The Future of Glacial Geomorphology

Lecture 13

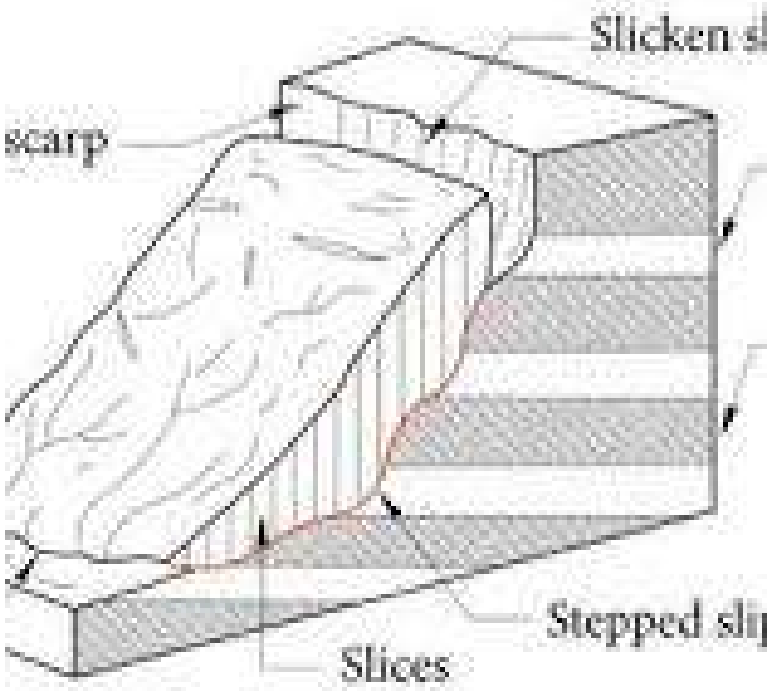
Skaftafelljokull (glacier)

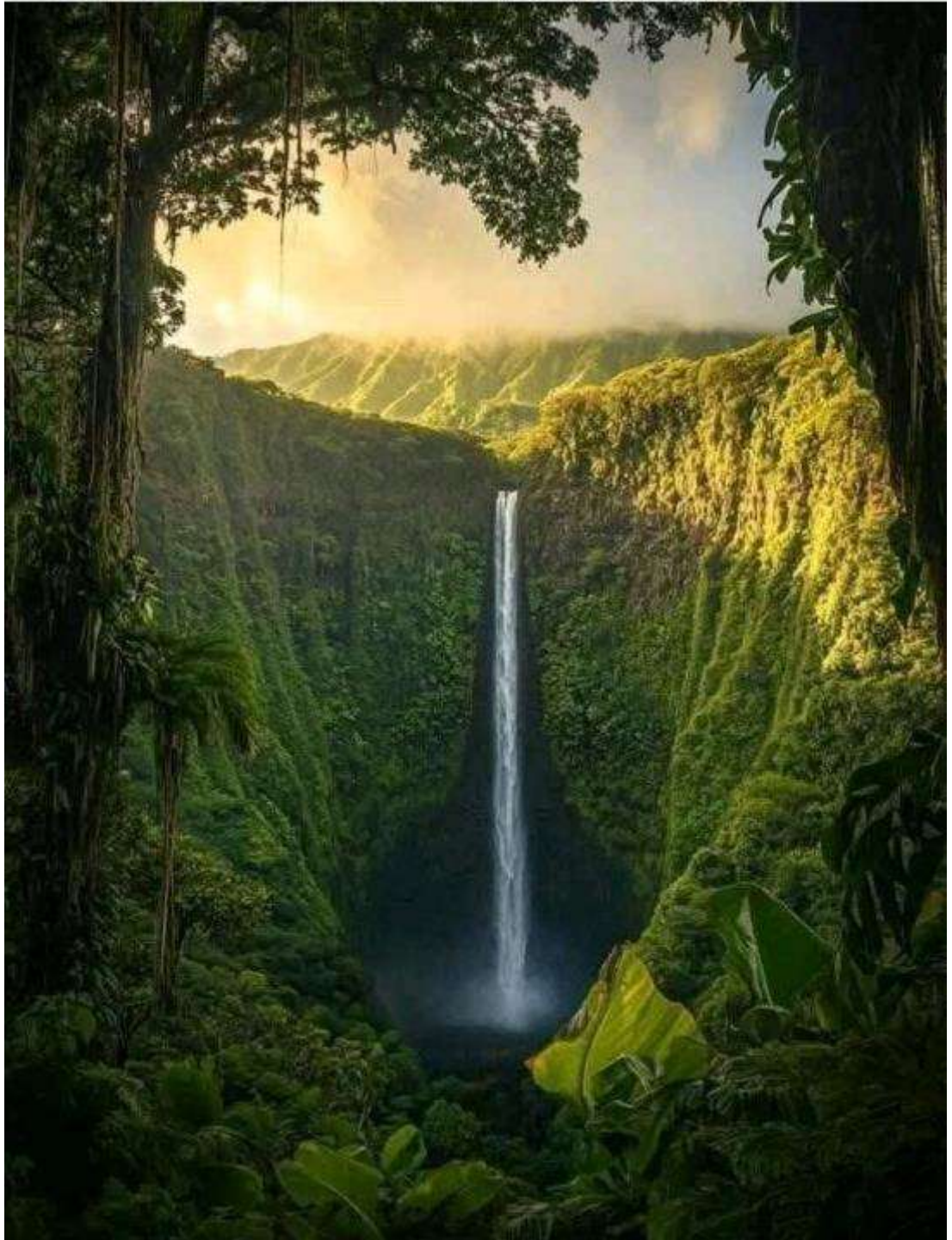
0. Social Media

Following Julian’s cautionary comment from last week, could this possibly be a real place?

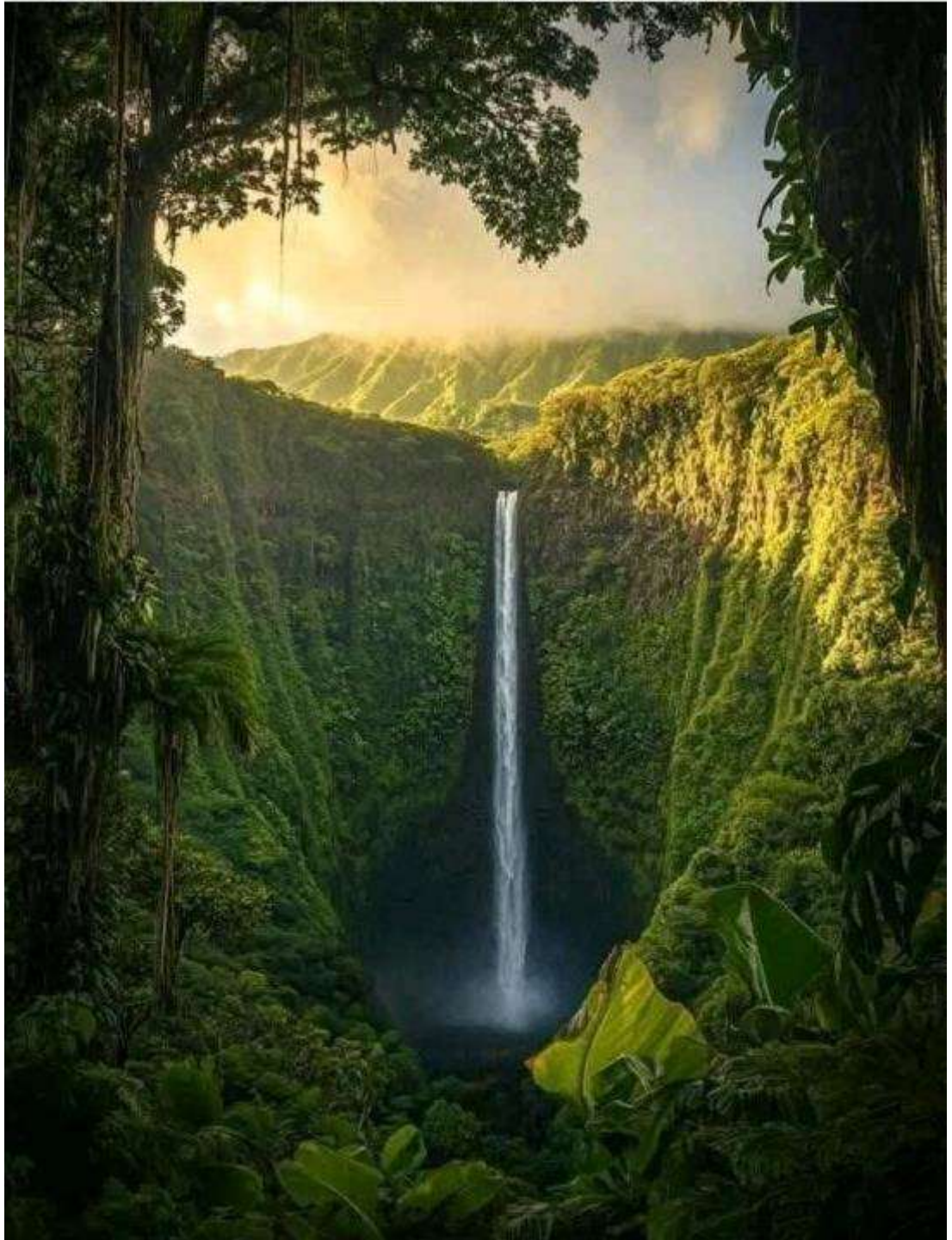
Could this be a cirque?

Probably actually a landslide scar





beautiful
waterfall

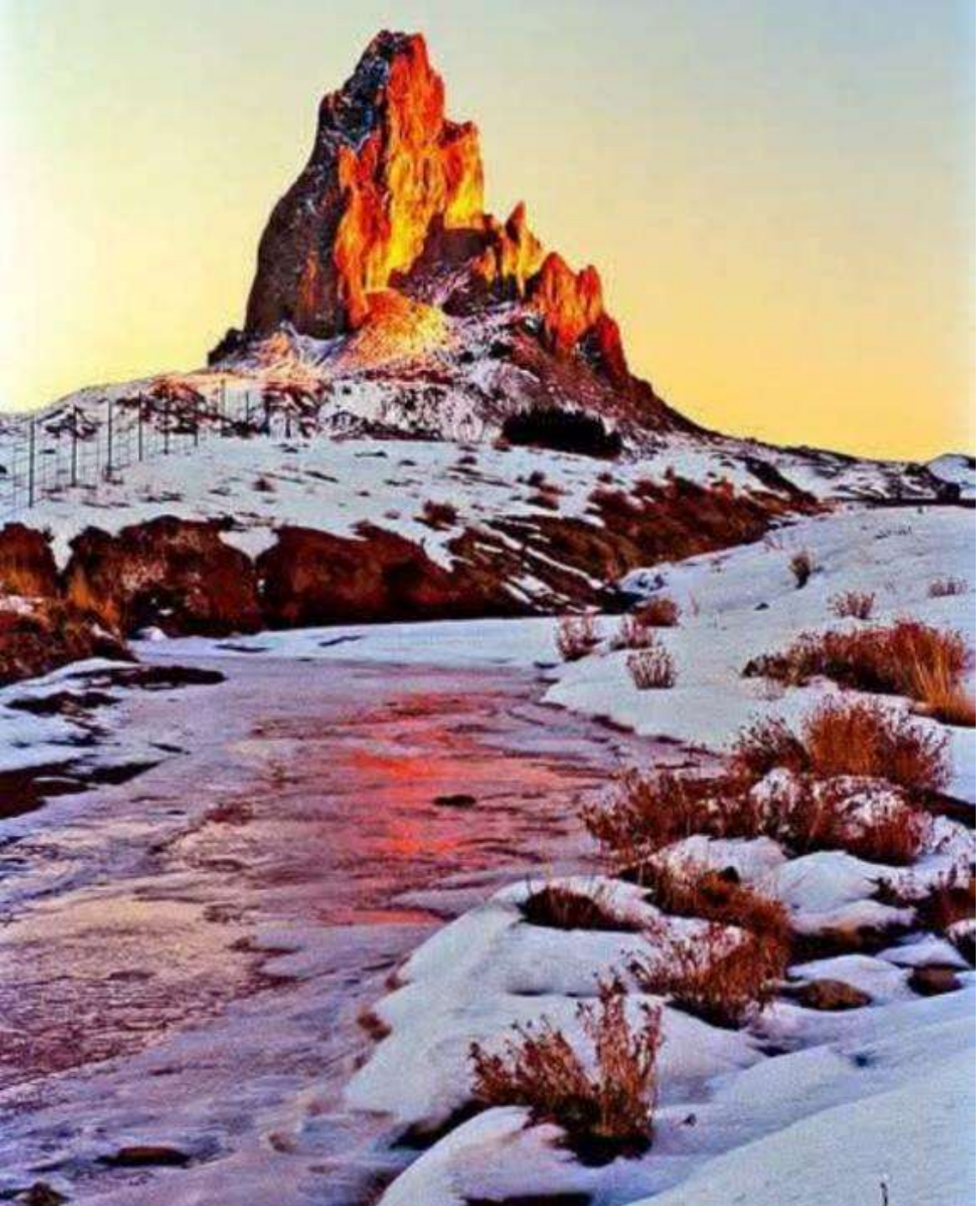


nothing specifically glacial about

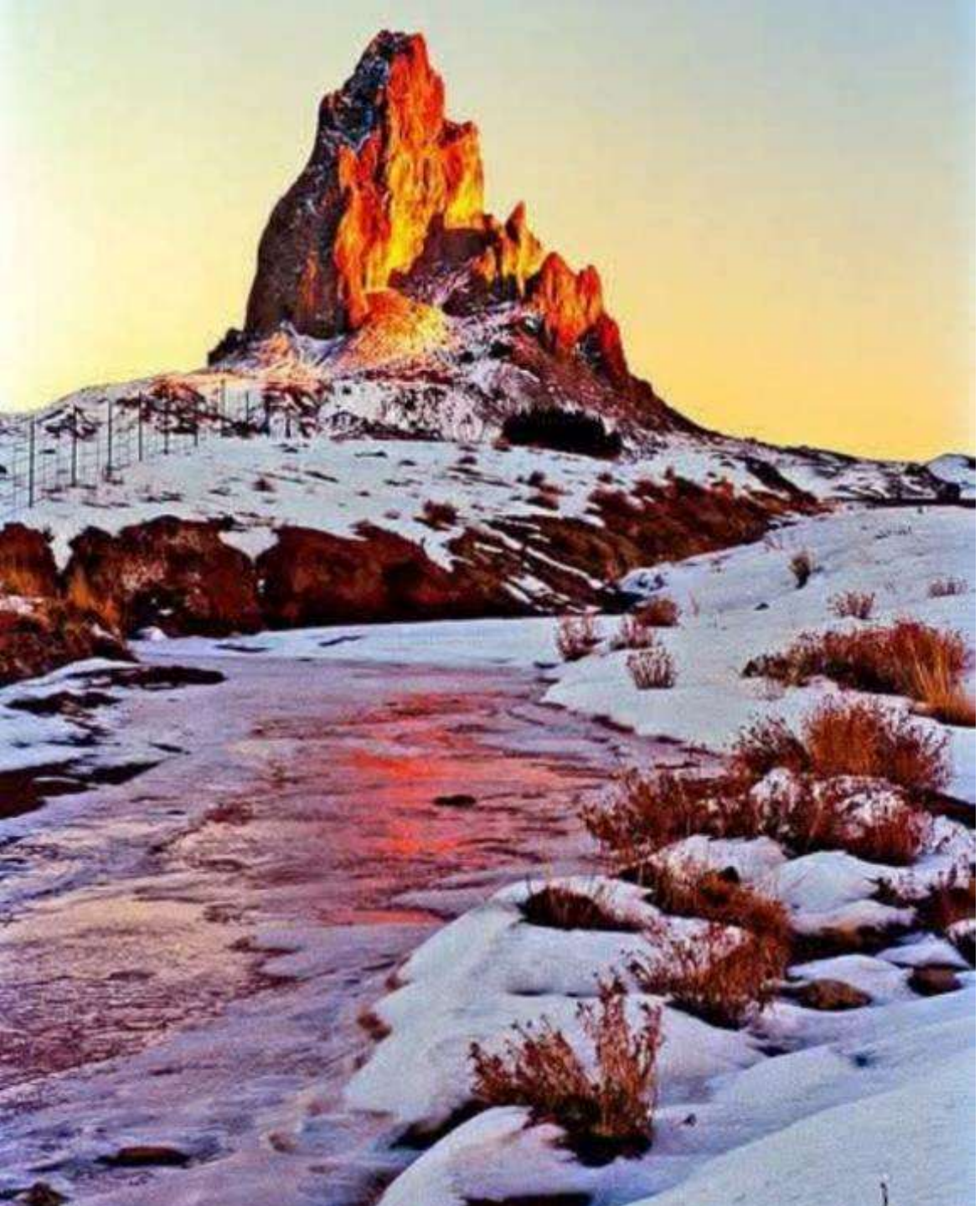
hill in background has
V-shaped fluvial gullies
not cirques

how about this one …

nothing in foreground
specifically glacial but hill in background has very convincing cirques

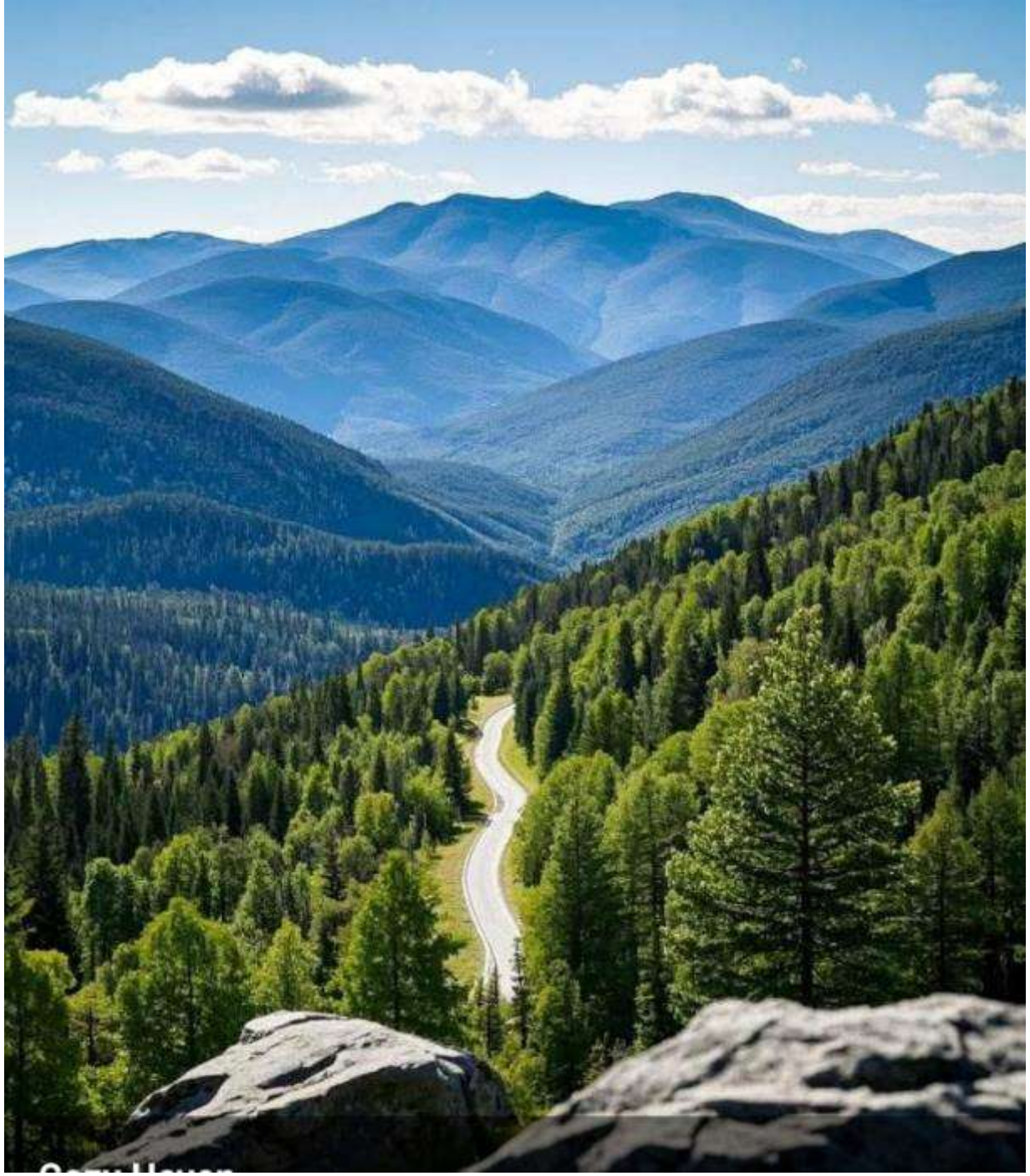


snow-covered terrain
stream
small jagged hill in background
(note telephone poles)

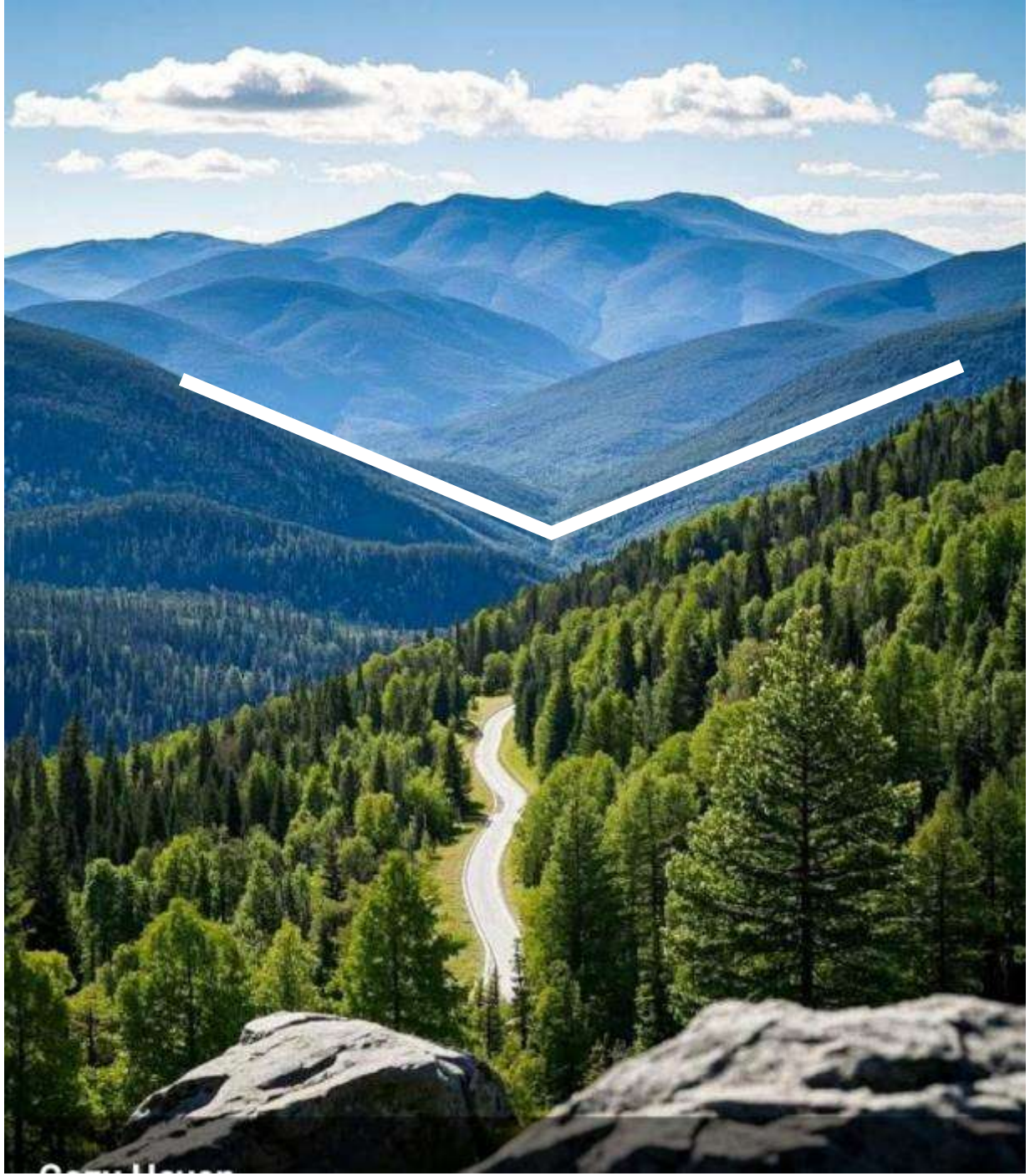


nothing specifically glacial

hill more likely a volcanic plug

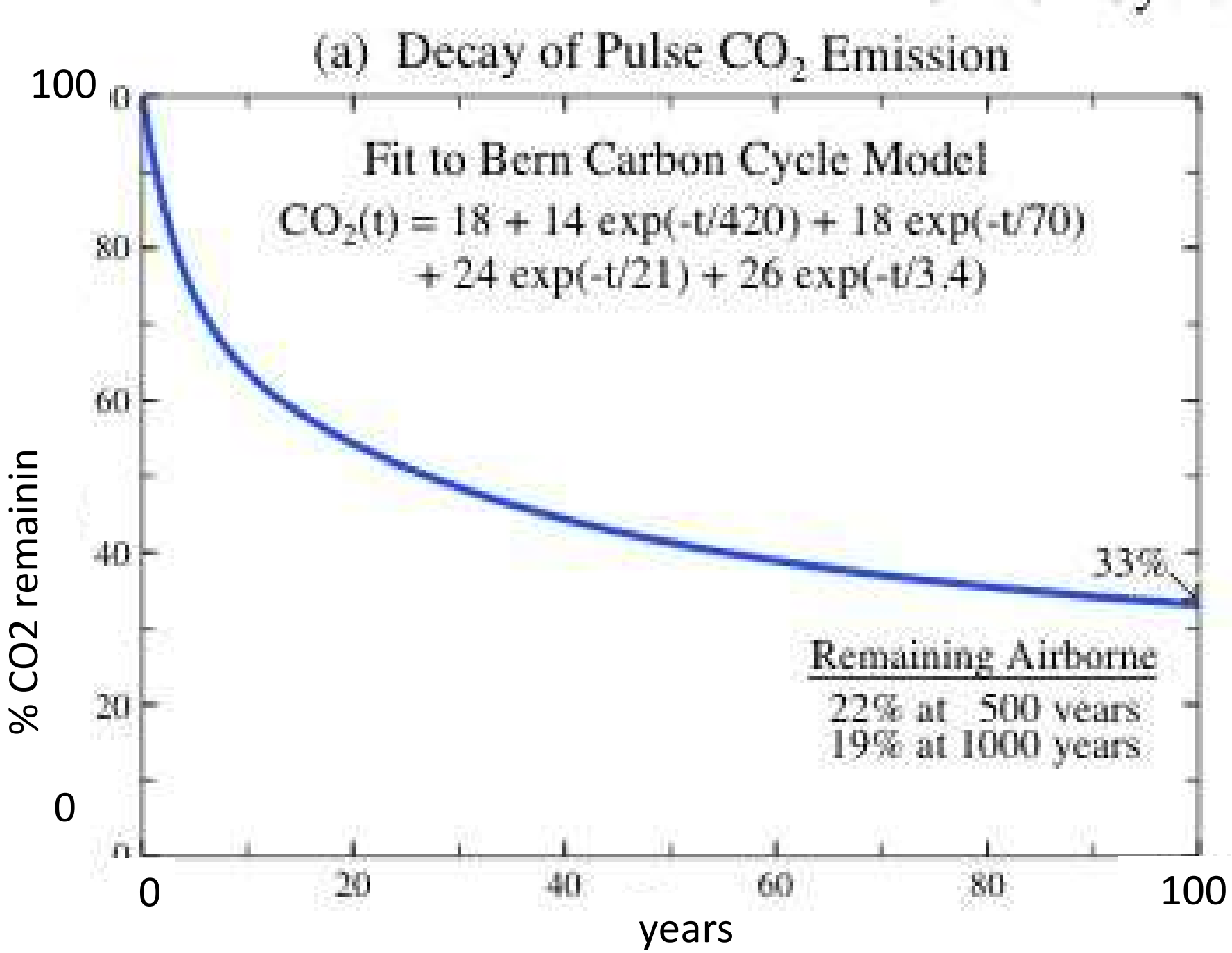


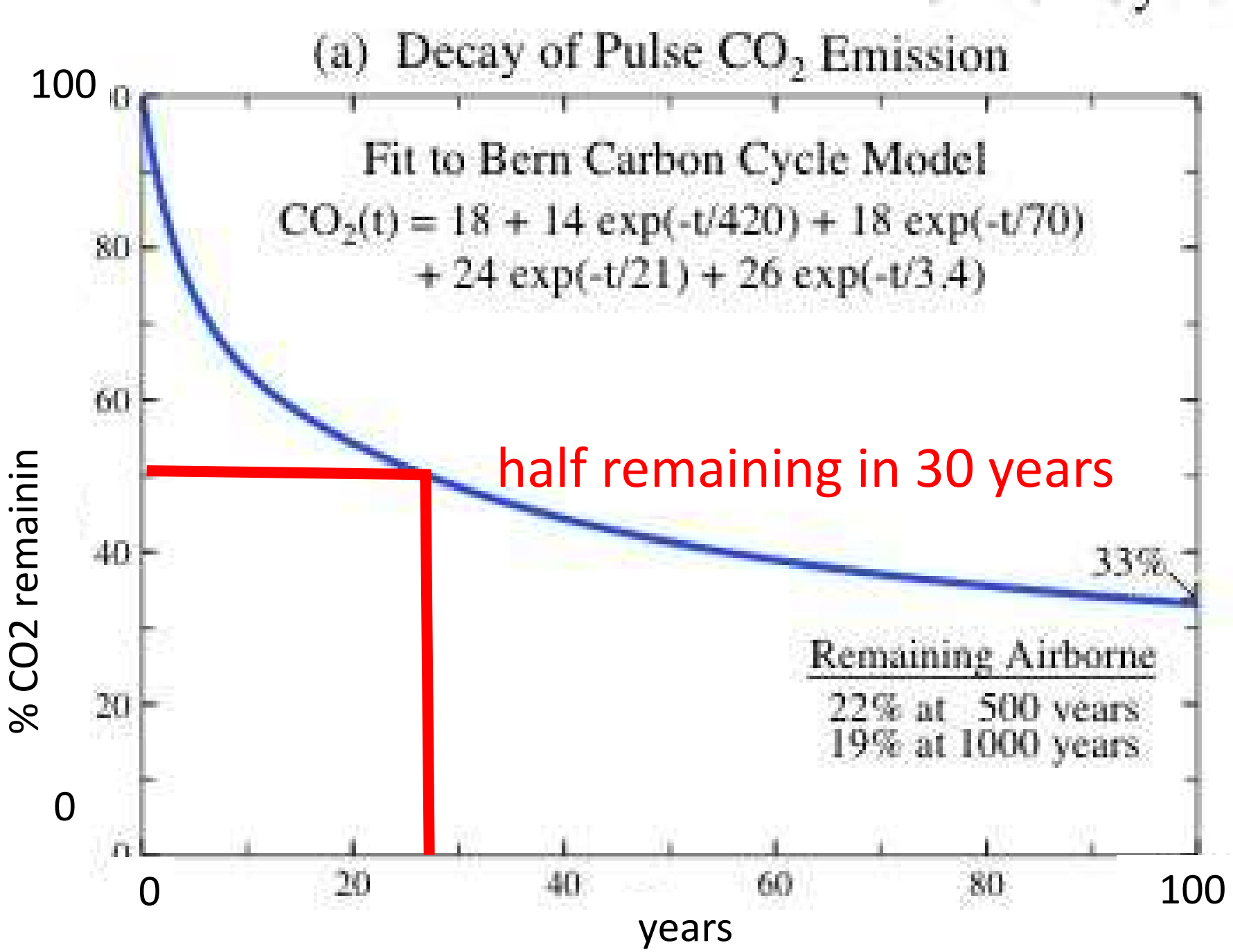
large valley

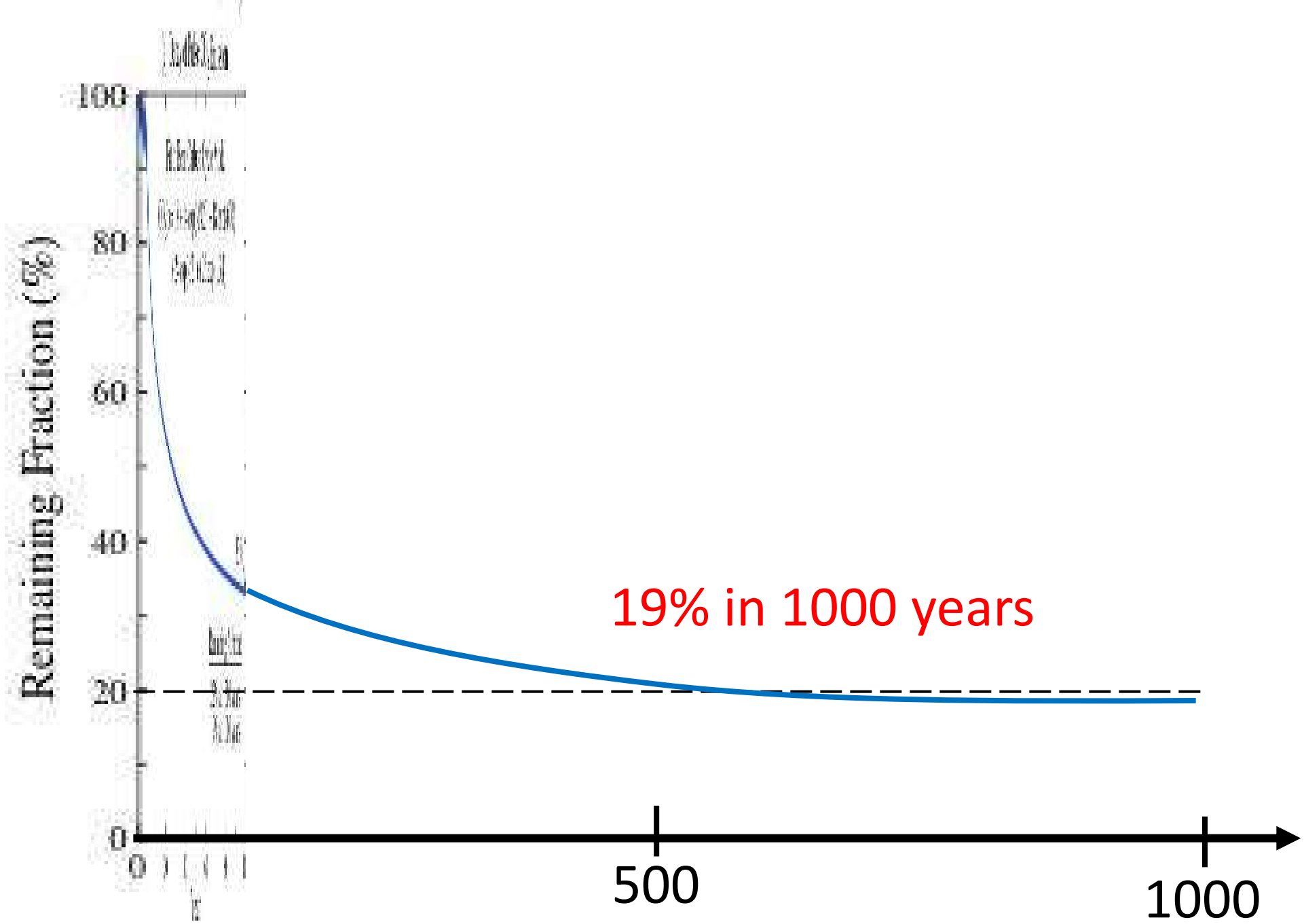


V-shaped, so probably not glacial

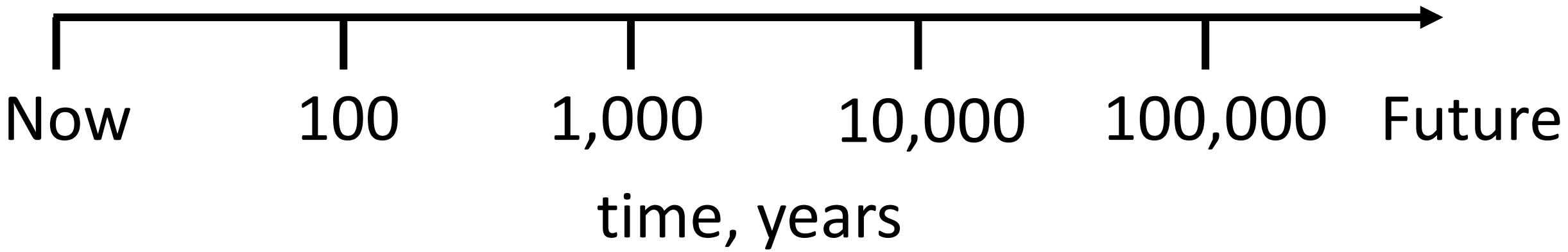
1. The future


(a) Decay of Pulse CO_2 Emission
Fit to Bern Carbon Cycle Model
$CO_2(t) = 18 + 14 \exp(-t/420) + 18 \exp(-t/70)$
$+ 24 \exp(-t/21) + 26 \exp(-t/3.4)$
33%
Remaining Airborne
22% at 500 years
19% at 1000 years
100
0
% CO2 remainin
0
20
40
60
80
100
years

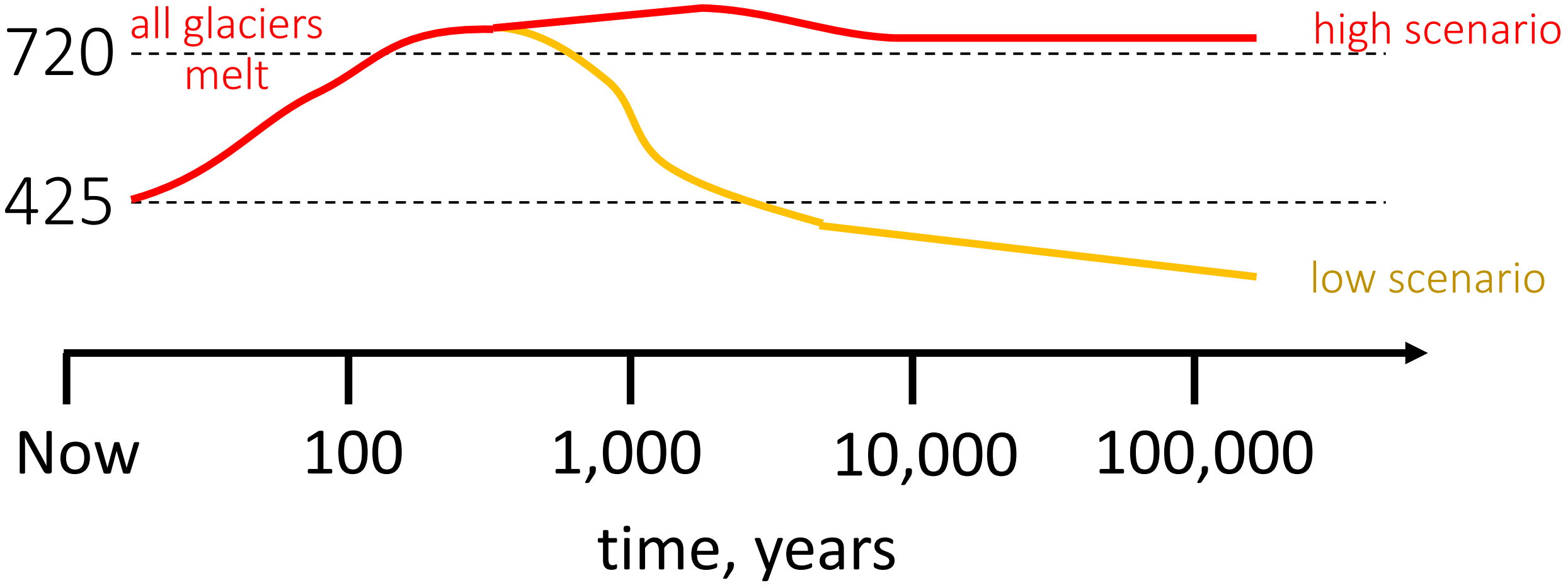

(a) Decay of Pulse CO_2 Emission
Fit to Bern Carbon Cycle Model
$CO_2(t) = 18 + 14 \exp(-t/420) + 18 \exp(-t/70)$
$+ 24 \exp(-t/21) + 26 \exp(-t/3.4)$
half remaining in 30 years
33%
Remaining Airborne
22% at 500 years
19% at 1000 years
100
0
% CO2 remainin
0
20
40
60
80
100
years


Remaining Fraction (%)
100
80
60
40
20
0
0
500
1000
19% in 1000 years

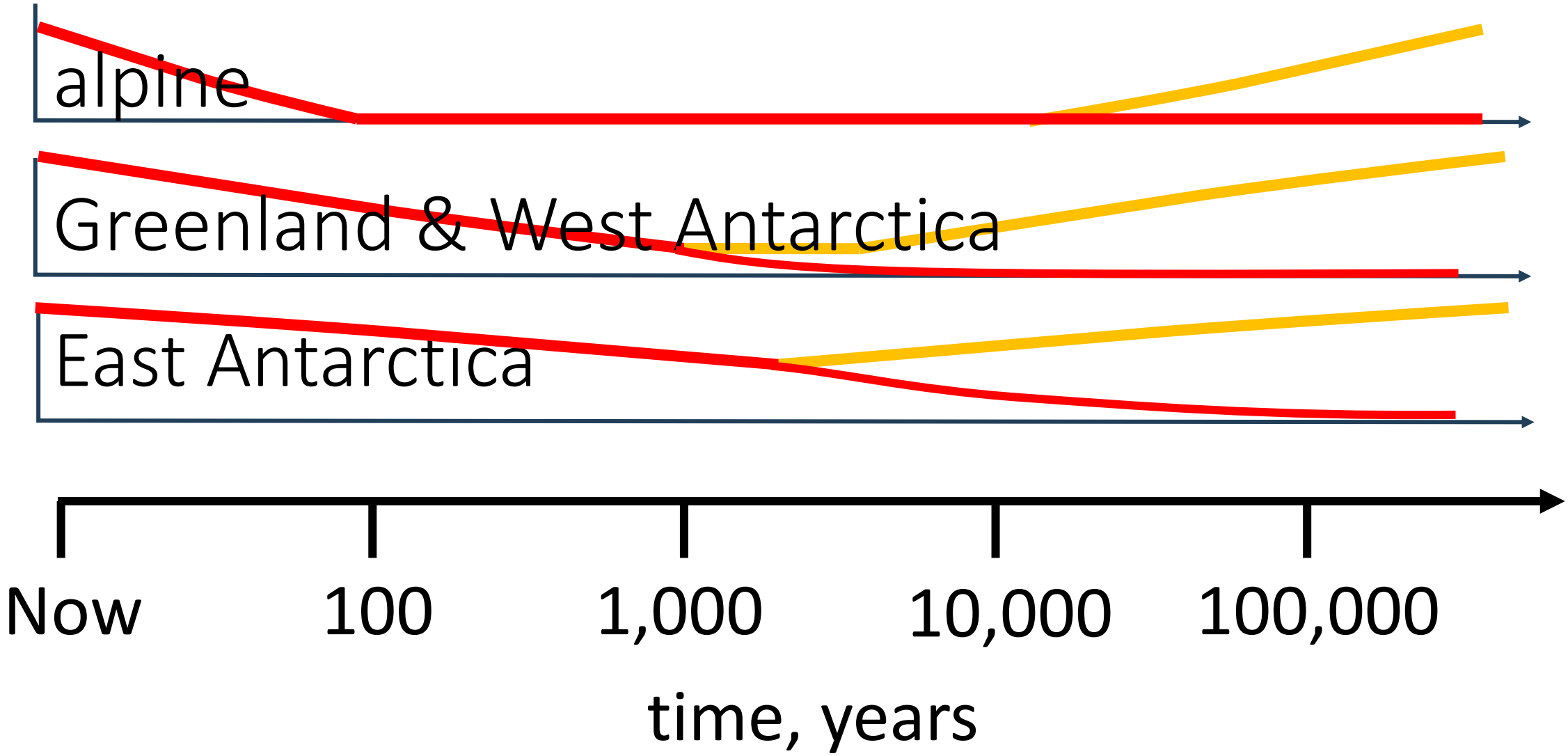
Timeline

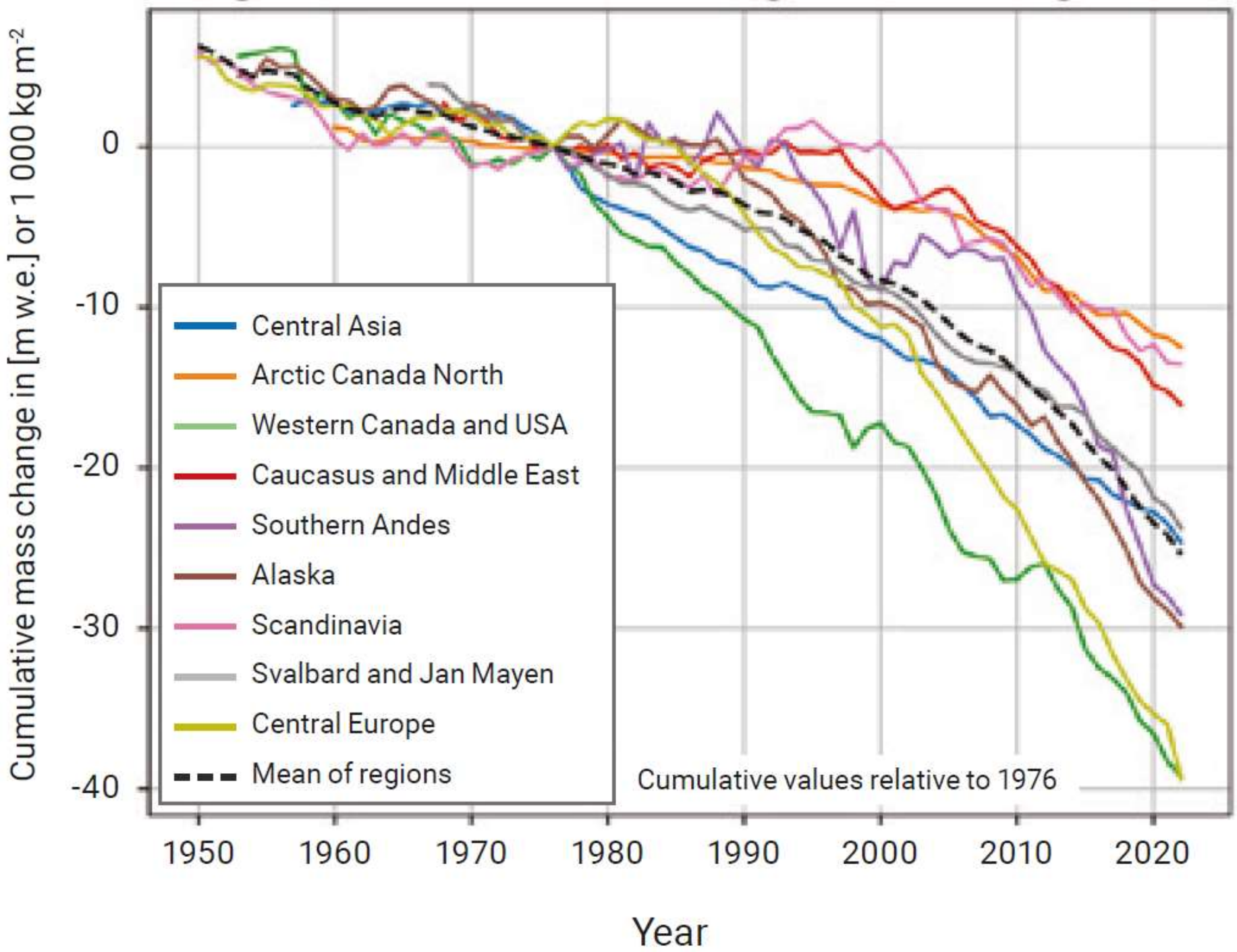


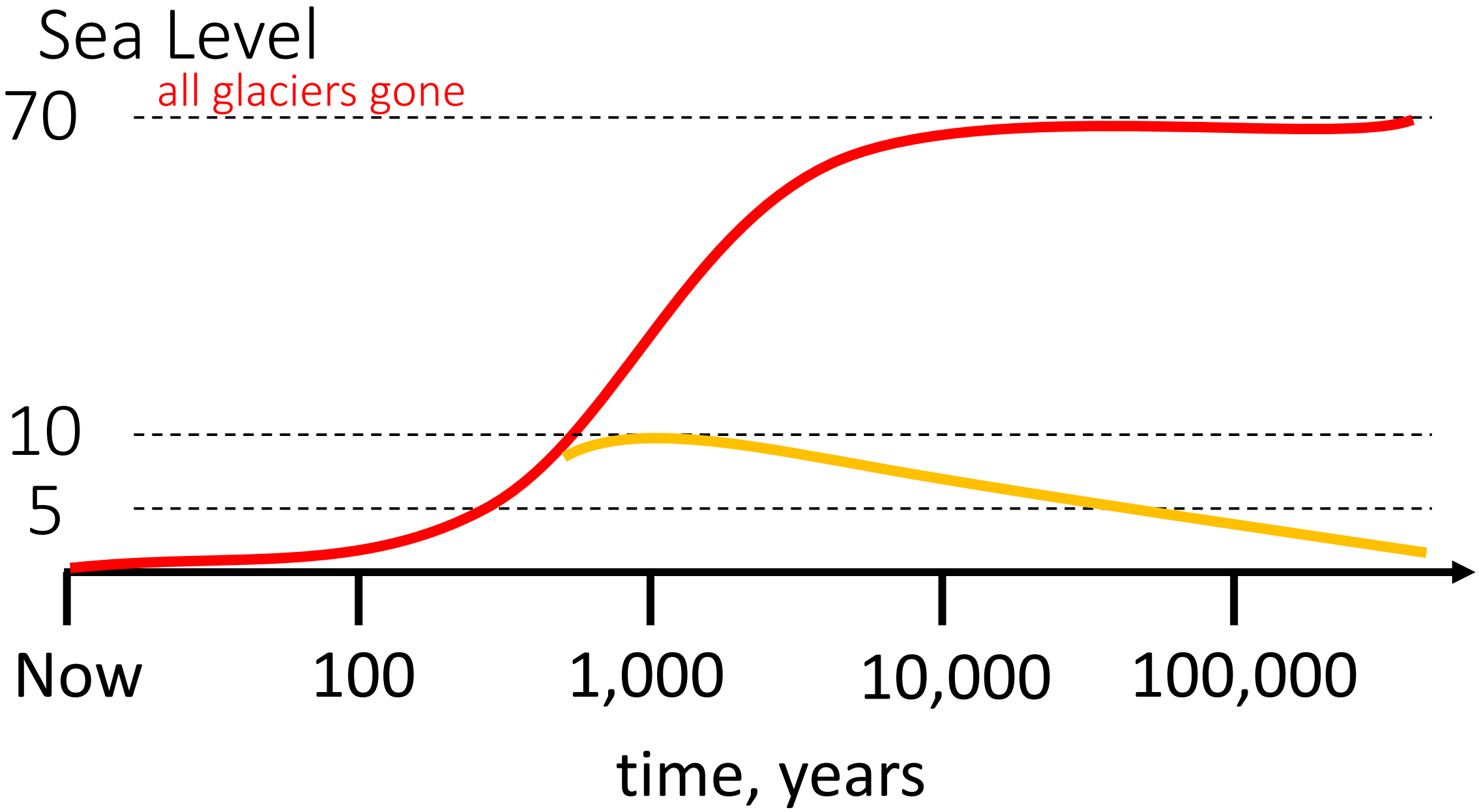
Atmospheric CO_2



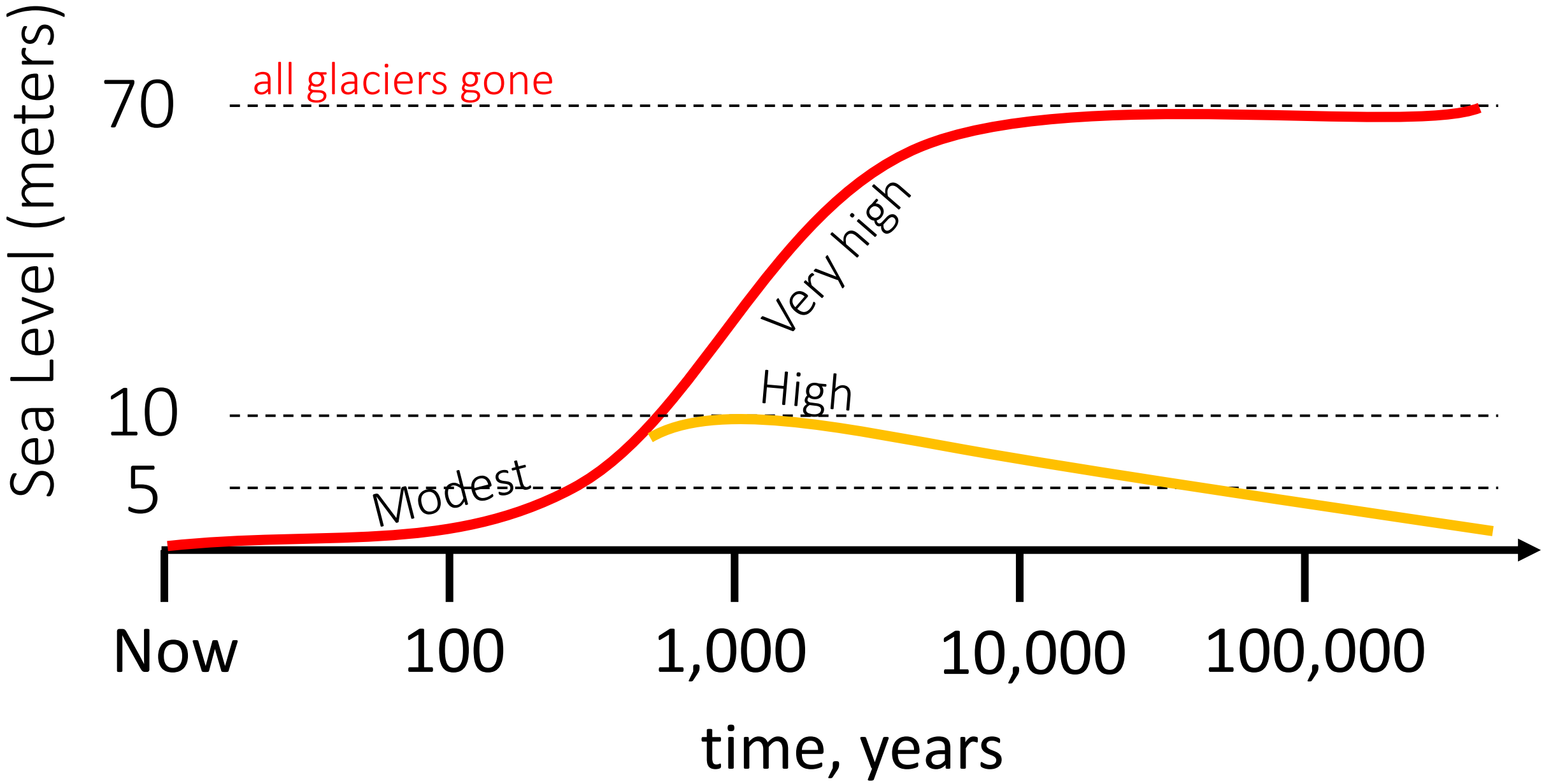
Glacial volume

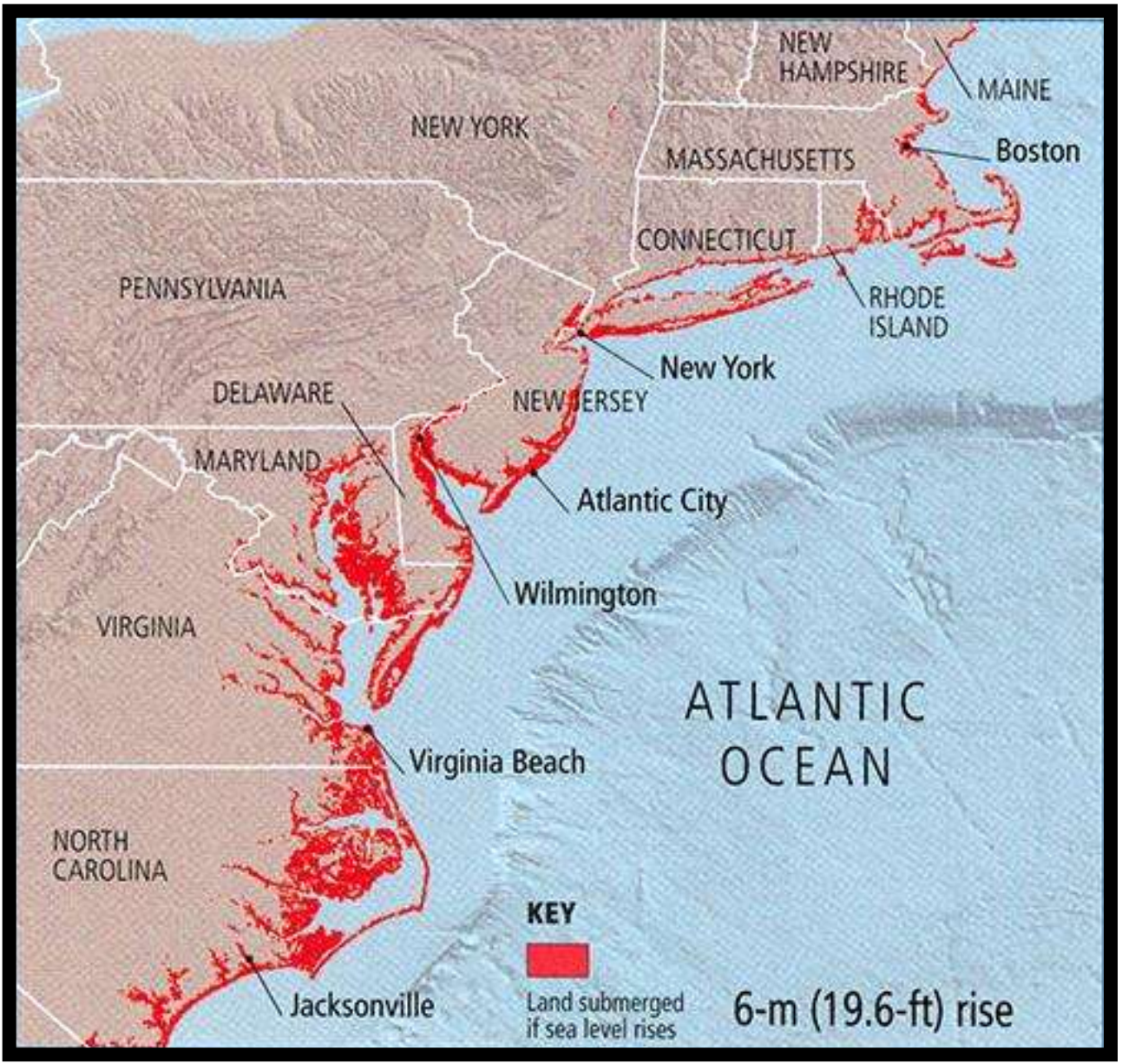



Cumulative mass change in [m w.e.] or 1 000 kg m-2
0
-10
-20
-30
-40
1950
1960
1970
1980
1990
2000
2010
2020
Year
Central Asia
Arctic Canada North
Western Canada and USA
Caucasus and Middle East
Southern Andes
Alaska
Scandinavia
Svalbard and Jan Mayen
Central Europe
Mean of regions
Cumulative values relative to 1976


Sea Level
all glaciers gone
70
10
5
Now
100
1,000
10,000
100,000
time, years

Human Impact of Rising Seas



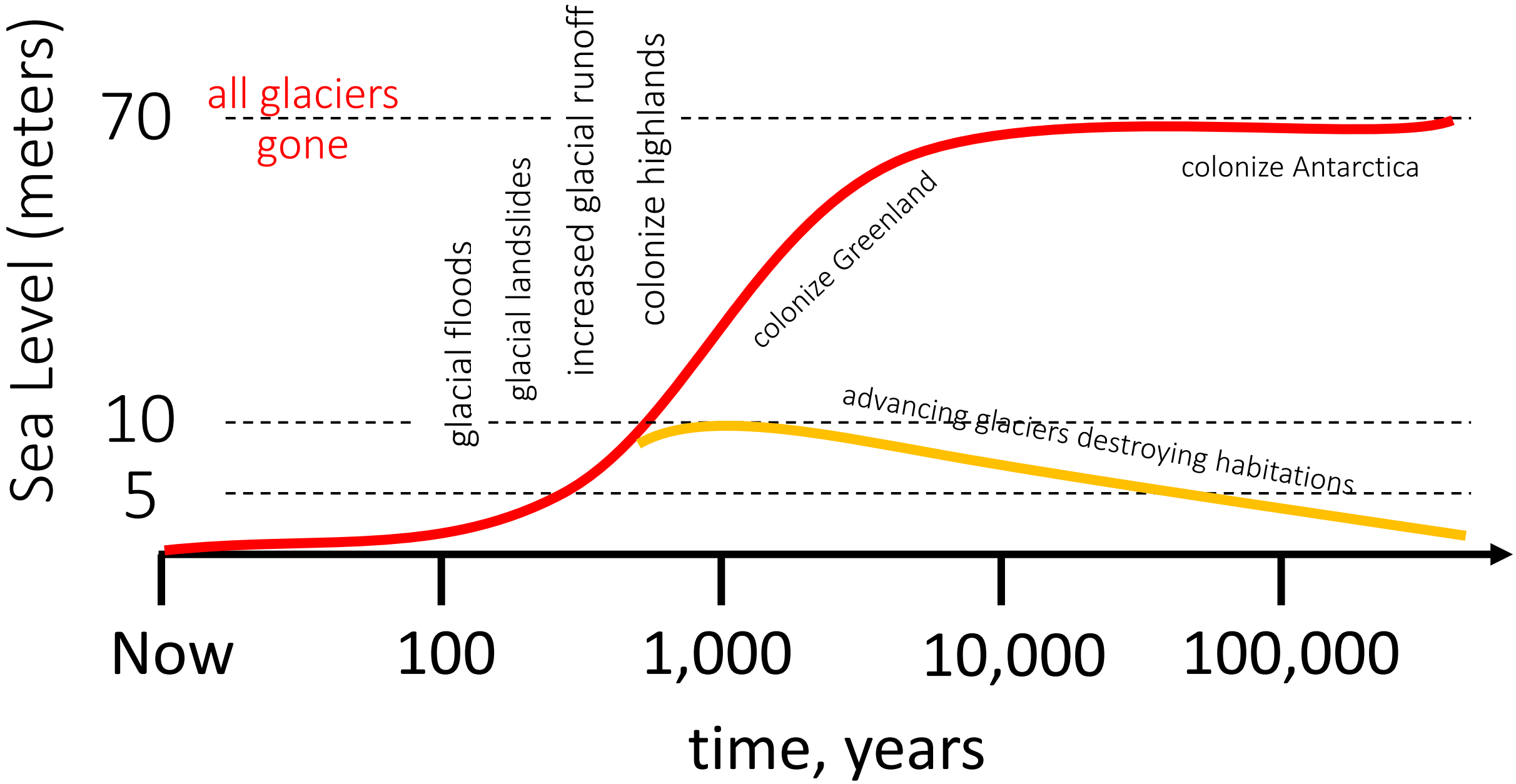

NEW HAMPSHIRE
MAINE
NEW YORK
MASSACHUSETTS
Boston
CONNECTICUT
PENNSYLVANIA
RHODE ISLAND
New York
DELAWARE
NEW JERSEY
MARYLAND
Atlantic City
Wilmington
VIRGINIA
ATLANTIC OCEAN
Virginia Beach
NORTH CAROLINA
KEY
Land submerged if sea level rises
Jacksonville
6-m (19.6-ft) rise

6 meters

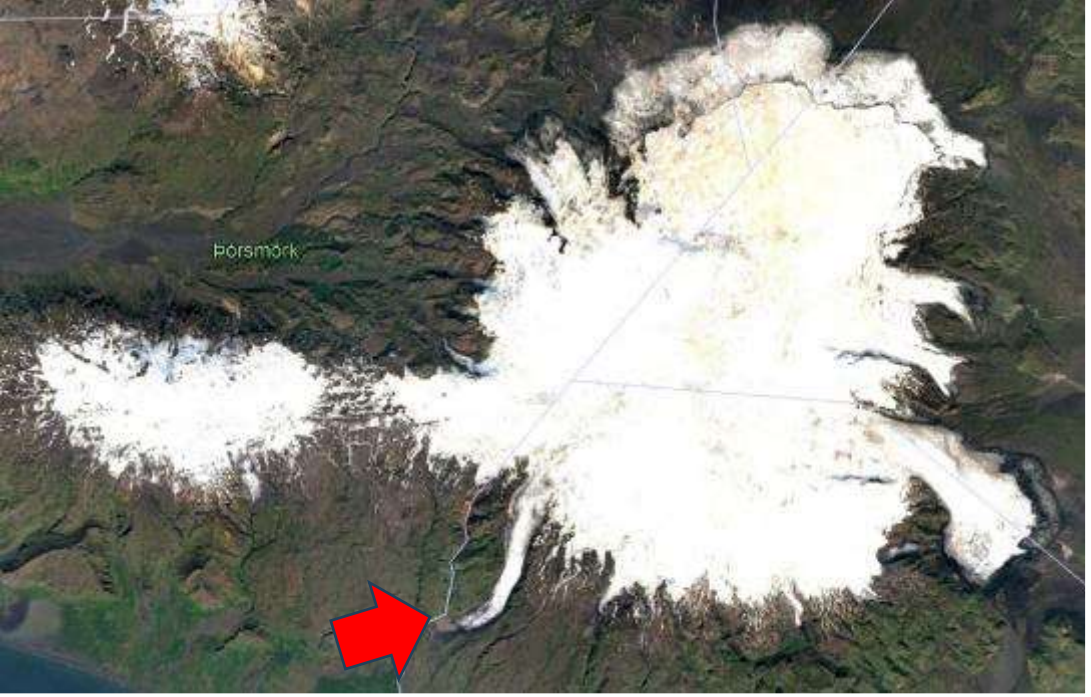

Boston
Providence
Newport
New
New Bedford
London
New York
Trenton
Atlantic
City
Dover
Annapolis
Fredericksburg
Richmond
Norfolk
Virginia
Beach
Kitty
Hawk
Greenville

70 meters

Other Human Impacts

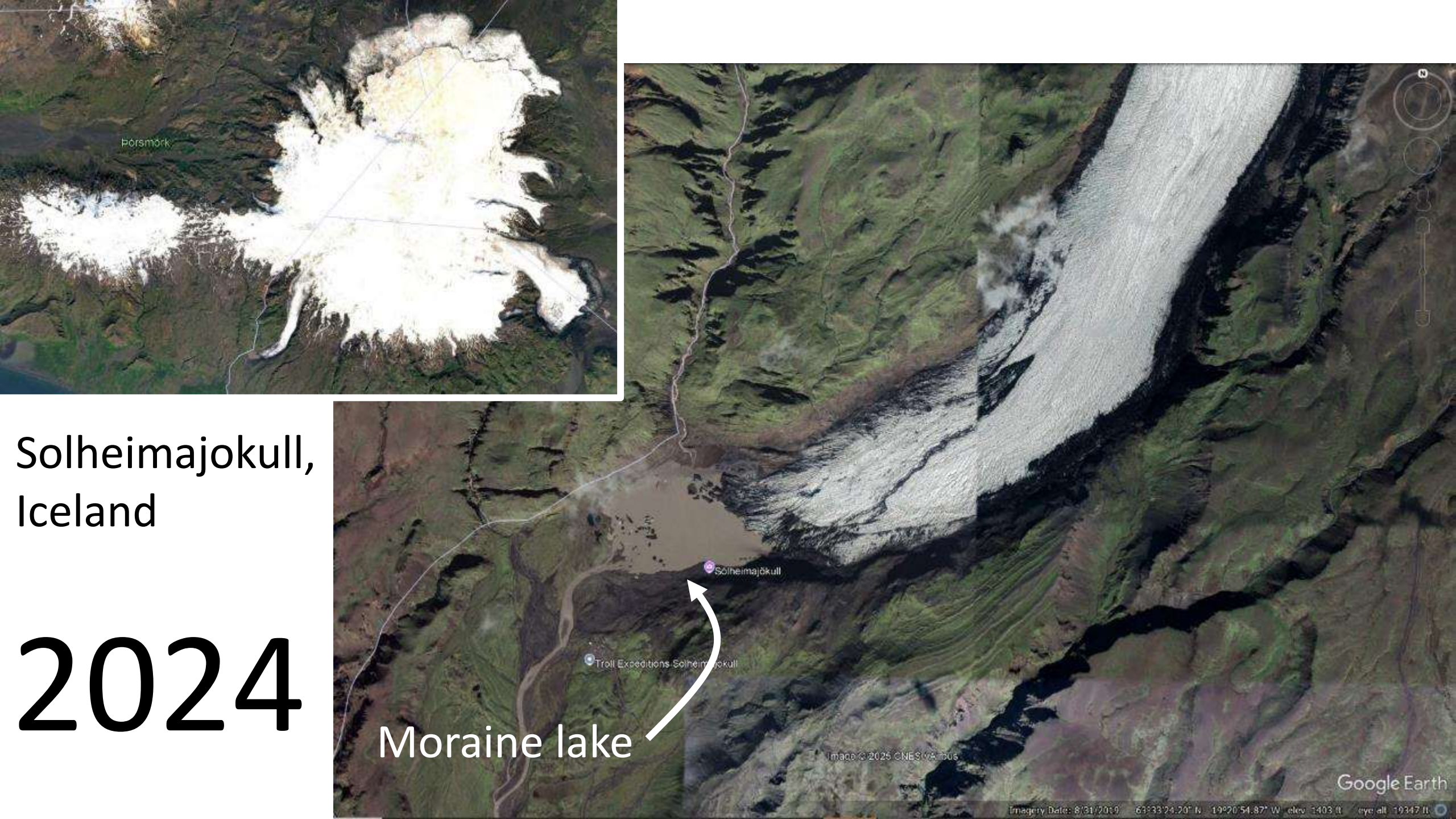


Other Human Impacts: Glacial Floods



Solheimajokull, Iceland

1986



Solheimajokull, Iceland

2024

Juneau, Alaska, August 6, 2024

source of water:
Suicide Bain
(lake)

ice dam:
Mendenhall
Glacier

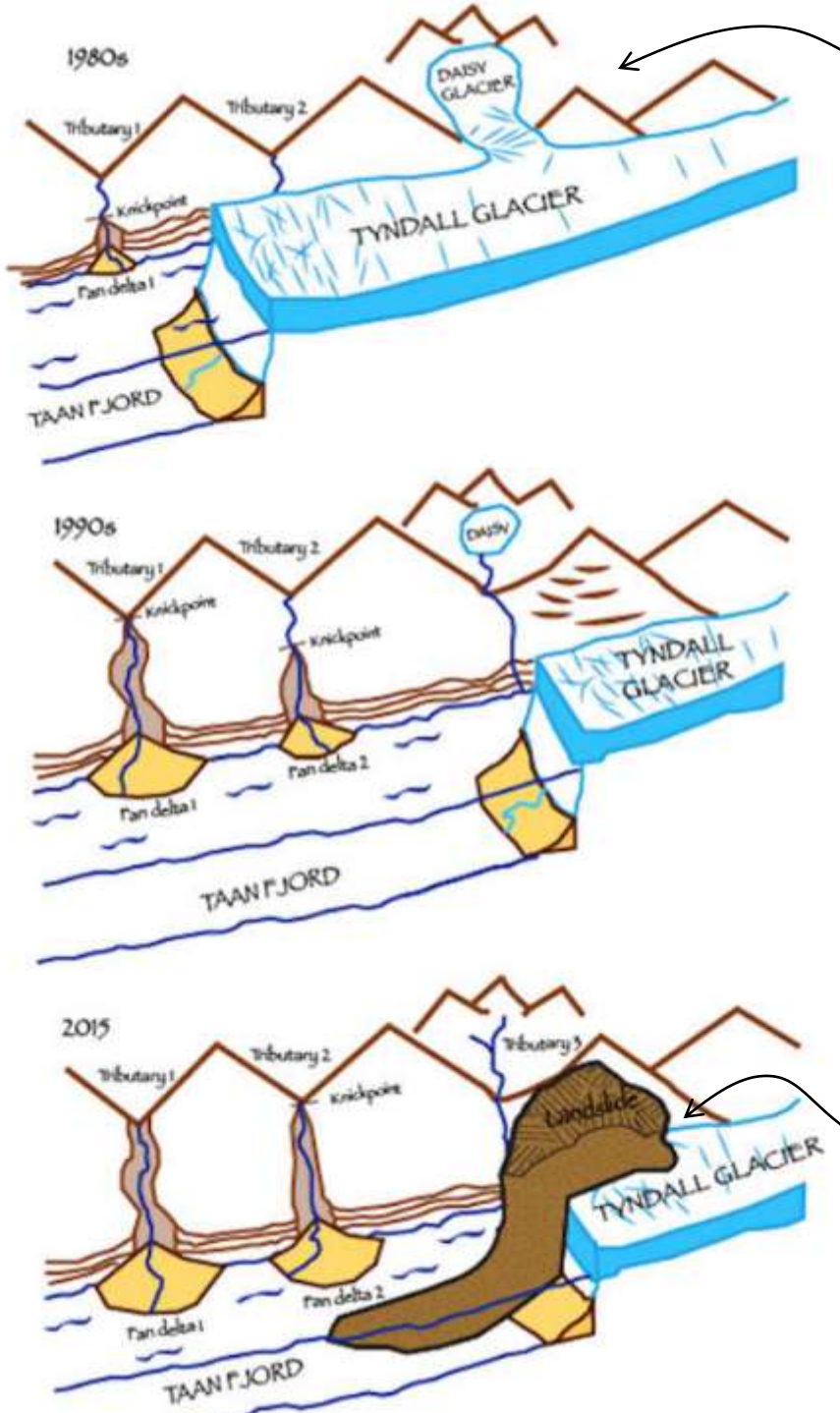
High water in Suicide Basin

Low water in Suicide Basin

Water escaping under glacier

Other Human Impacts: Glacial Landslides

October 2015 landslide, Tyndall Glacier

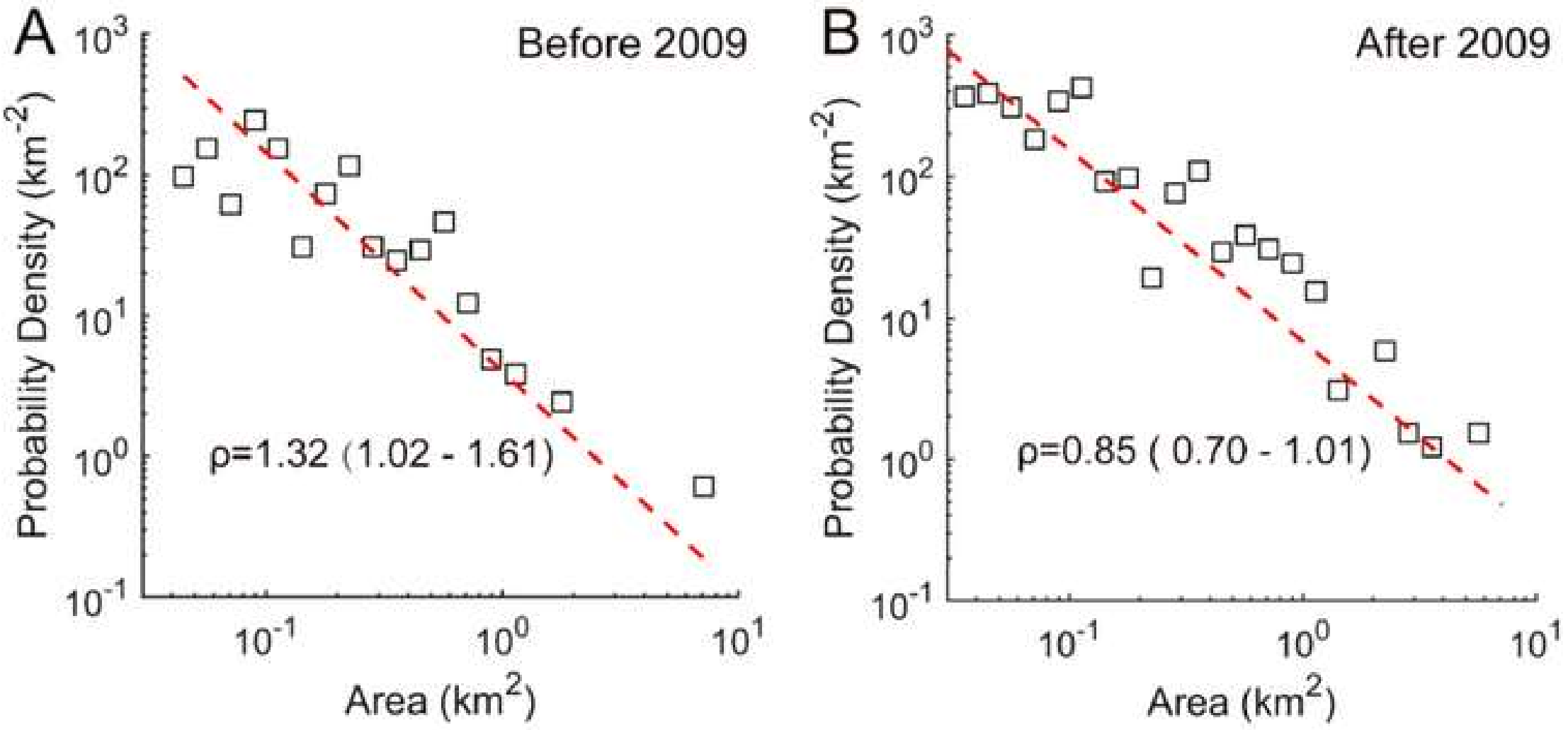


this is the hill that failed
note that it's being
supported by the glacier

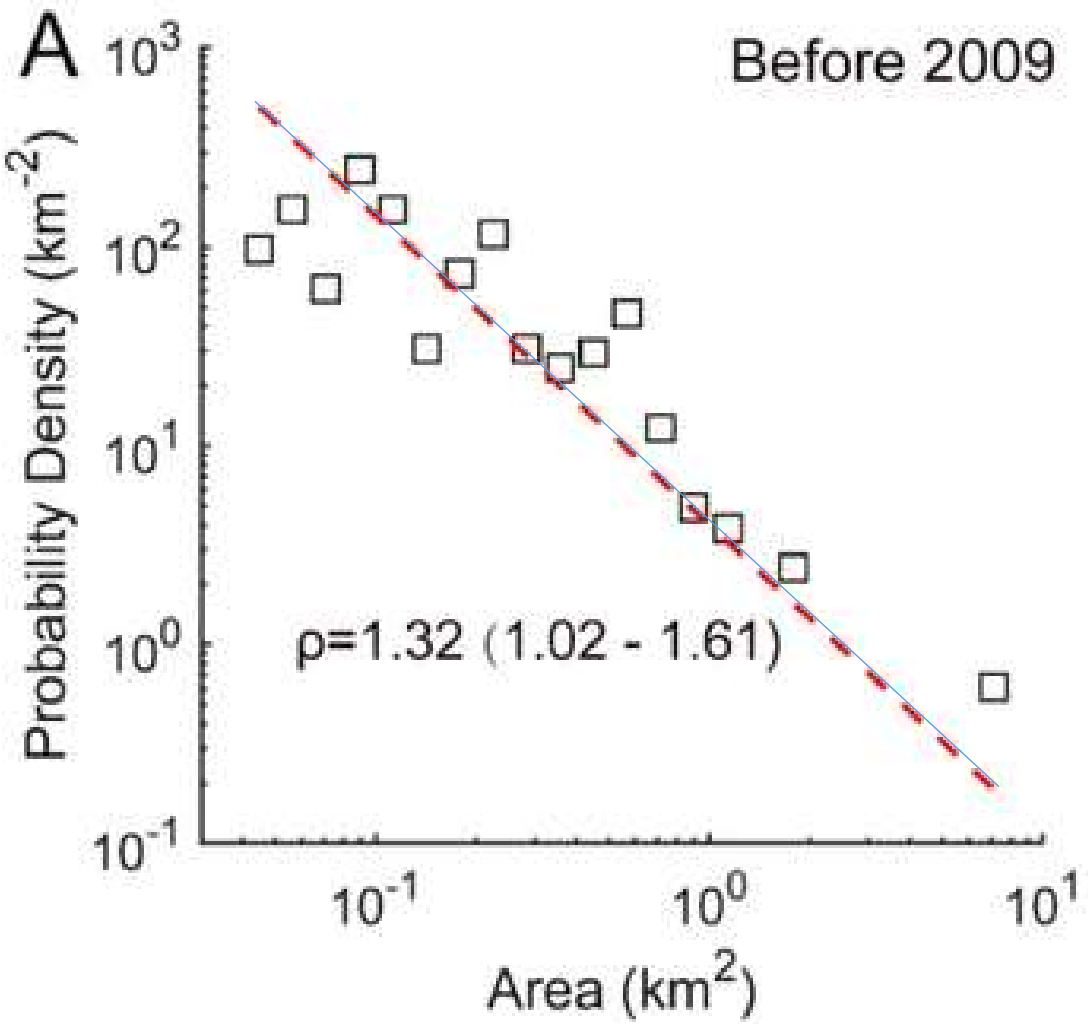
reduction in glacial ice
destabilized hillside

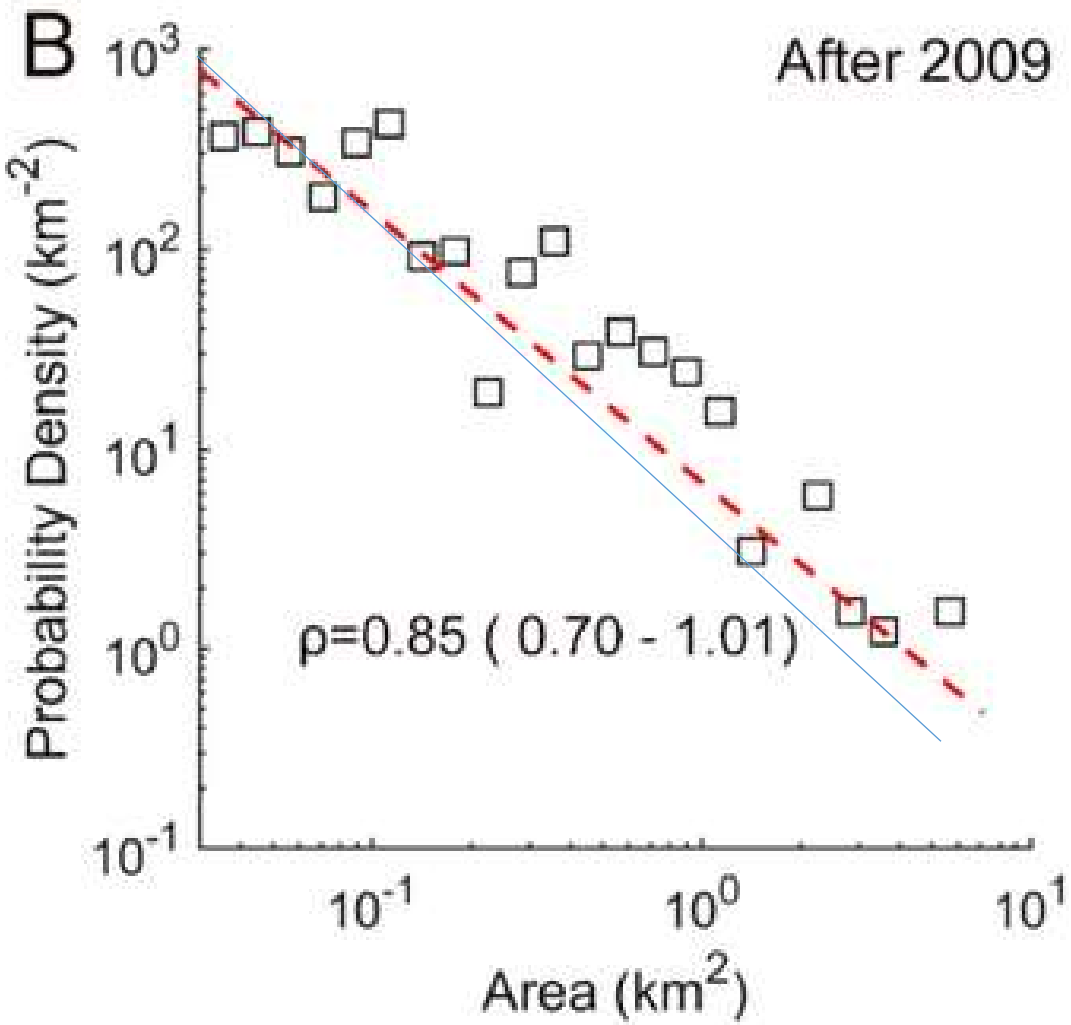
landslide can dam stream and lead to flood

landslide probability



Frequency-size plots useful in understanding interplay of rate and size

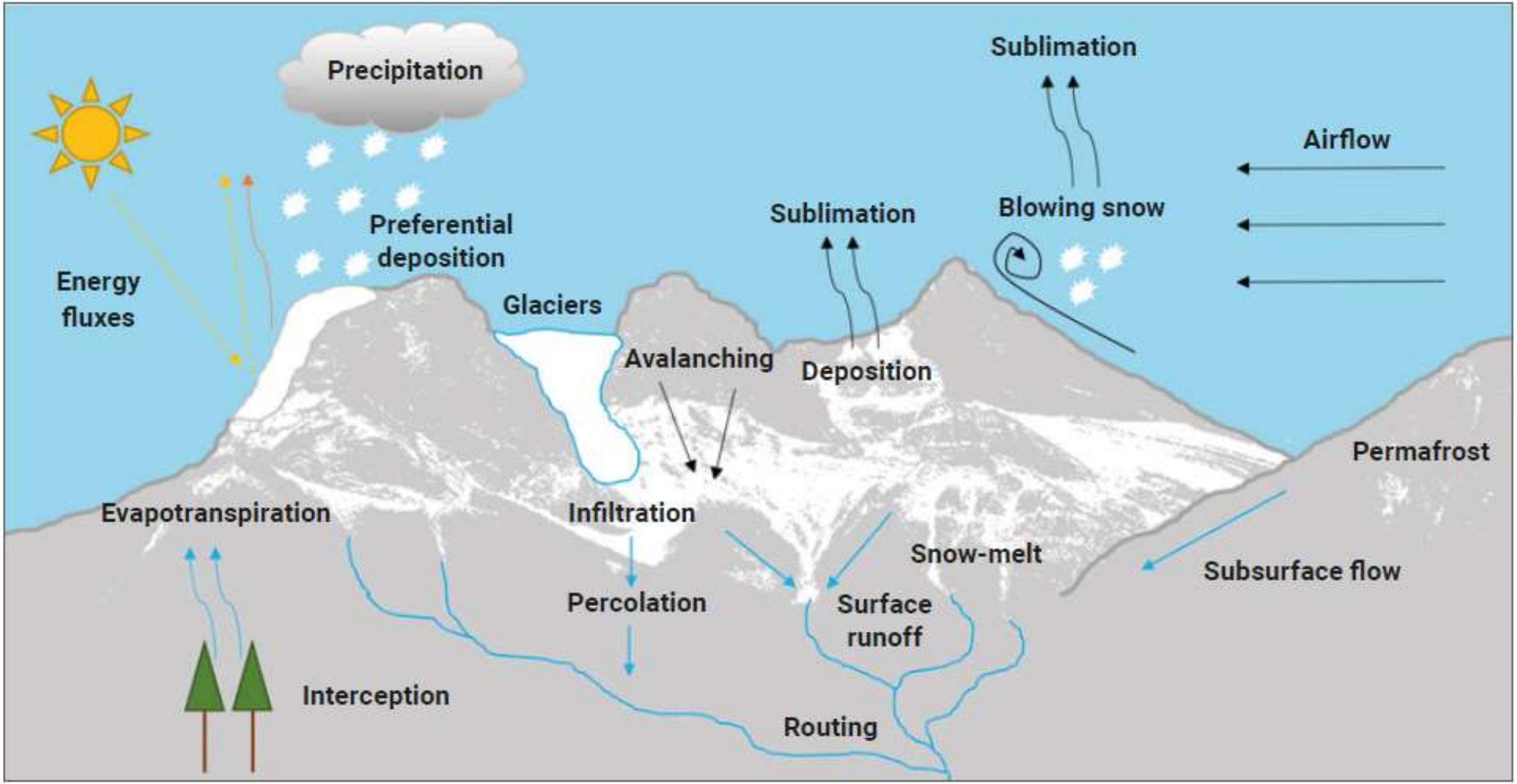




Large landslides appear to have become more probable

Other Human Impacts: Changes in stream flow

Alpine hydrology



Basin	Area ('000 km²)	Glacier area (%)	Precipitation (mm per year)	Run-off (mm per year)	Glacier melt run-off (%)	Snowmelt run-off (%)	Rainfall run-off (%)	Base flow (%)
Amu Darya	268	4.36	676	407	4.4	74.4	5.4	15.8
Helmand	74	0	360	195	0	77.5	5.2	17.4
Indus	473	6.28	832	577	5.1	39.7	43.9	11.4
Tarim	1,081	3.10	335	47	3.2	23.9	47.3	25.6
Ganges	202	4.37	1,763	1,293	3.1	10.3	64.7	22.0
Tibetan Plateau	415	0.83	451	117	2.3	15.3	32.8	49.6
Brahmaputra	400	2.73	2,018	1,575	1.8	13.2	62.1	22.8
Irrawaddy	49	0.15	3,638	3,223	0	5.1	78.2	16.7
Salween	119	1.45	1,091	627	1.4	14.7	55.7	28.3
Mekong	111	0.26	1,066	528	0.3	7.4	55.1	37.2
Yangtze	687	0.39	1,127	849	0.2	5.5	71.0	23.3
Yellow River	273	0.05	751	468	0.1	9.6	63.9	26.5

Glacier melt run-off (%)	Snowmelt run-off (%)	Rainfall run-off (%)
4.4	74.4	5.4
0	77.5	5.2
5.1	39.7	43.9
3.2	23.9	47.3

Glacial melting makes only a small contribution to river runoff

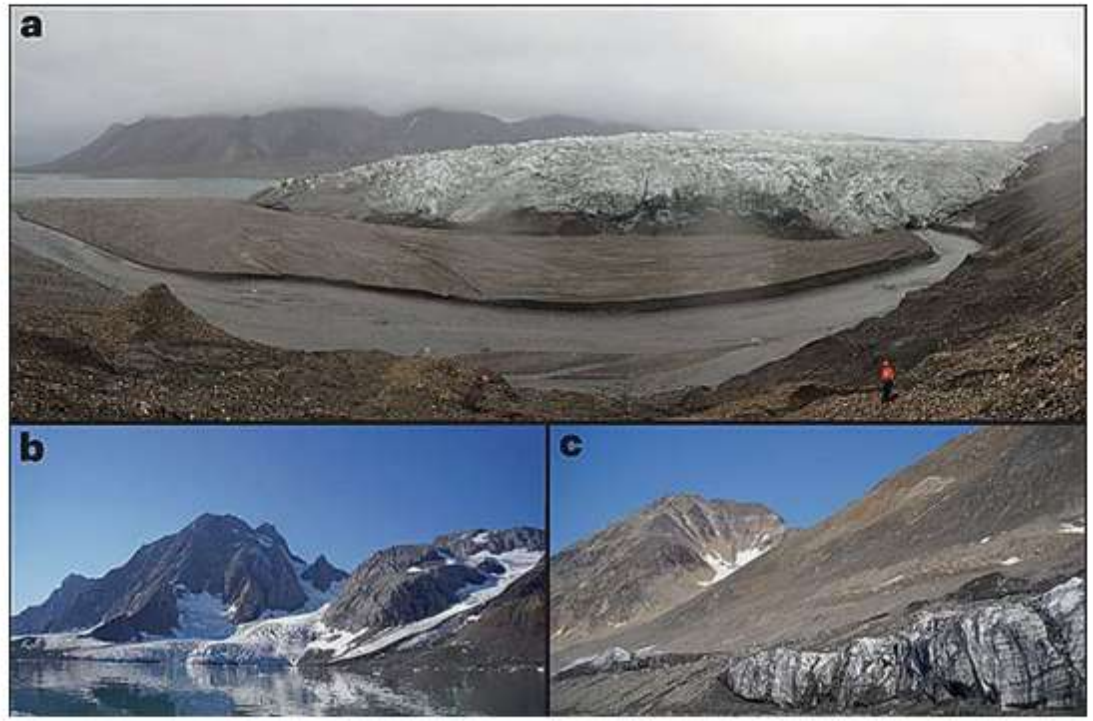
So critical question is degree to which global warming affects alpine snow pack

not glacial retreat, per se

Other Human Impacts: Colonization of formerly glaciated regions

Global warming exposes 1,620 kilometers of new Greenland coastline

by Bob Yirka , Phys.org



Geodiversity of new coastlines developed after retreat of Arctic marine-termina...

An international team of polar ecologists, geographers, and marine scientists has found that global warming has, over the past 20 years, melted enough glacier ice in Greenland that an additional 1,620 kilometers of that country's coastline is now exposed to the elements.

SUSTAINABLE FUTURE

Greenland's melting ice is clearing the way for a mineral 'gold rush'

PUBLISHED FRI, JAN 17 2025-1:12 AM EST | UPDATED FRI, JAN 17 2025-1:35 AM EST

Sam Meredith
@IN/SAMUELMEREDITH
@SMEREDITH19

KEY POINTS

- Greenland, a vast but sparsely populated island situated between the Arctic and North Atlantic Oceans, has been transformed by the climate crisis in recent decades.
- The changing environment has seen parts of Greenland's ice sheet and glaciers replaced by wetlands, areas of shrub and barren rock.
- For mining companies, Greenland's ice retreat could facilitate the start of a mineral "gold rush."

RELATED


From seaweed burgers to 'upcycled' potato chips, the food industry is going 'nature positive'


Like defense, Goldman says ESG investors should bring oil and gas stocks in from the cold


Canada is aiming to beat China in the critical race for rare earth metals

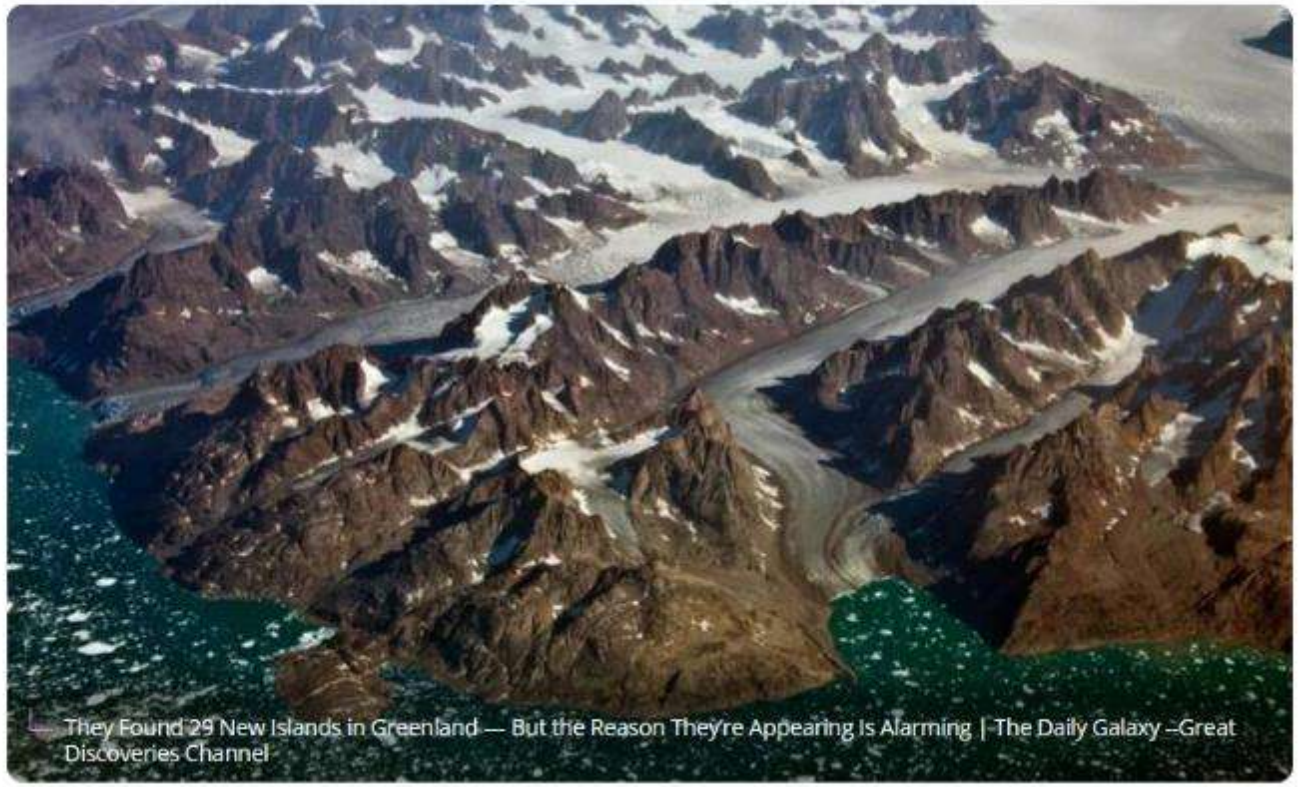

World's first-ever global

News

They Found 29 New Islands in Greenland — But the Reason They're Appearing Is Alarming

Scientists have identified 29 new islands in Greenland—but the reason they're appearing is a stark warning about the planet's accelerating ice loss.

Lydia Amazouz | Published on March 26, 2025 | Read : 3 min | 0



They Found 29 New Islands in Greenland — But the Reason They're Appearing Is Alarming | The Daily Galaxy –Great Discoveries Channel

Lasts posts

They Swam With Dinosaurs—Now These Jurassic-Era Fish Are Dying Out Because of...

Nature

Geologists Have Uncovered a Brand New Continent in Arctic Breakup Zone

News

95% of Flu and Herpes Infection Neutralized by Chewing Gum in Minutes — And It's FDA-Compliant

Science

Astronomers Have Announced the Discovery of the Most Promising "Evidence" to Date of Potential Life on a Planet Outside Our Solar System

Space

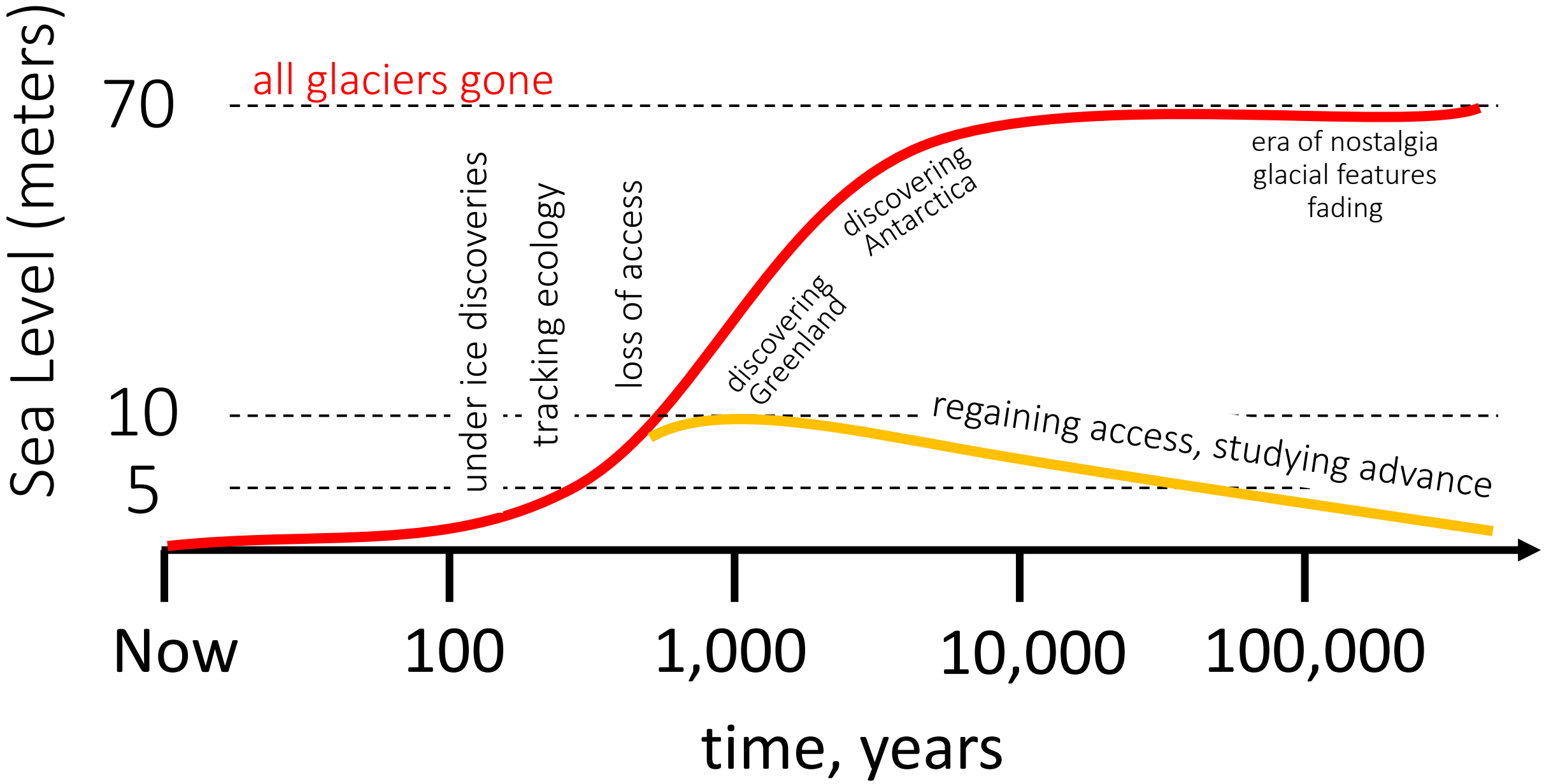
Other Human Impacts: Readvance of Alpine Glaciers

Other Human Impacts: Readvance of Alpine Glaciers

No one has yet built a house in the valley …

but that’s not to say that a town could spring up there in a thousand years

Intellectual Impact of Loss of Glaciers



Intellectual Impacts: Under-the-ice discoveries


Change brings opportunity.
Nido Qubein
BrainyQuote

Ötzi, also called The Iceman, between 3350 and 3105 BCE

Ötzi

reconstructed clothes

ax

northern Canada


BBC

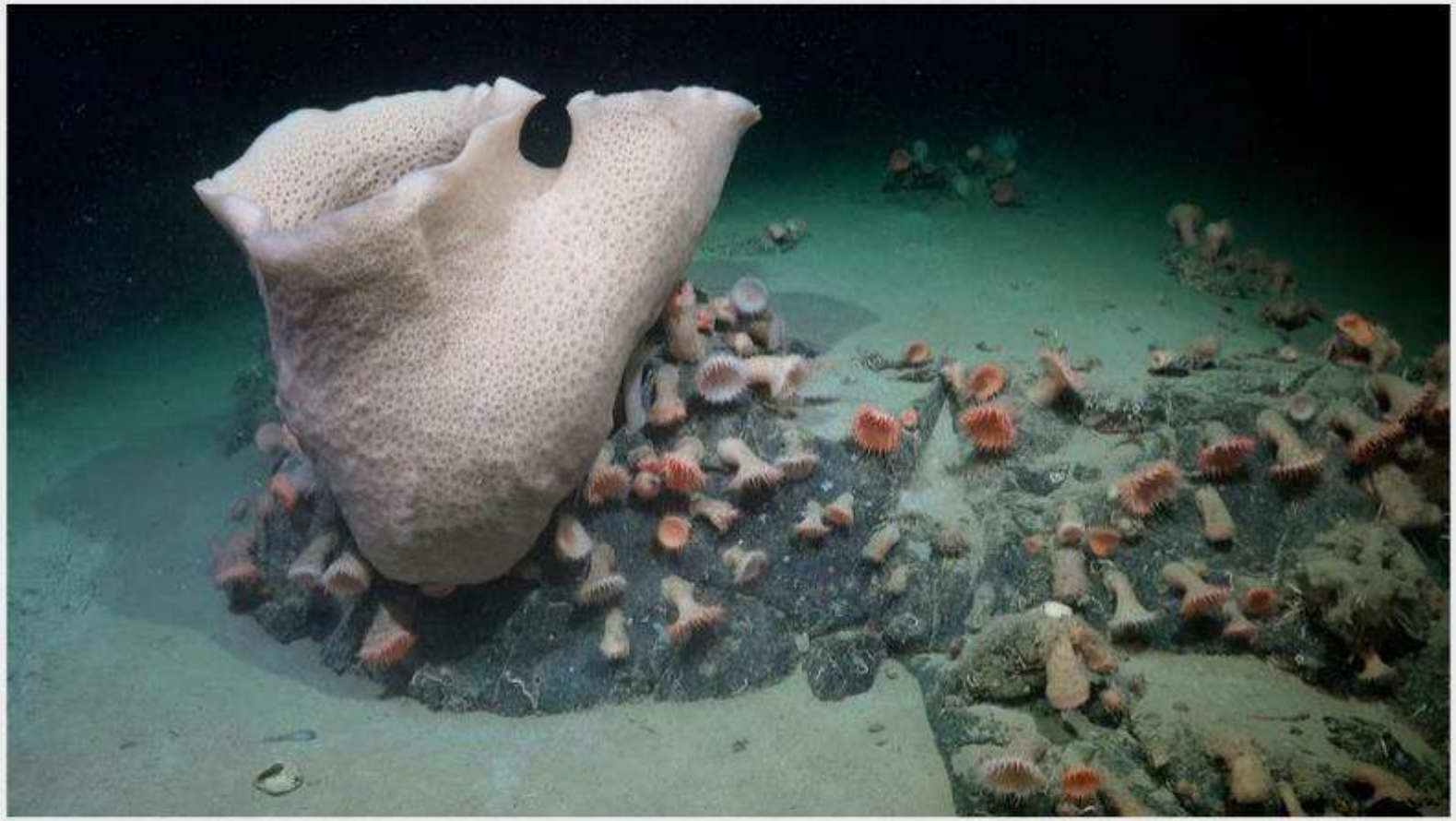
Intellectual Impacts: New ecology

MARCH 21, 2025 | 3 MIN READ

Stunning Antarctic Sea Creatures Discovered after Iceberg Breaks Away

A calving iceberg exposed a region that never before had been seen by human eyes, revealing a vibrant, thriving ecosystem

BY ASHLEY BALZER VIGIL EDITED BY ANDREA THOMPSON



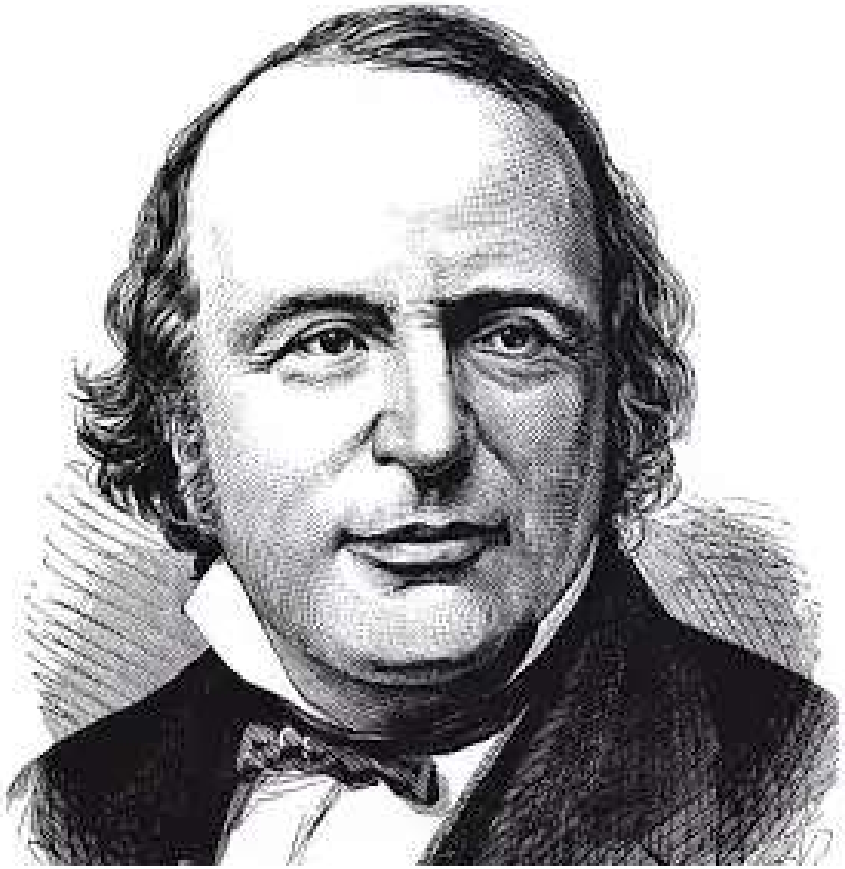
A large sponge, a cluster of anemones, and other life is seen nearly 230 meters deep at an area of the seabed that was very recently covered by the George VI Ice Shelf in Antarctica. Sponges can grow very slowly, sometimes less than two centimeters a year, so the size of this specimen suggests this community has been active for decades, perhaps even hundreds of years. ROV SuBastian/Schmidt Ocean Institute

Intellectual Impacts: Loss of access

Fjallsjokull (glacier)

Group photo with Claire, Nicole, Hannah, An, Lisa, Chen, Meghan, Dan, Ananstasia, AJ, Claire, Vansa and me, Bill Menke

Fjallsjokull, 2011
Columbia University
Iceland Fieldtrip



Swiss Geologist
Louis Agassiz
discoverer of the
Ice Age

The present is the key to the past

The Ice Age was discovered by people who has ready access to modern glaciers

Mt Kilimanjaro

My cousin (Nate Estes) by the Uhuro Peak sign

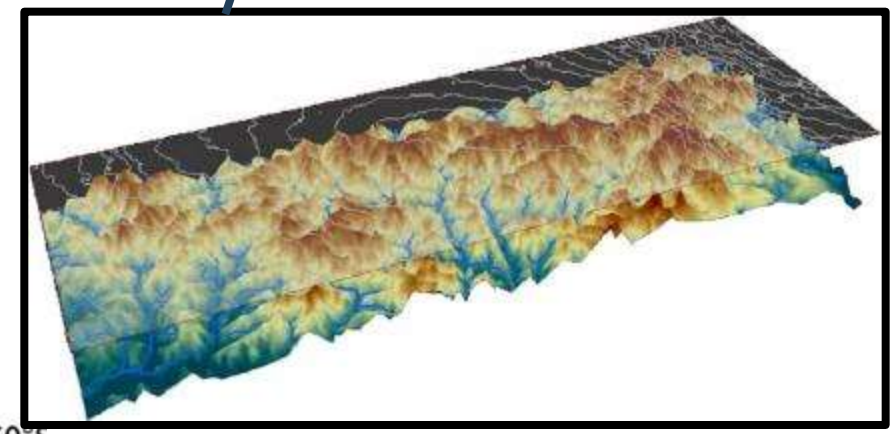
What if it took
a week-long hike

Furtwangler Glacier at sunrise

to see a tiny glacier this this?

Intellectual Impacts: Discovery of Greenland and Antarctic geology

Although Antarctic bedrock topography has been mapped using radar, very little is known about its geology



Gamburtsev Subglacial Mountains

Intellectual Impacts in the Low CO_2 Scenario:

Studies of Glacial Advance

Science

Scientists are analyzing data from Denali's Muldrow Glacier surge, which might unravel answers about the world's glaciers

By Emily Mesner
Published: November 14, 2021

A view up the Muldrow Glacier shows jagged ice and crevasses, photographed on Sunday, April 18, 2021. (Photo by Chris Palm)

As most glaciers are in retreat,
studies of glacial advance are currently limited to surging glaciers, which are atypical

Intellectual Impacts in the High CO_2 Scenario:

Nostalgia over glaciers

Erosion wears away all of the Earth's surficial features.

Shiprock (New Mexico), is all that is left of a 27 ma volcano

The remaining portion was formed ~1 km underground. The volcanic edifice is completely gone

Will glacial morphological features become limited to a few instances where they were lithified

Drop-stone from the Late Paleozoic Glaciation (300 ma)

Dinosaur Fossil (80 ma)

Avgar Shohamy, Alma
aa4718

Dixon, Jada
jid2118

Esler, Julian
jae2192

Geoghegan, Eva
emg2234

Hall, Colin
ch3302

Harlan, Dev
dh3142

Lee, Rachel
rrl2127

Martin, Lydia
lam2295

Miller, Vivian
vrm2123

Rodriguez Martinez, Miguel
mr4210

Saru Magar, Ashik
as7305

Yao, Madeleine
my2867

It’s up to you