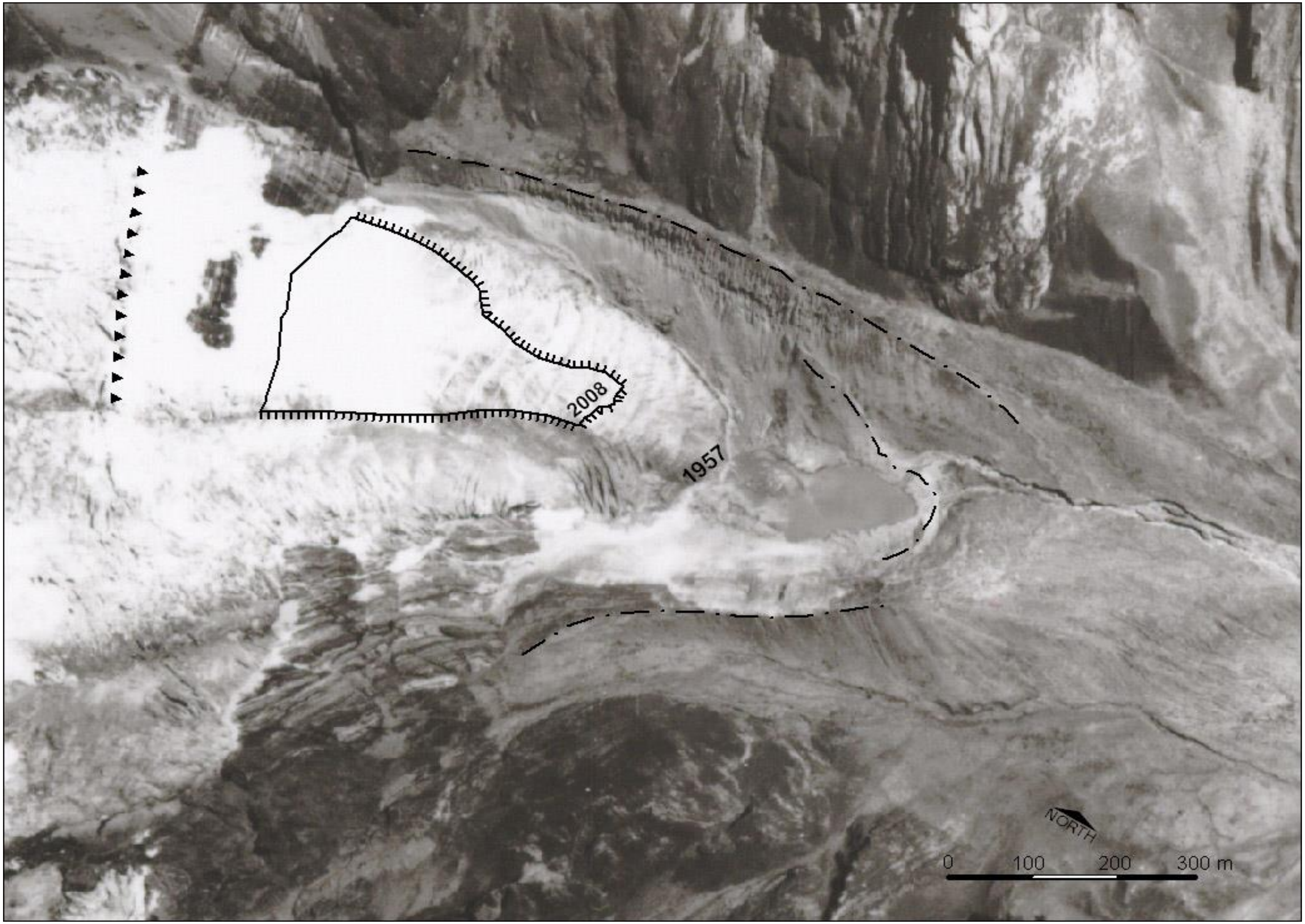


Cordillera Huayhuash : Nevado Yerupaja (6635 m a.s.l.)

Dynamický vývoj ledovce Yerupaja v letech 1972–2020



Yerupaja glacier retreat (1972–2020)



Yerupaja glacier retreat (1957 – 2008)

Total retreat: 230-350 m, annual retreat: 4–7 m.

Cordillera de Huayhuash


Proglacial Cangrajanca Lake
Water supply from falling glaciers

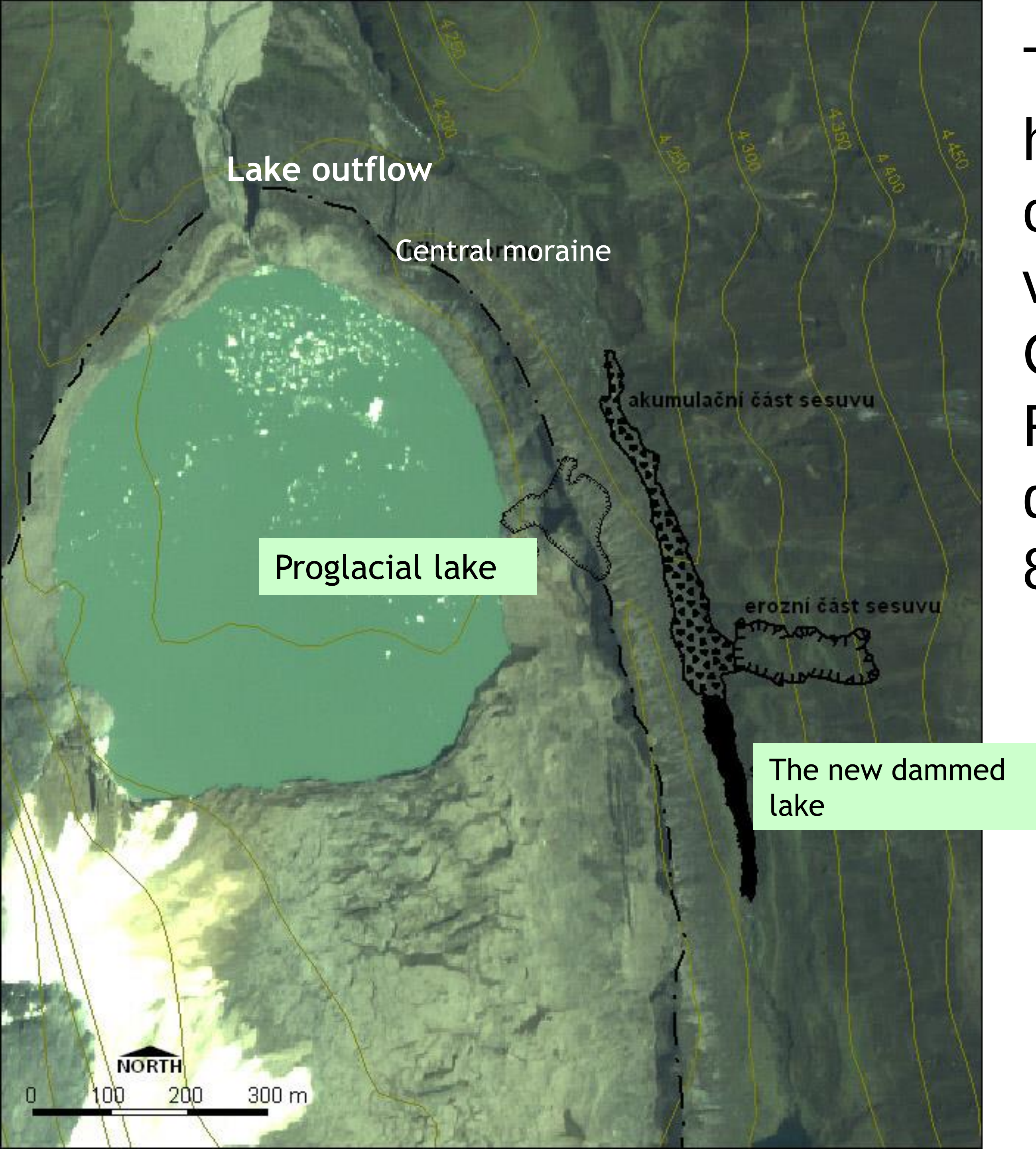
Rainfall-related debris flows in Carhuacocha Valley

The debris flow was triggered by cumulative rainfall combined with an extreme precipitation event:

- From the end of January to the beginning of March 2009, the Cordillera Huayhuash experienced abnormally high precipitations exceeding **<u>270 mm</u>**.
- The annual precipitation at the nearby Cajatambo station (distance 25 km) is **563 mm**.
- 10 days prior to flow – 56,2 mm
- 24 h prior to flow – 18,4 mm

QuickBird images of the study area.
a: Pre-failure (2003), b: Postfailure (2009).

The relief and hydrographic changes in the valley of Carhuacocha River after debris flows from 8.3.2009



Geophysical analyses

Project Kyrgyzstan 2005

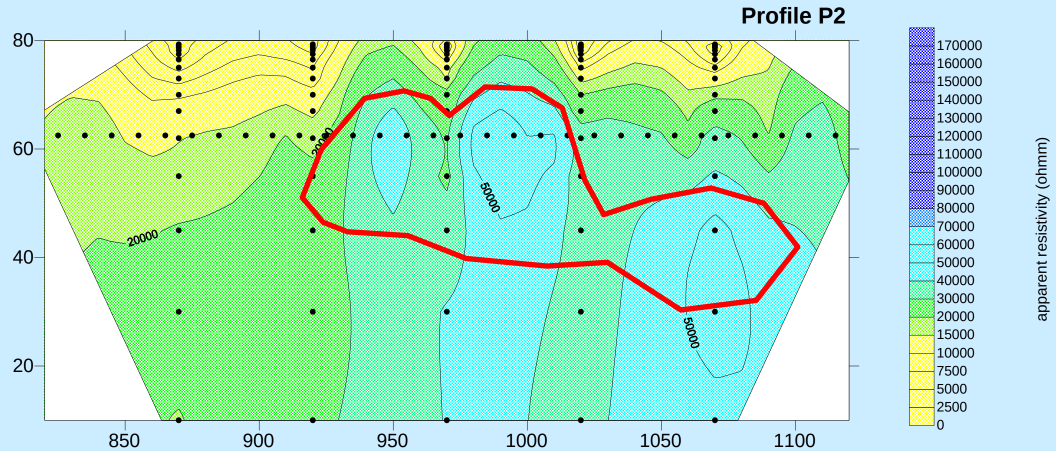
Geophysical Investigation of Dams
by VES and SRP Method

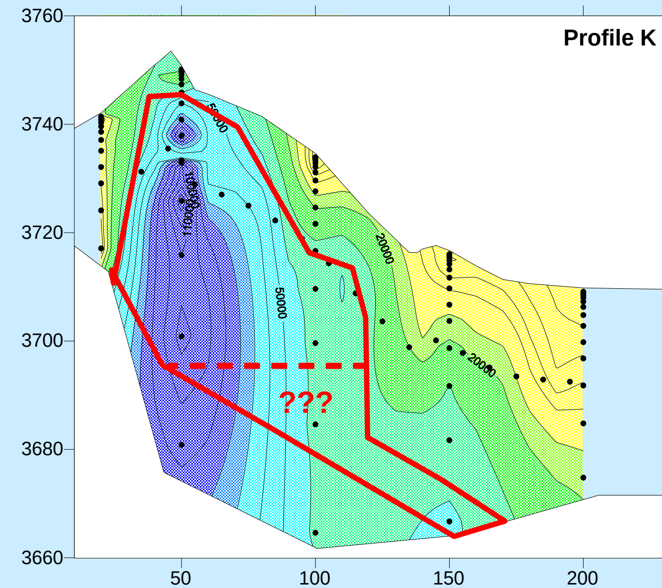
Date of measurement: 2005 07. 16.
10 Celsius degree, snow

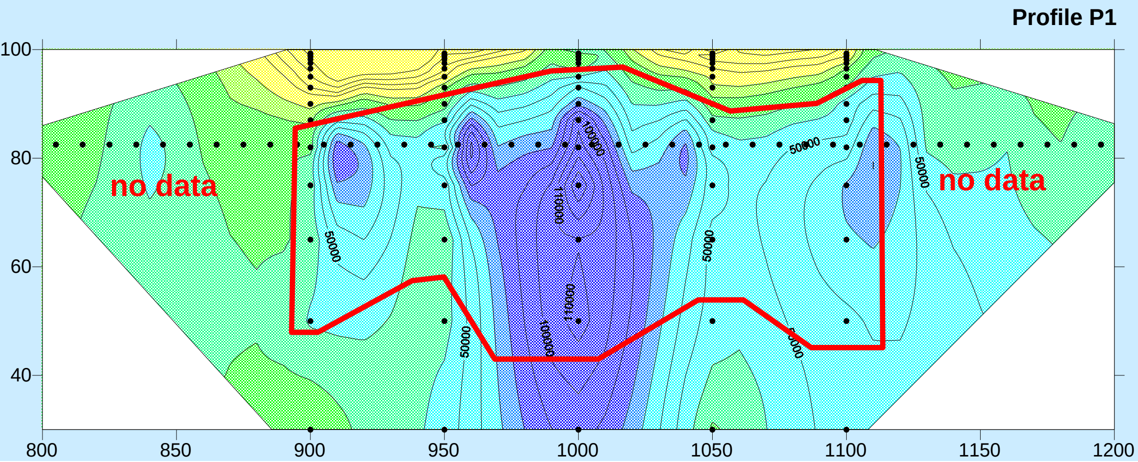
Fig 2: Location: Kumtor Lake Dam
Profile P1, P2, K
Cross-section of apparent resistivity
by VES and SRP method

SCALE: 1 : 2000 / 1 : 1000

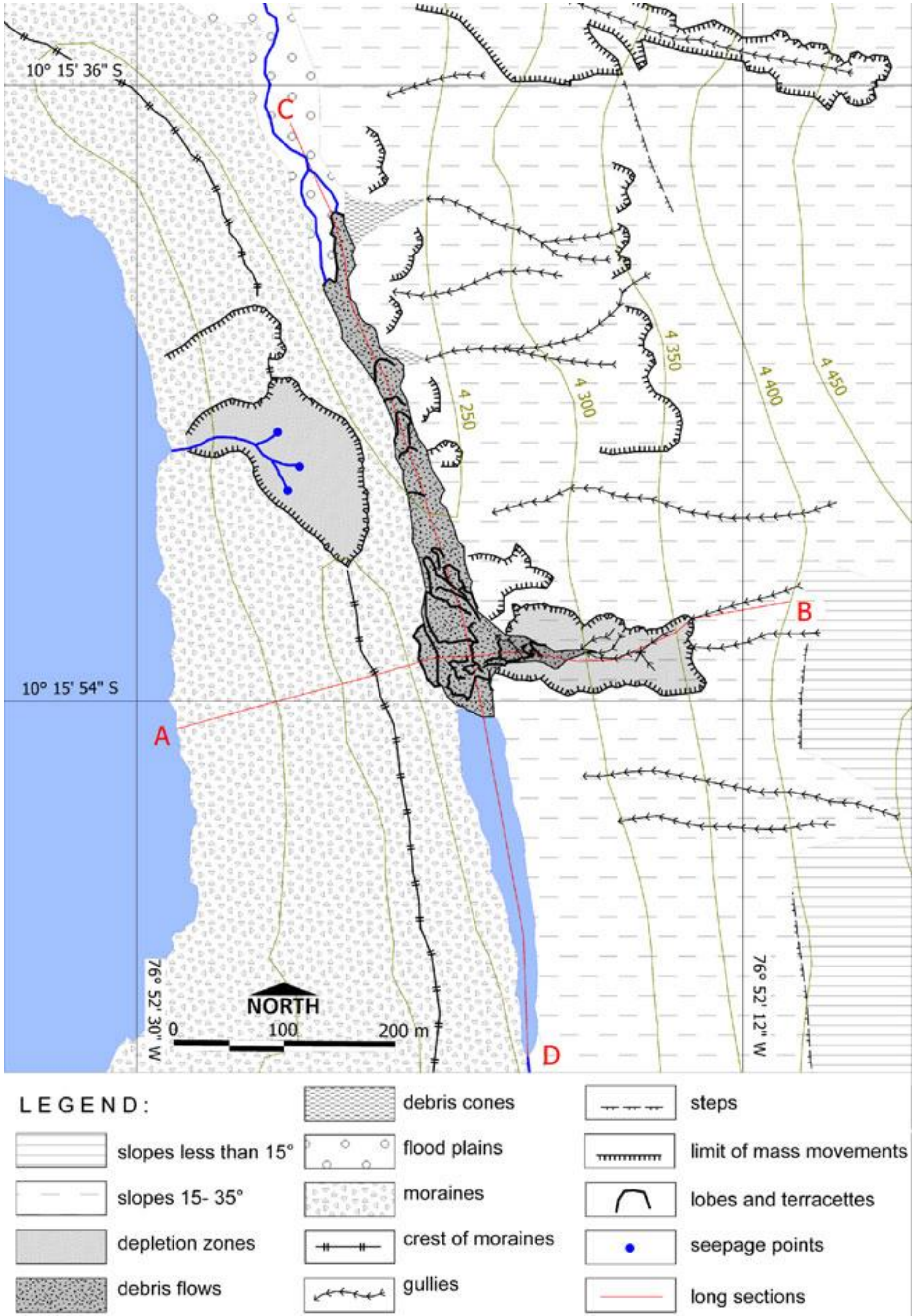
extent of ice







The new lake (E) dammed
by the landslide (A,B,C,D)



New hydrographic situation after landslide:

→ water percolated through the moraine dam of Cangrajanca Lake
→ lateral moraine disturbed by groundwater erosion

Lateral moraine: disturbed by groudwater erosion

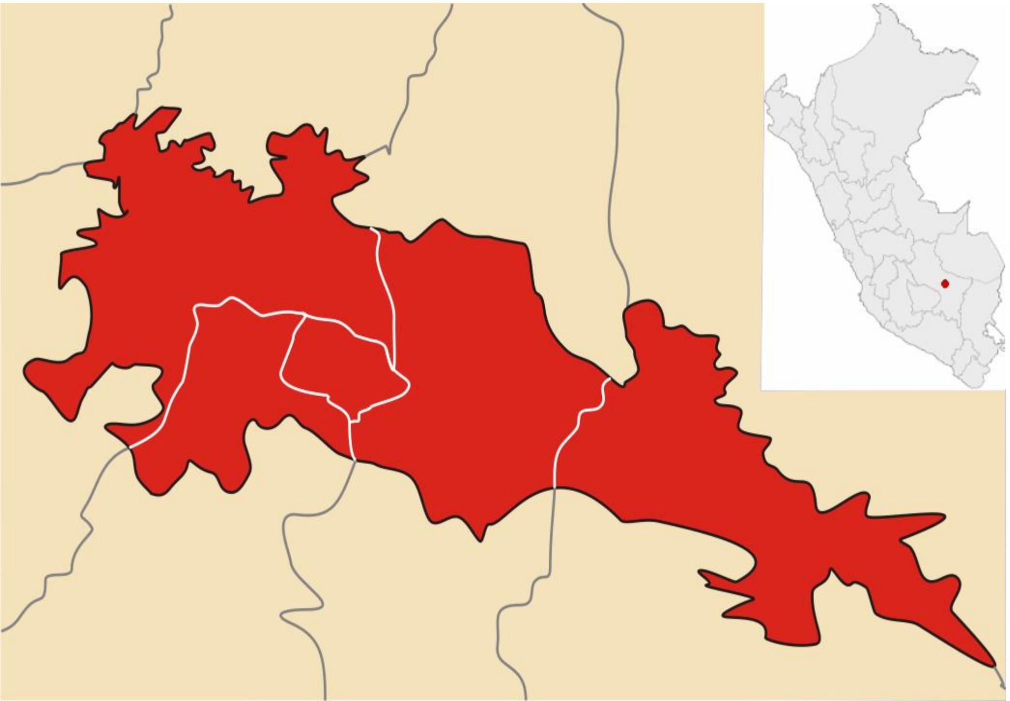
Climate Change Impact on the southern part of Andes

Cordillera Vilcanota, Peru

Negativní důsledky změny klimatu na hydrologické poměry v regionu Cuzco (Peru)

Malý rozvojový projekt – Česko +Peru

Vymezení regionu



Metodika

- rešerše odborných publikací
- analýza vlastních dat - datahosting FIEDLER AMS s.r.o.

FIEDLER
ELEKTRONIKA PRO EKOLOGII

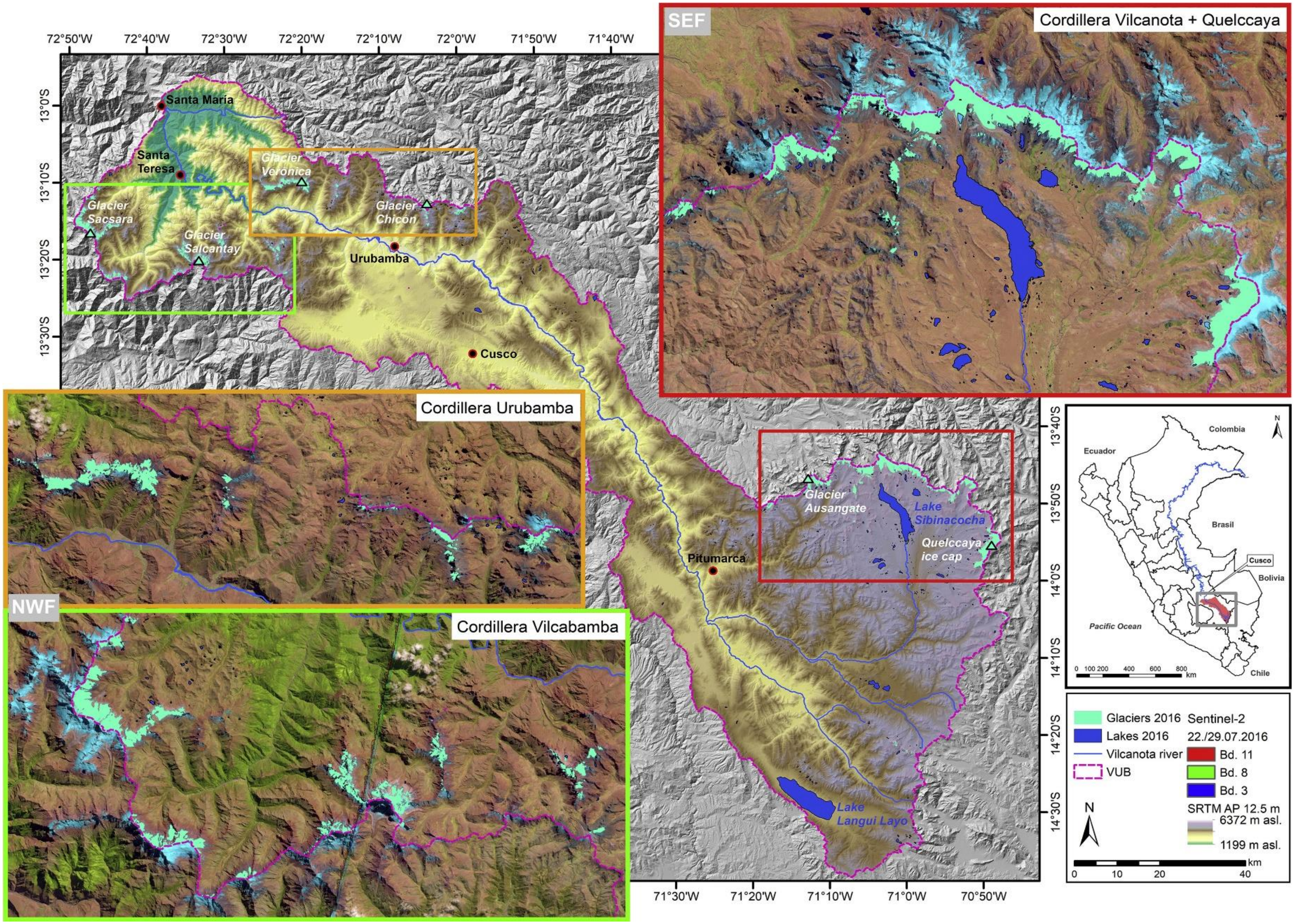
Dílčí! výstupy

- ústup ledovců
- pokles hladiny jezera Piuray

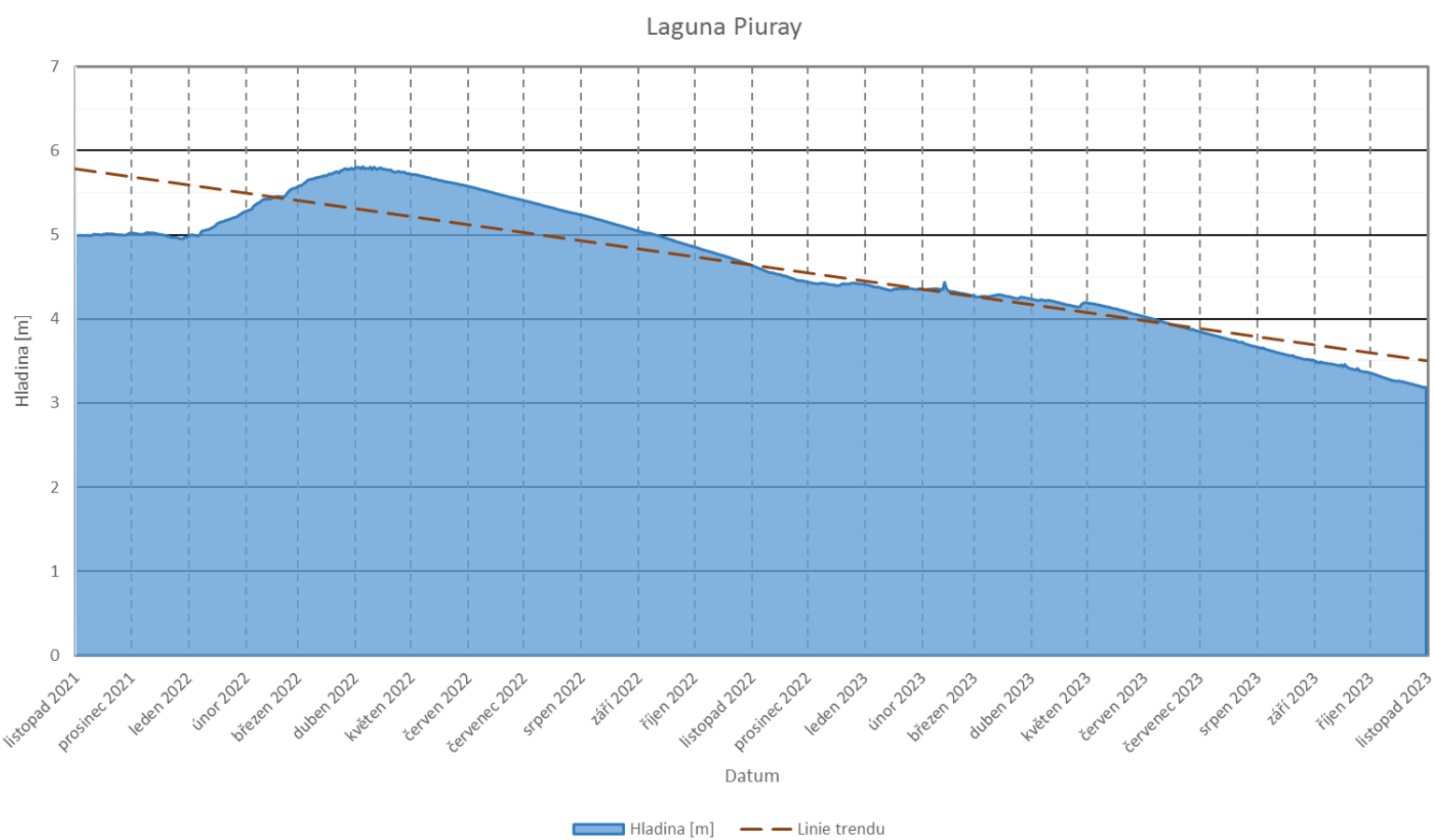
Year	Glacier area (km^2)	Percent of initial area (%)	Total glacier volume (km^3, $\tau = 1$ bar)	Total glacier volume (km^3, $\tau = 1.2$ bar)
1962	440	100	17.0	20.4
1985	444	101		
1996	344	78		
$2006_{10\%}$	297	68	10.3	12.4
$2006_{20\%}$	297	68	9.2	11.0

Cordillera	Year	Area (km^2)
Vilcabamba	1985	68.09
	1990	65.03
	1995	62.19
	2000	59.44
	2005	55.07
	2010	52.35
	2015	47.6
Urubamba	1985	38.06
	1990	34.53
	1995	31.04
	2000	29.82
	2005	25.11
	2010	19.65
	2015	16.48

Salzmann, N. et al., 2013, *Glacier changes and climate trends derived from multiple sources in the data scarce Cordillera Vilcanota region, southern Peruvian Andes* https://doi.org/10.5194/tc-7-103-2013.
Veettil, B.K. et al., 2018, *Regional climate forcing and topographic influence on glacier shrinkage: eastern cordilleras of Peru* https://doi.org/10.1002/joc.5226.



SEF
Cordillera Vilcanota + Quelccaya
Cordillera Urubamba
NWF
Cordillera Vilcabamba
72°50'W
72°40'W
72°30'W
72°20'W
72°10'W
72°0'W
71°50'W
71°40'W
13°0'S
13°10'S
13°20'S
13°30'S
13°40'S
13°50'S
14°0'S
14°10'S
14°20'S
14°30'S
71°30'W
71°20'W
71°10'W
71°0'W
70°50'W
Santa Maria
Santa Teresa
Glacier Verónica
Glacier Chicón
Glacier Sacsara
Glacier Salcantay
Urubamba
Cusco
Glacier Ausangate
Lake Sibinacocha
Quelccaya ice cap
Pitumarca
Lake Langui Layo
Colombia
Ecuador
Brasil
Cusco
Bolivia
Pacific Ocean
Chile
0 100 200 400 600 800 km
Glaciers 2016
Lakes 2016
Vilcanota river
VUB
Sentinel-2
22./29.07.2016
Bd. 11
Bd. 8
Bd. 3
SRTM AP 12.5 m
6372 m asl.
1199 m asl.
0 10 20 40 km

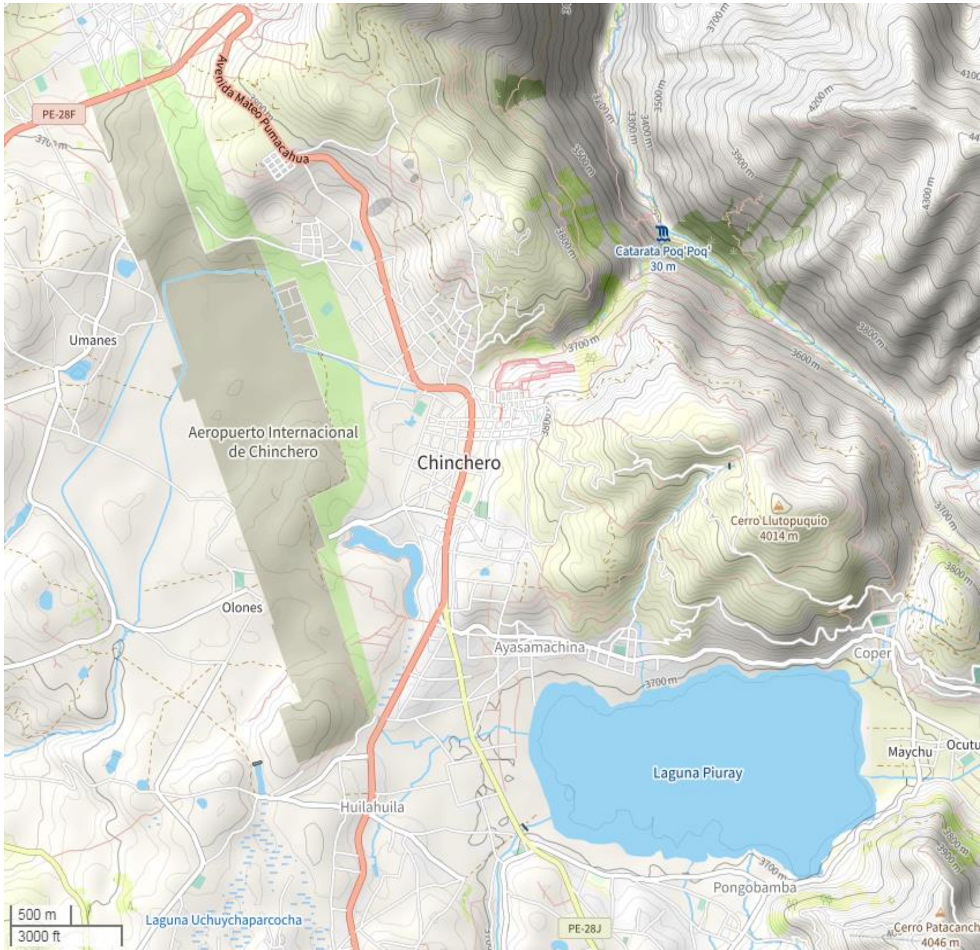


Laguna Piuray
Hladina [m]
0
1
2
3
4
5
6
7
listopad 2021
prosinec 2021
leden 2022
únor 2022
březen 2022
duben 2022
květen 2022
červen 2022
červenec 2022
srpen 2022
září 2022
říjen 2022
listopad 2022
prosinec 2022
leden 2023
únor 2023
březen 2023
duben 2023
květen 2023
červen 2023
červenec 2023
srpen 2023
září 2023
říjen 2023
listopad 2023
Datum
Hladina [m]
Linie trendu

Negativní důsledky změny klimatu na hydrologické poměry v regionu Cuzco (Peru)

Potenciál dalších výzkumů v regionu

- hydrologická bilance jezera Piuray
- kvalita vody jezera Piuray – kontroverze (letiště)
- dlouhodobá spolupráce, další regiony



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