Mountain Glacier Fluctuations in the Holocene

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PREVIOUS GLOBAL WARMING (5 - 7°C)

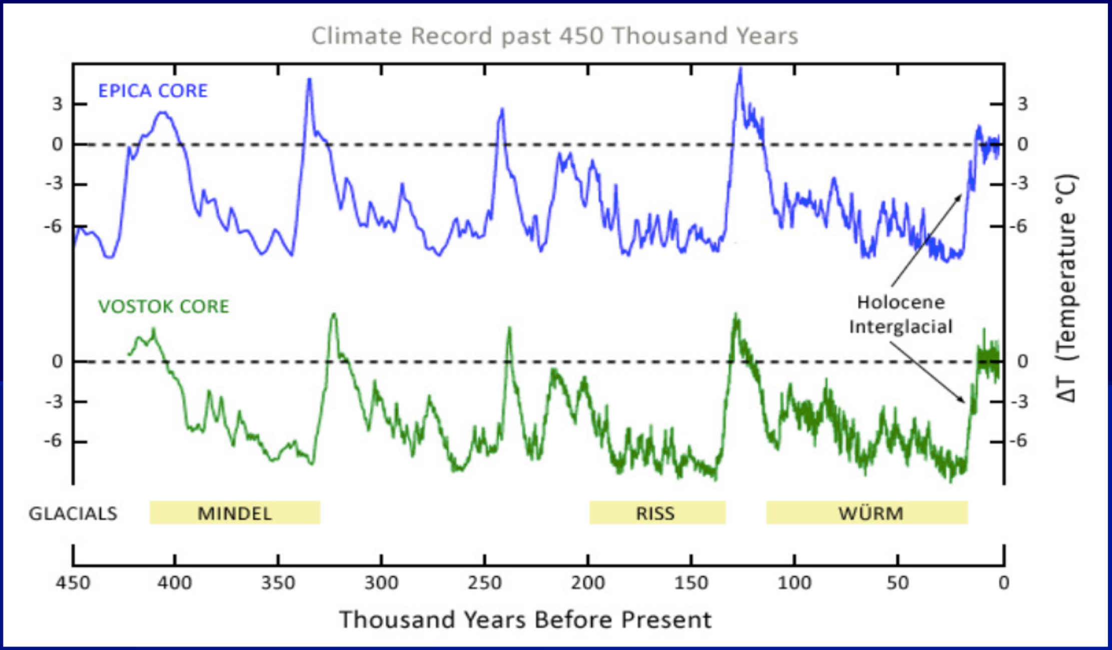
20 000 YERAS AGO

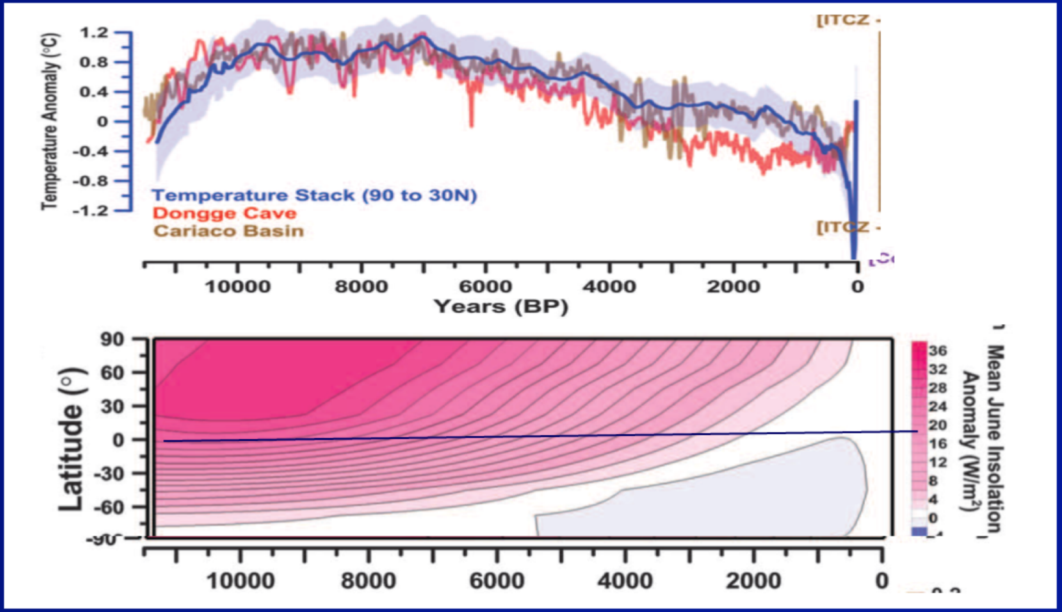
TODAY

THE HOLOCENE PERIOD

The Holocene period is the last of a long series of **interglacials** initiated millions years ago.

It started 11,700 years ago and **we are living in this period,** which **provides the climatic context of the birth and evolution of the civilizations**

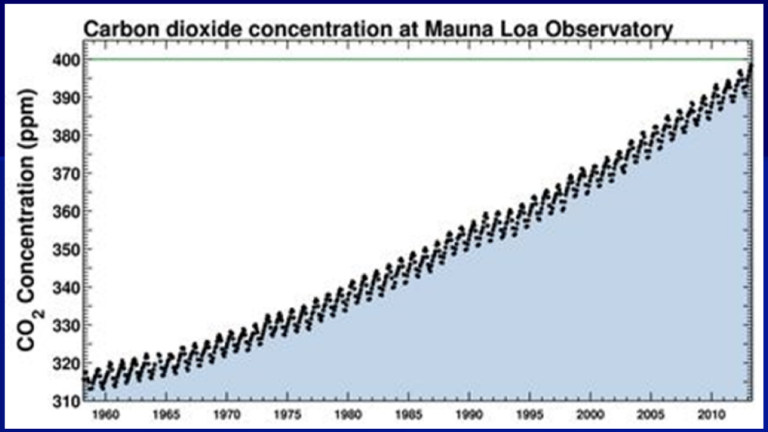


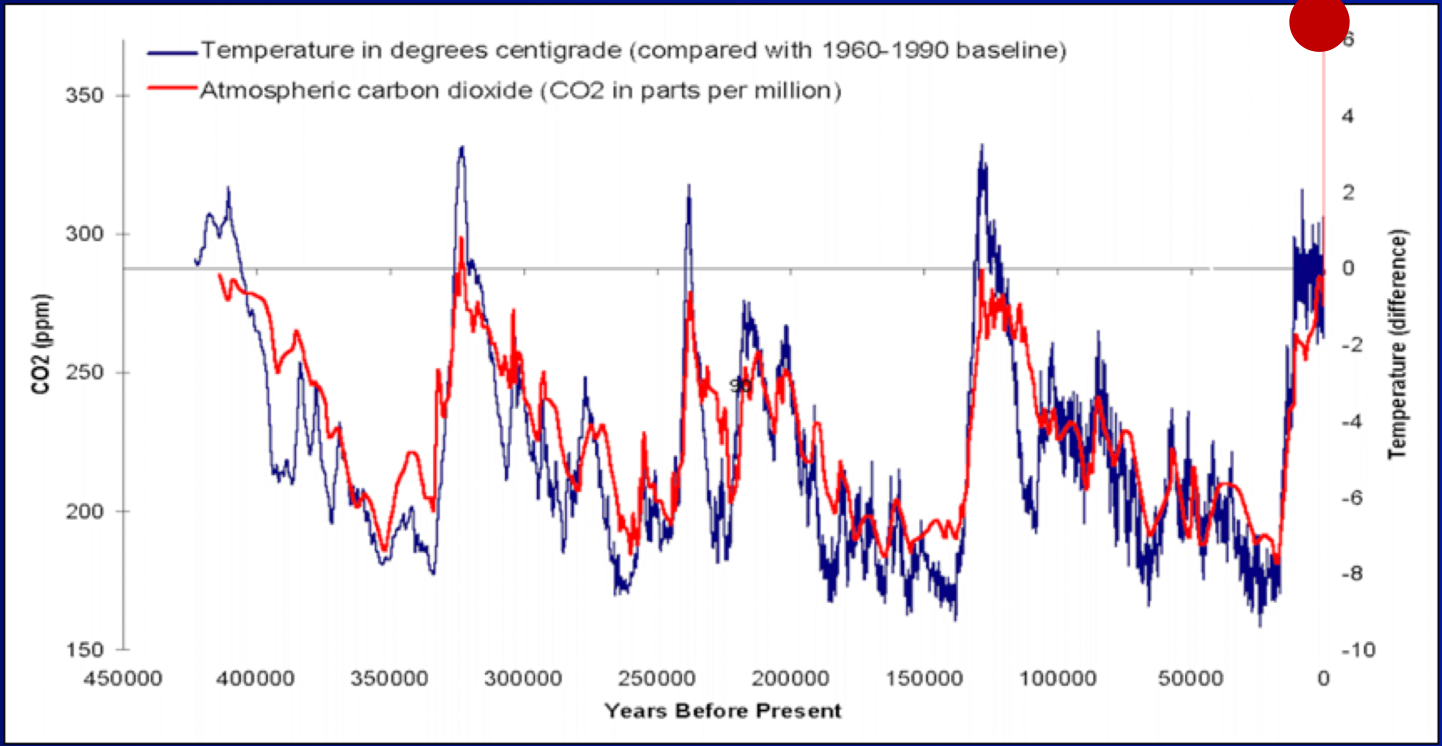


CO2 and Temperature

Appr. 700 ppm

By 2100





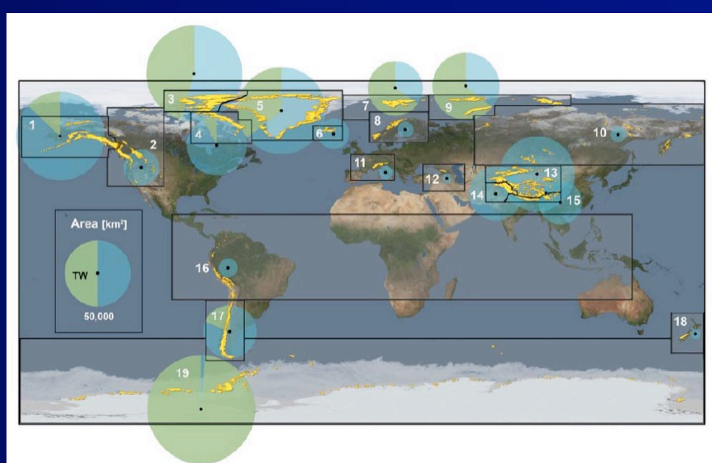
Main Questions:

Can it be natural?

Causes of these changes?

Glaciers as climatic proxies

- relatively simple physical systems
- independent from other paleoclimatic data (proxies)
- almost globally distributed



Gardner at al., 2013

- What happened with glaciers in 19th - 21th centuries?
- How do we study glacier history?
- What do we know about glacier variations in the past 10000 years?
- How it is related to the climate changes?


ЛЕДНИКОВЫЙ ЦИРК
Располагается в верхней части ледника и представляет собой заполненную льдом впадину.
ХРЕБТЫ И ОТРОГИ
Образуются в результате продолжительной эрозии ледниковых цирков.
ЦЕНТРАЛЬНАЯ МОРЕНА
При слиянии двух ледников долин морены объединяются в одну, идущую по центру.
ЗОНА АБЛЯЦИИ
Так называют зону, в которой происходит таяние ледника.
МОРЕНЫ
Осадочные материалы, увлекаемые ледниками.
U-ОБРАЗНЫЕ ДОЛИНЫ
Альпийские ледники меняют рельеф, создавая корытообразные долины U-образного профиля.
ЯЗЫК
Участок долины, по которому движется лед.
Озеро

Rone Glacier, European Alps

1856

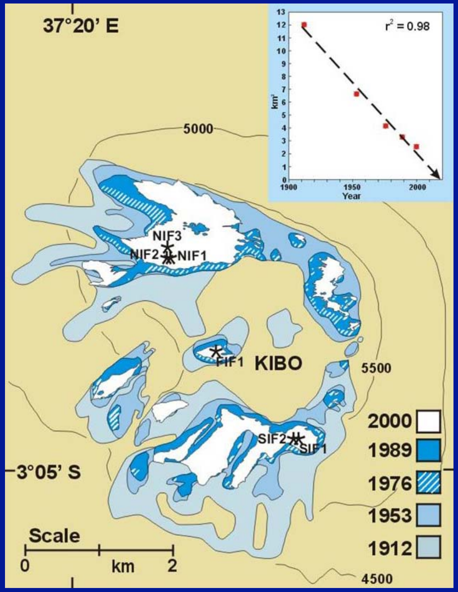
1900

Early 2000s

Kilimanjaro, Africa

1993

2000



Thompson et al. (2002)

Frias Glacier, Patagonia

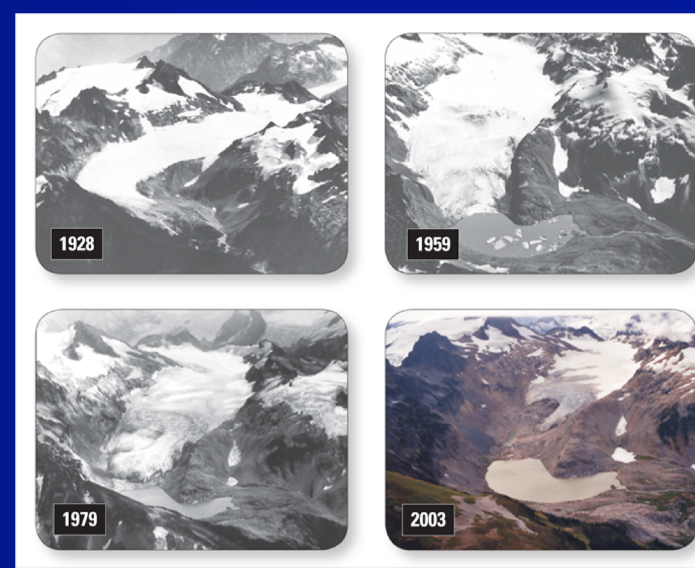
Glaciar Frias, Monte Tronador unknown, ~ 1942

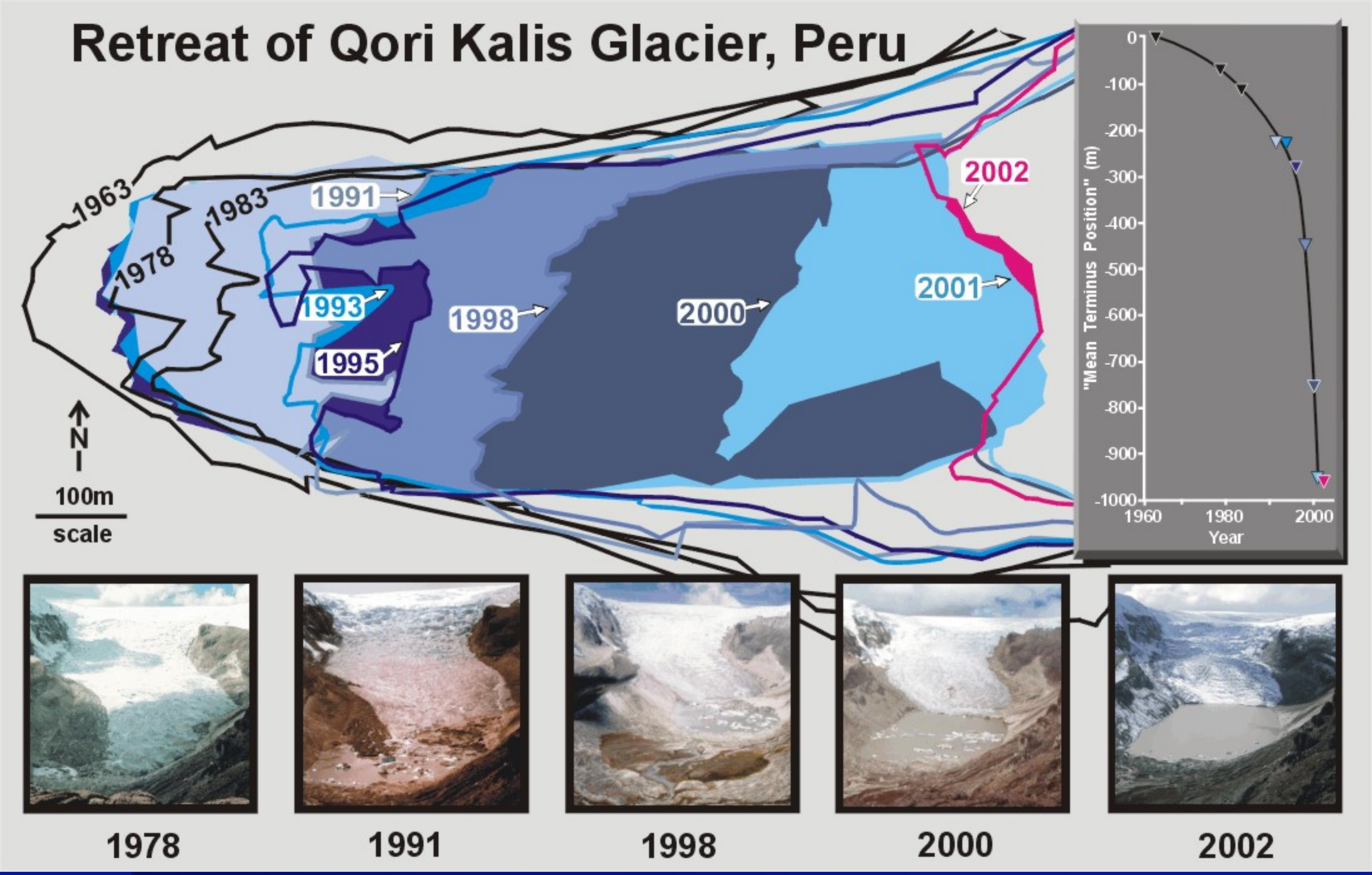
Alpine of the Americas Project, 2012

Muir Glacier, Alaska

Fedchenko Glacier, Central Asia

S.Cascade Glacier, NA Cordilllera

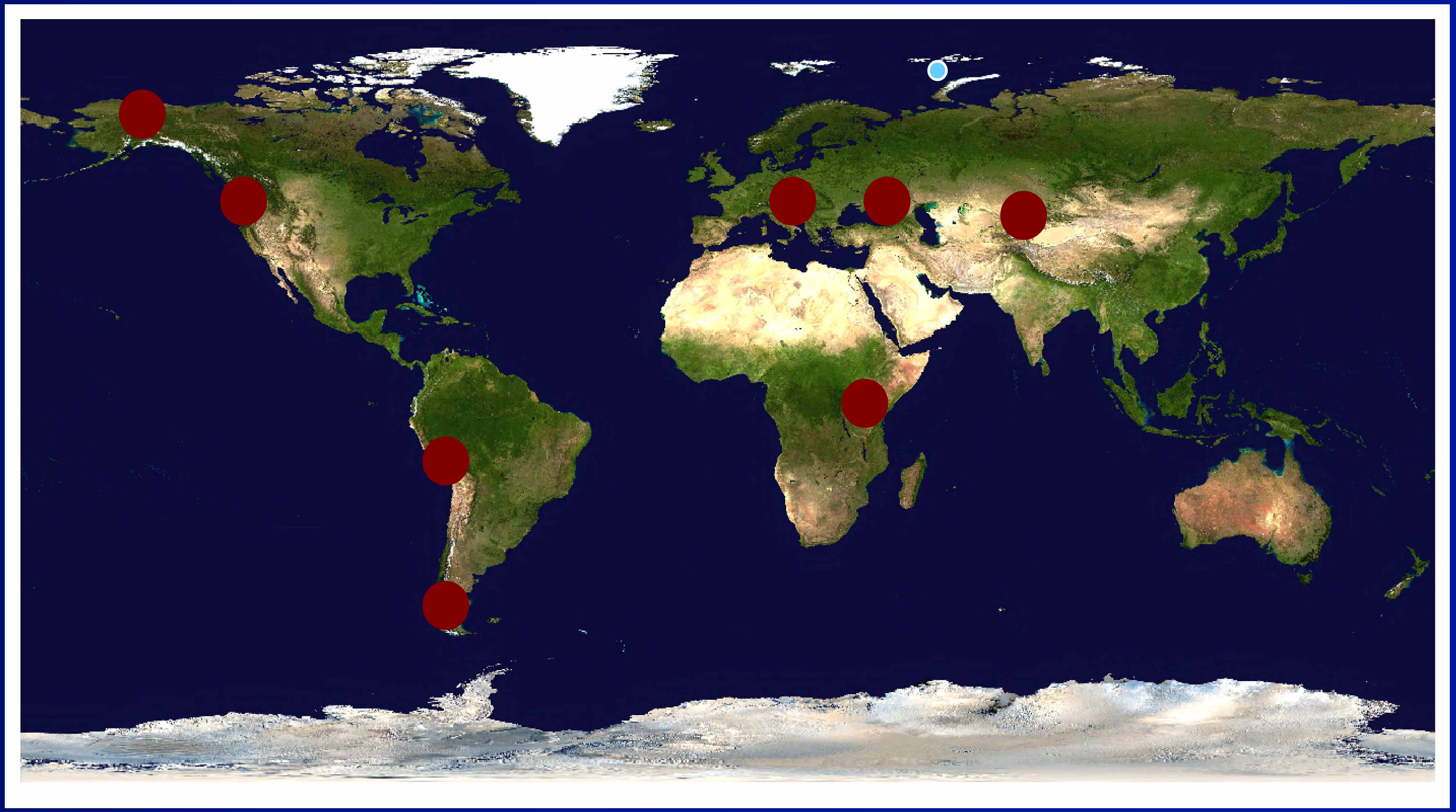




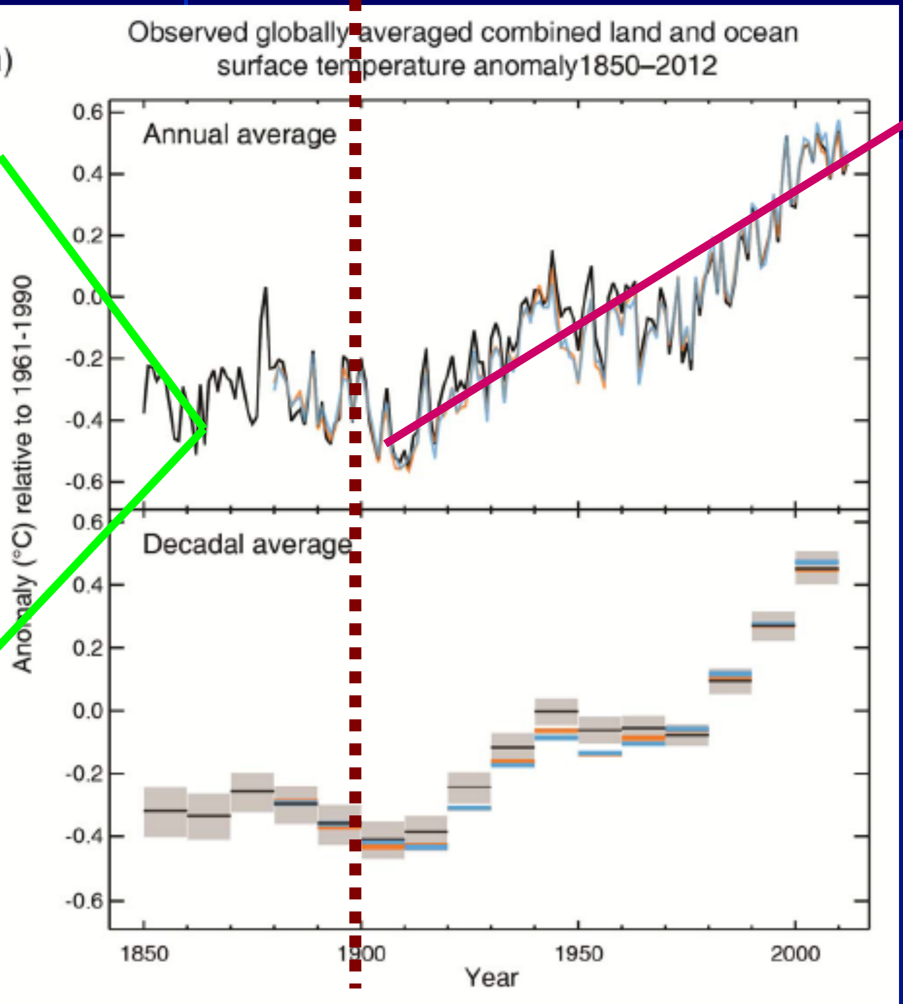
Thompson , 2002

Kashkatash Glacier, N.Caucasus

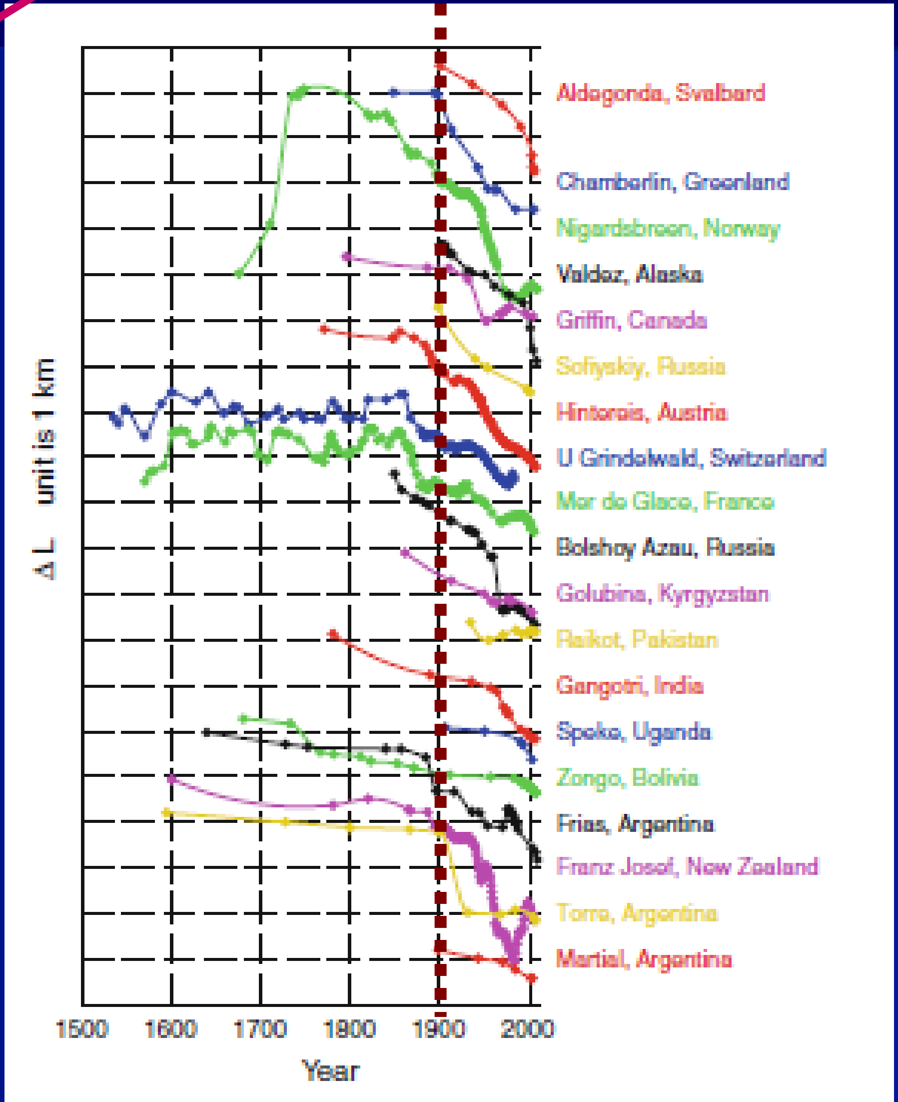
Global glacier retreat?



Global coherence of glacier variations

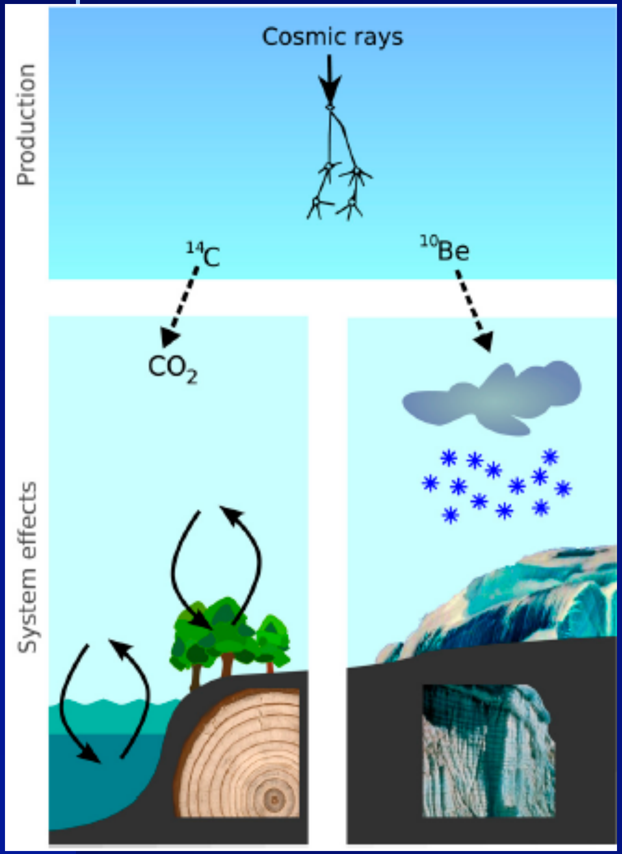


Glacier length variations (1500-2000)



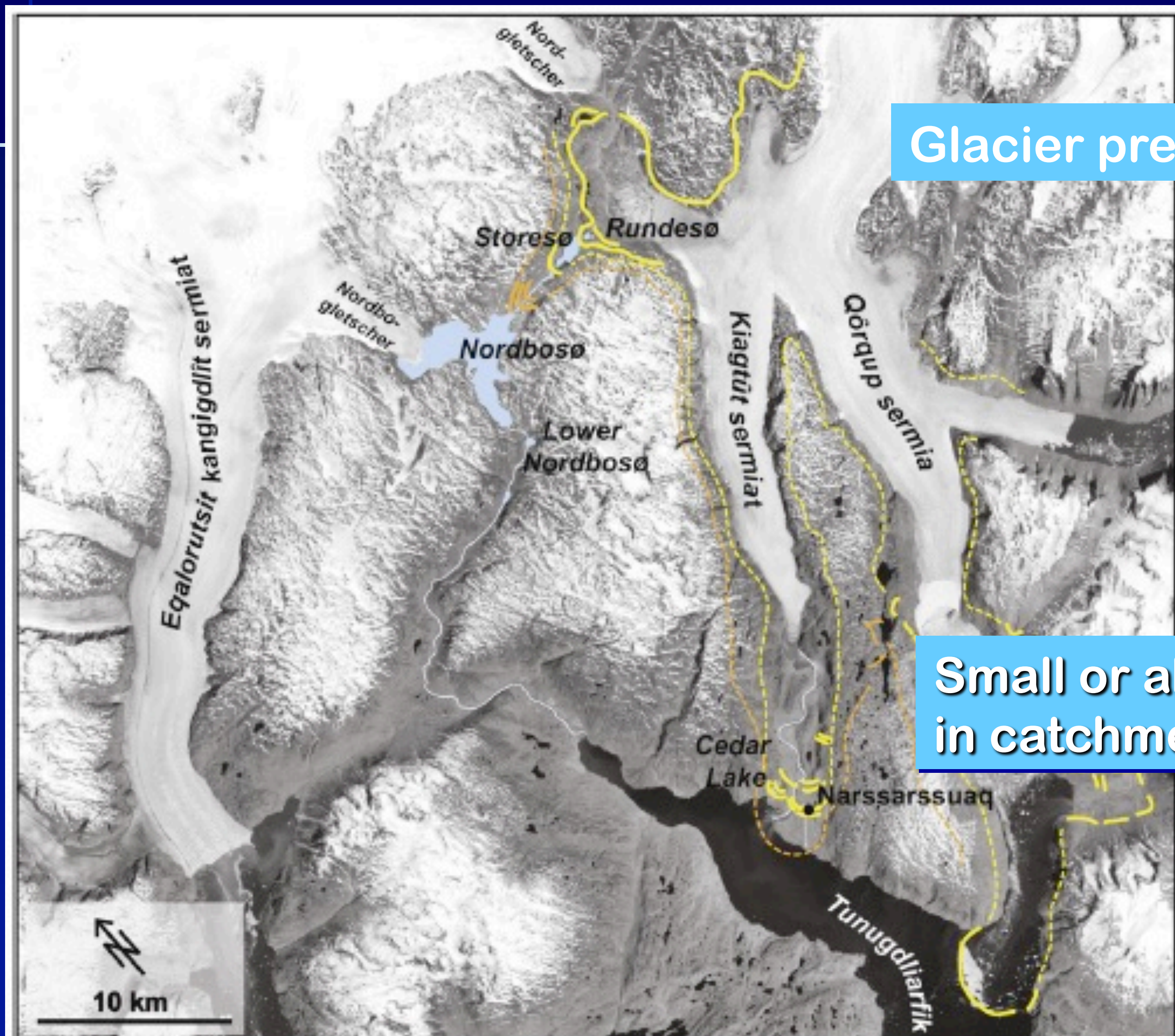
How do we learn about the glaciers in the past?

Glaciers larger than today: moraines



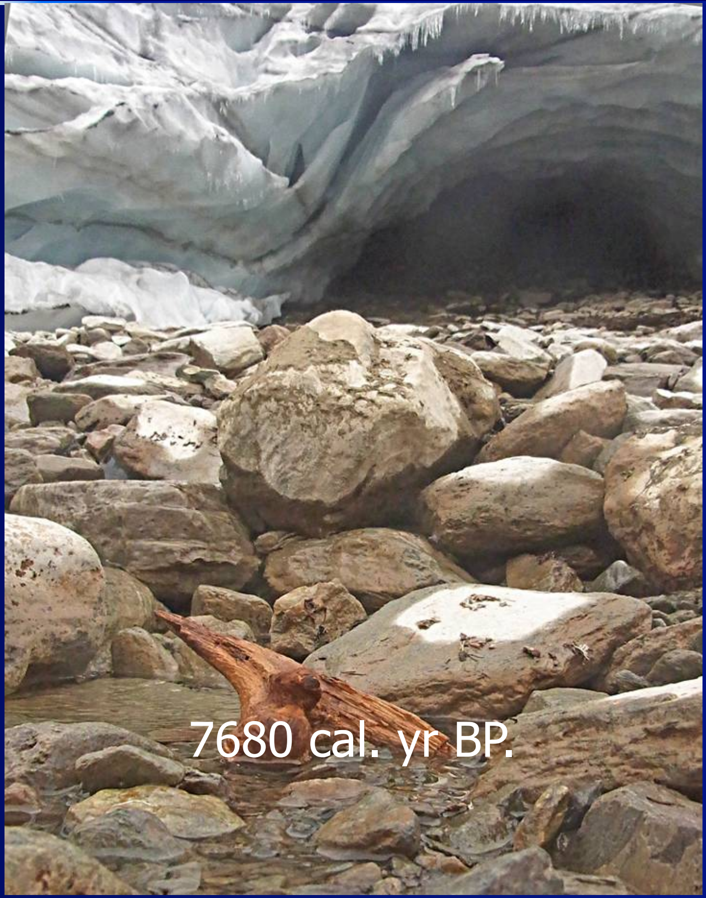
Steinhilber et al., 2011

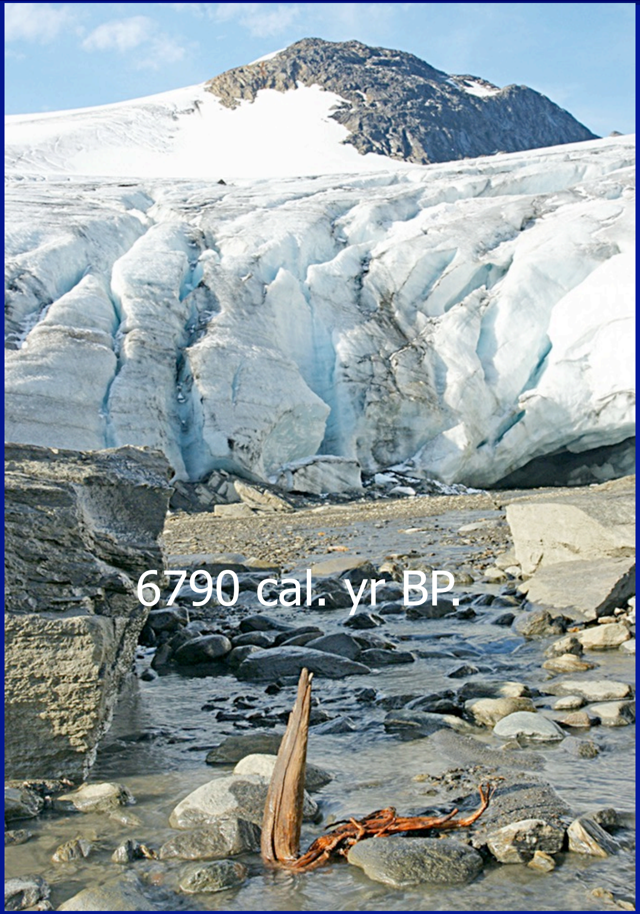
Glaciers smaller than today: lake sediments



(Larsen et al., 2011)

Wood by modern glaciers (Scandes, Sweden)



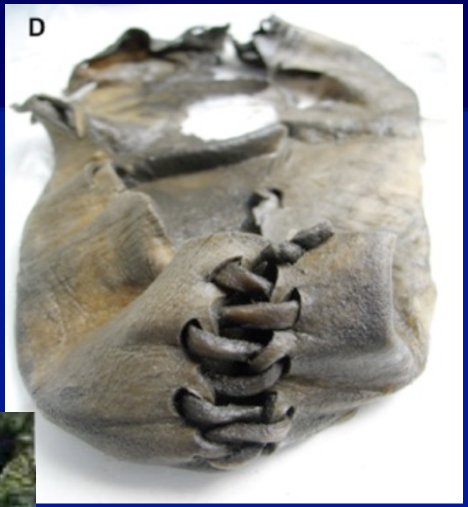


Oeberg, Kullman, 2011

Archeological evidences

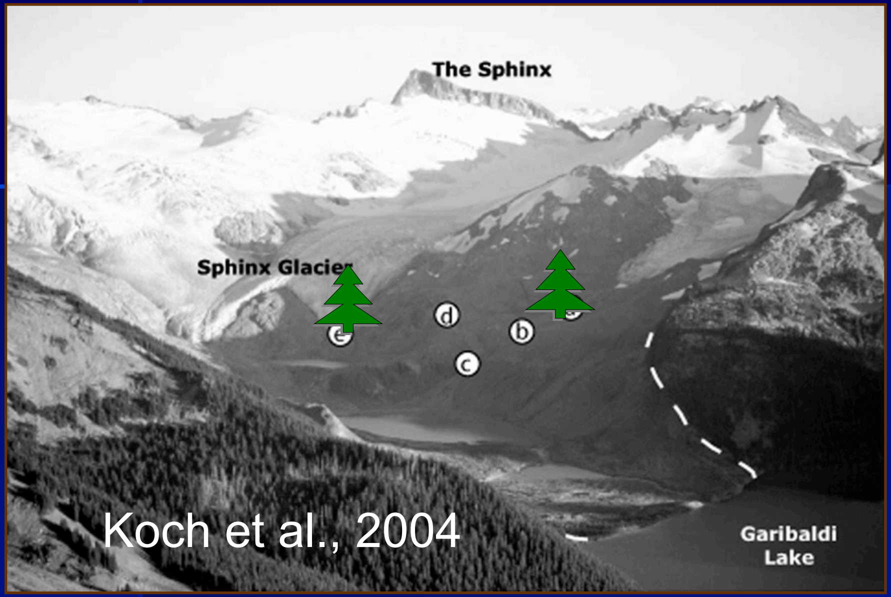
Pocketnife, Canada, 550 yrs BP (Krajvick, 2002)

Oetzi, the alpine iceman
5300 yrs BP,



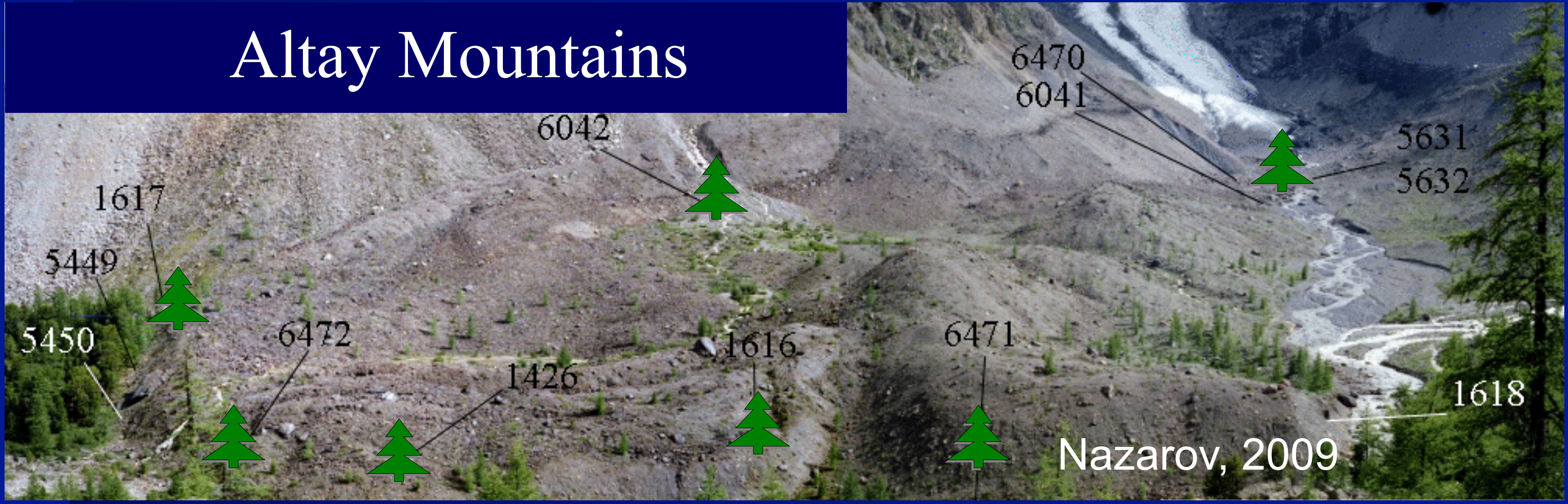
Leather shoe, Norway, ca 3400 yrs BP
(Nesje et al., 2011)

North American Cordillera



The Alps

Altay Mountains

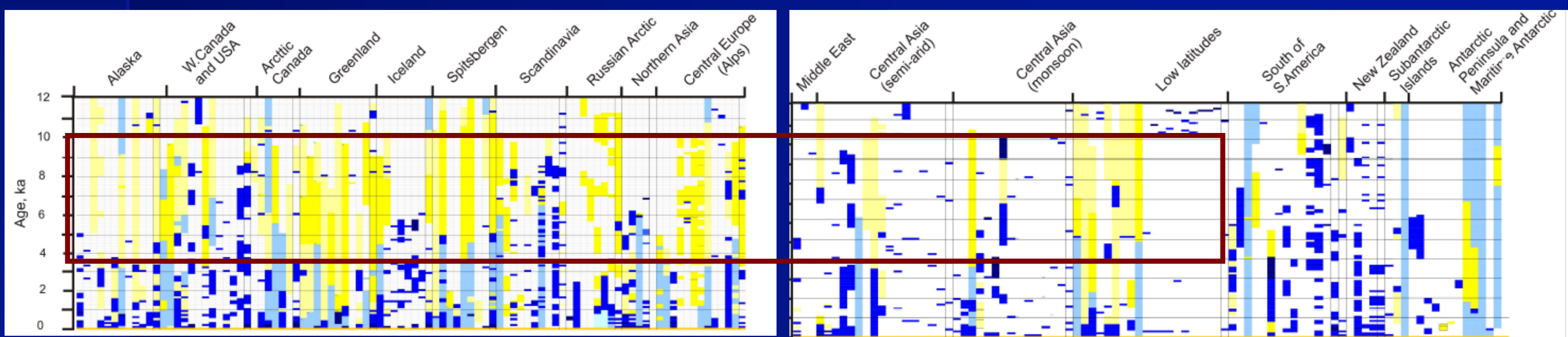


Glacier advances/retreats over the Holocene

12 000 years ago

Northern Hemisphere

Southern Hem.

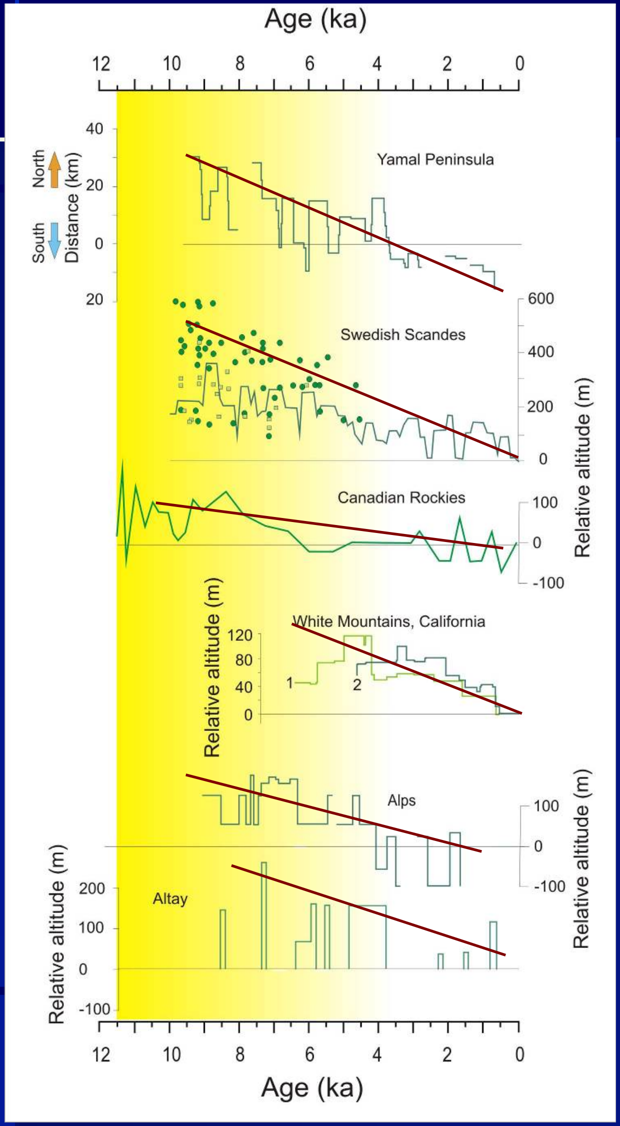


0 years ago

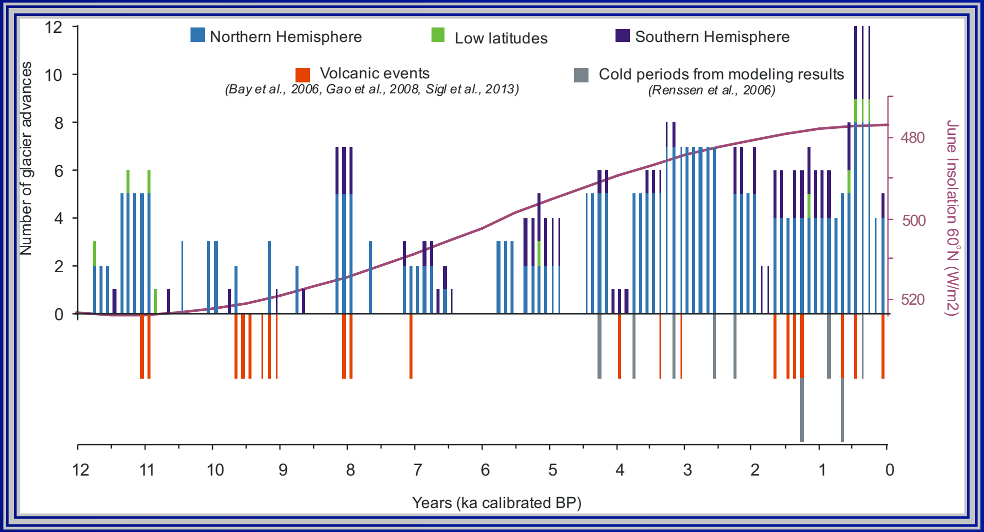
Glaciers were generally smaller than now between ca 10 and 4.5 ka in the high and mid latitudes of Northern Hemisphere

Solomina et al., 2015, QSR

Upper and Northern tree lines in the Holocene

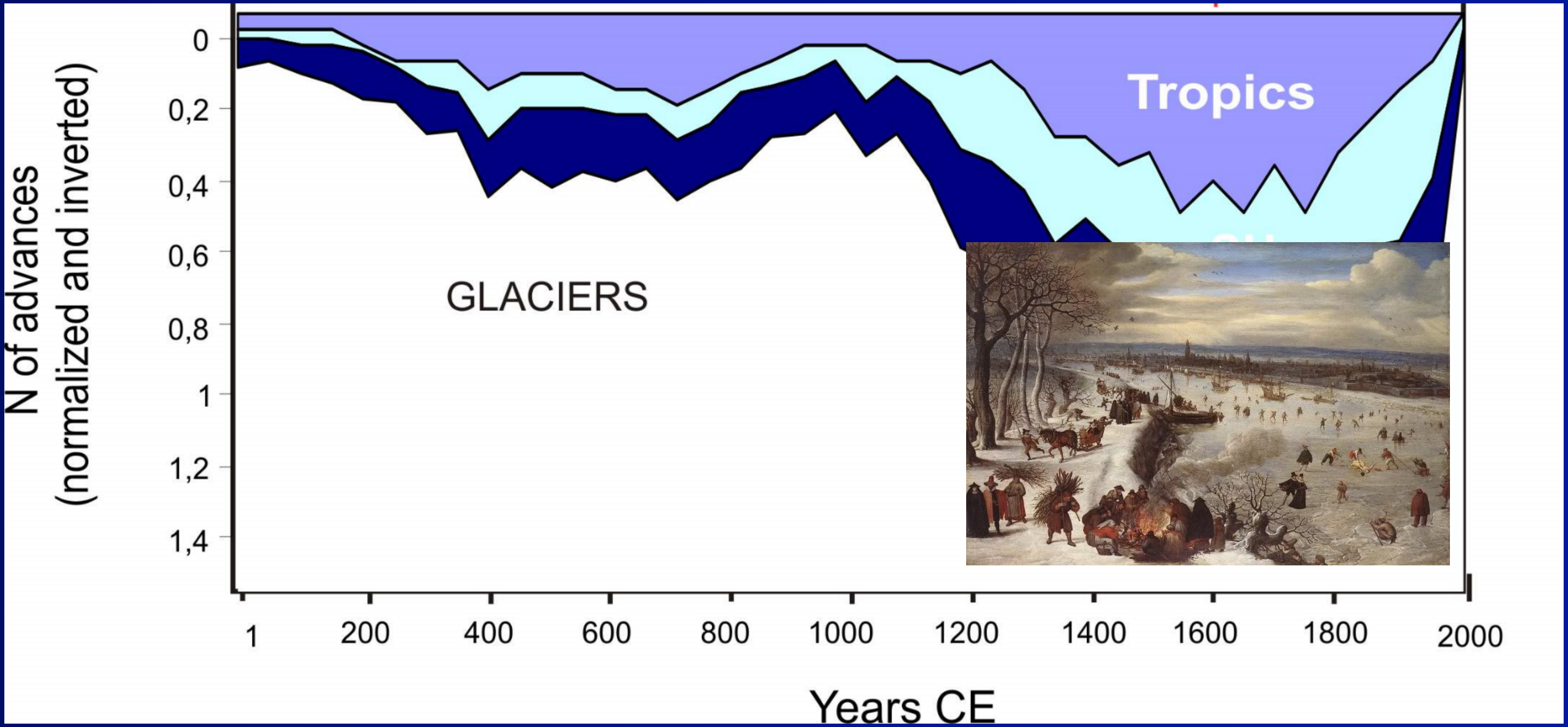


Number of glacier advances in the Holocene



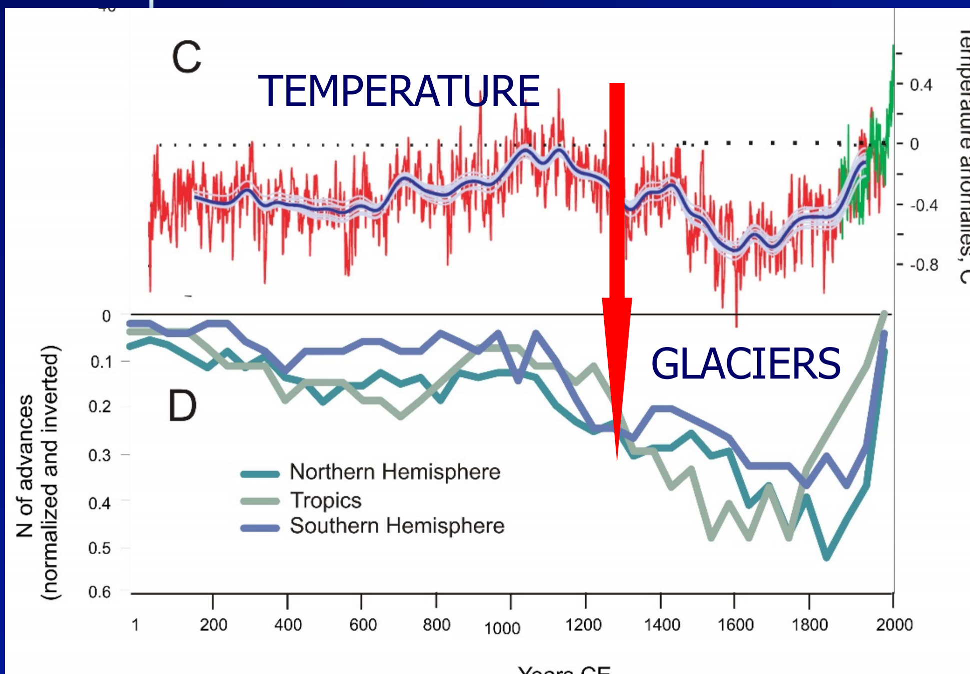
Solomina et al., 2015 QSR

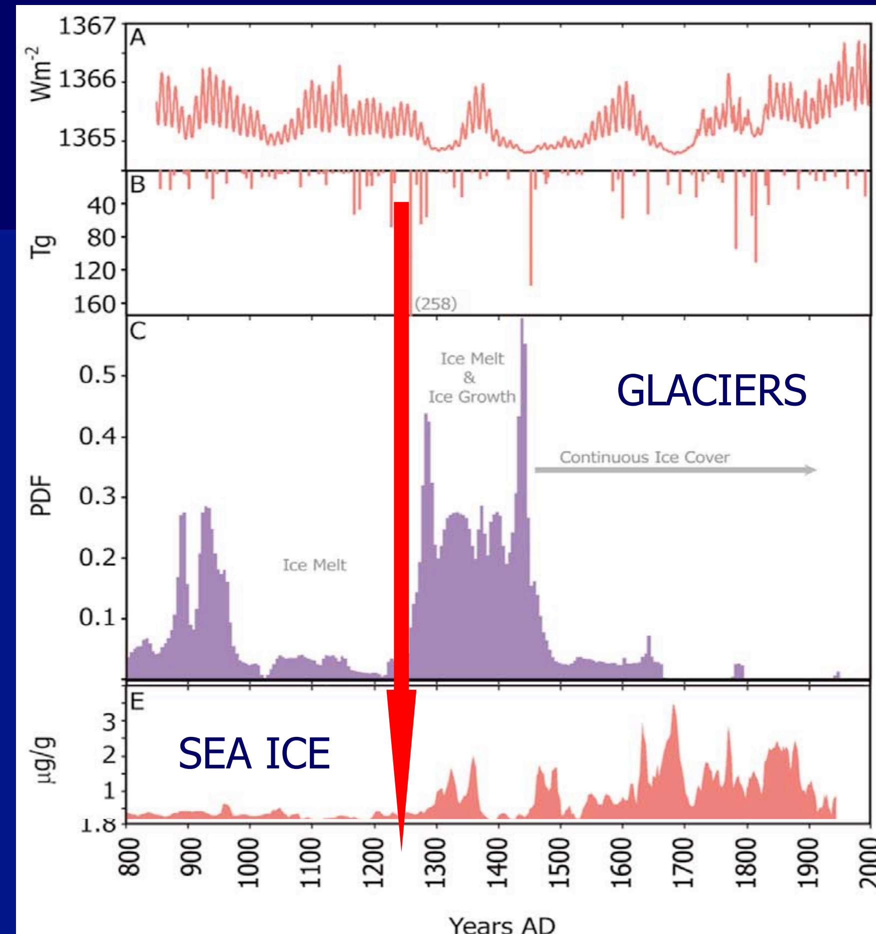
Number of glacial advances in the past 2000 years



Solomina et al., 2016, QSR

Little Ice Age

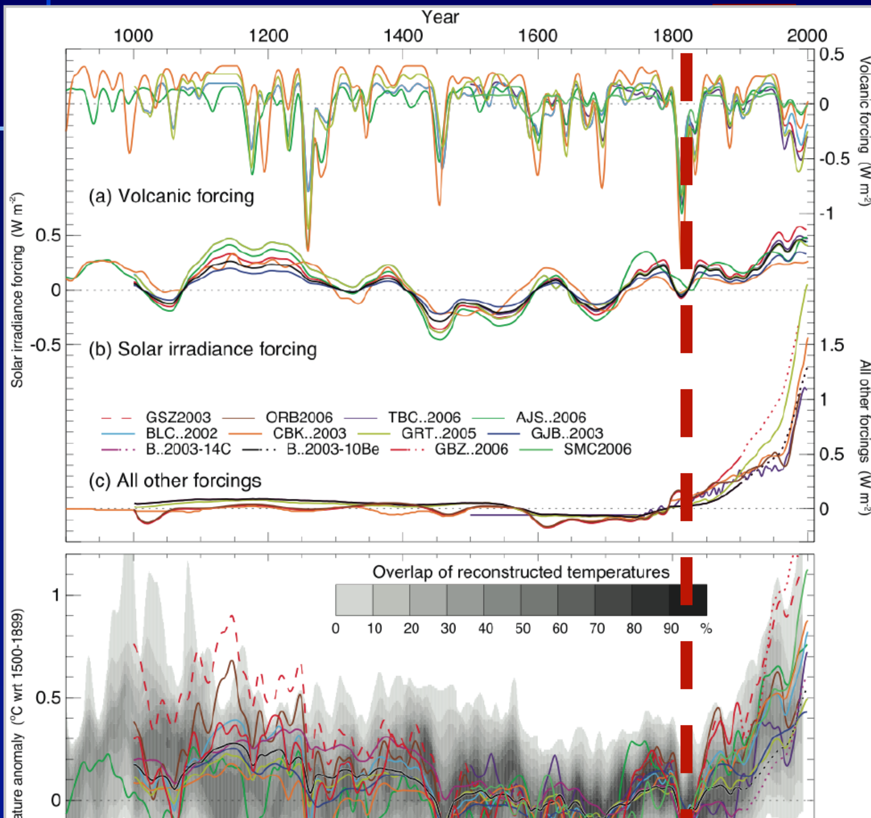


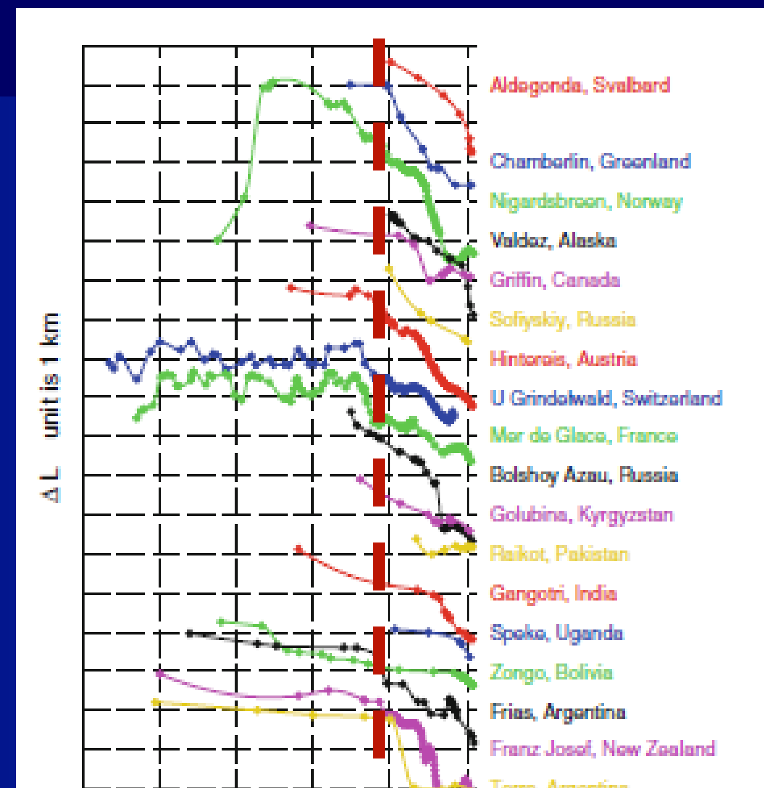


Ice-cap growth from Arctic Canada and Iceland shows that LIA summer cold and ice growth began abruptly between 1275 and 1300 AD, followed by a substantial intensification 1430–1455 AD. Intervals of sudden ice growth coincide with two of the most volcanically perturbed half centuries of the past millennium.

Miller et al., 2012

What is unusual in the modern glacier retreat?





High rates and global character

Radiative forcings and simulated temperatures during the last 1100 years (IPCC, 2007)

Glacier length variations, 1500-2000 CE (Leclerq, Oerlemans, Cogley, 2011)

Future climate?

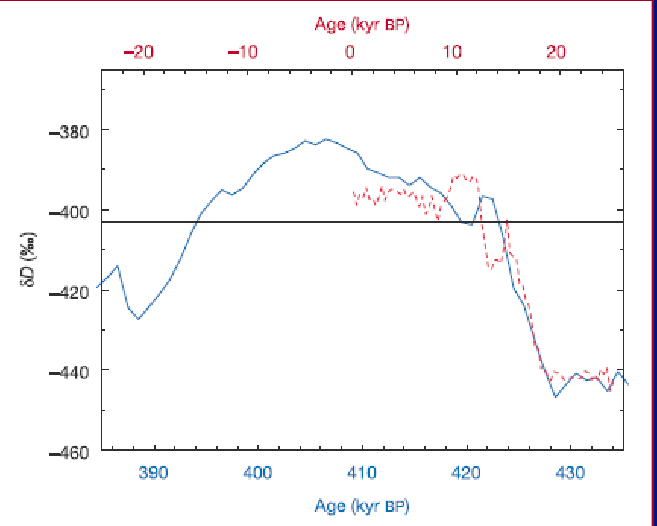
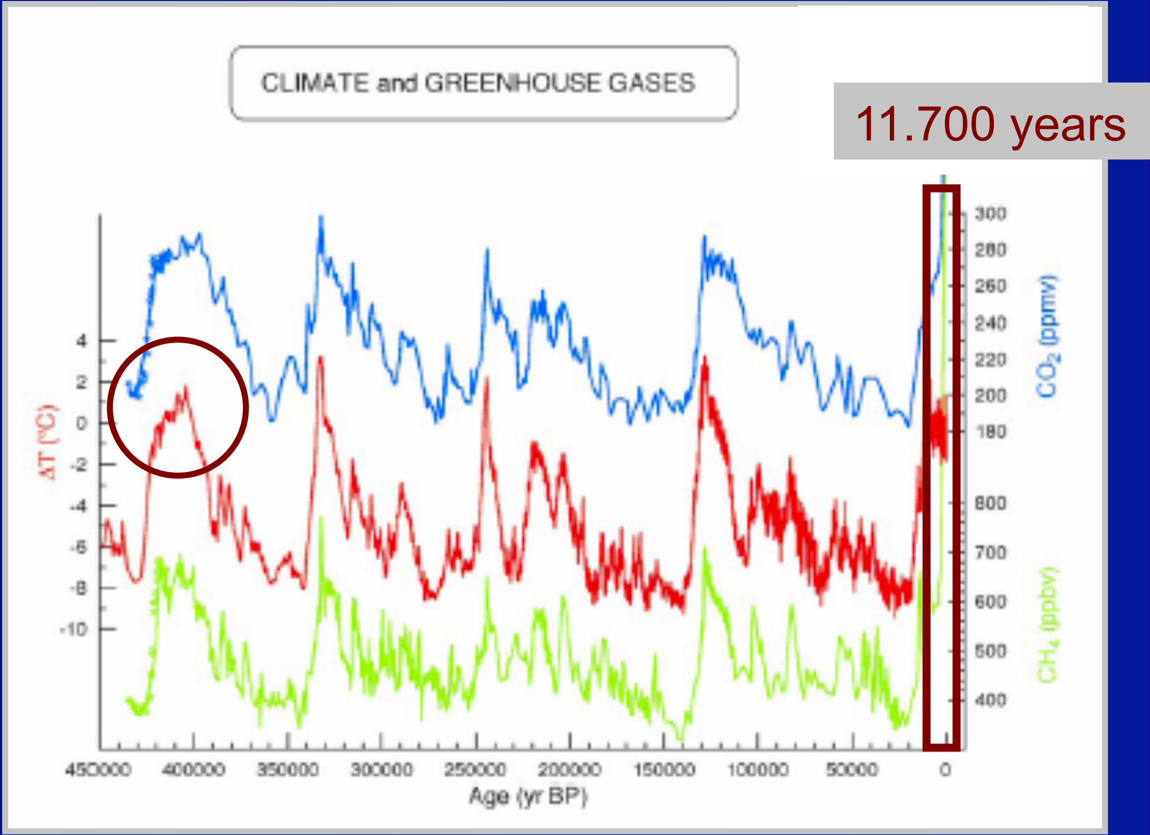


Figure 5 Comparison of Termination V plus MIS 11 with Termination I plus Holocene. δ*D* data for MIS 11 (1-kyr averages) are shown as a solid blue line using the lower *x* axis; data for the Holocene are shown as a dashed red line using the upper *x* axis. Various alignments could be made, but we have adjusted the *x* axes so that the start of each termination is aligned. A horizontal line is drawn at −403‰.



IPCC, 2007

CONCLUSIONS

Glaciers as climatic proxies

- Glacier fluctuations integrate the temperature and precipitation signals, and these signals are often a challenge to separate. However, in the high to mid latitudes of the NH glaciers tend to demonstrate a coherent pattern of fluctuation, despite the great difference in their types, sizes, location and other characteristics.

- The general trends of Holocene glacier fluctuations in the extra-tropical areas of the NH are coherent with the shifts in the Northern and upper tree line. This coincidence is mutually supportive and is consistent with summer temperature as the driver in Holocene glaciation.

- In some cases the large changes inferred from glacier records are more pronounced than reconstructions based on high resolution records (i.e., lakes sediments, tree-rings, ice cores) and models driven by solar forcing. This observation may indicate that other proxies and model results tend at times to underestimate the amplitude of Holocene climate change.

Long-term Holocene glacier changes (orbital scale)

- The role of orbital forcing in Holocene glacier variability is most evident in the magnitude of long-term glacier advances in the high and mid latitudes of the NH, where glaciers were generally small in the Early to Mid Holocene and were progressively more extensive in the second half of the Holocene.

- In the SH, glaciers in New Zealand appear to follow the orbital trend, which are opposite to the NH.

- Glacier fluctuations in monsoonal Asia and in Southern South America generally do not correlate with the orbital trends, instead responding to more high resolution forcing in these regions.

- In both hemispheres, glacier advances in the Mid Holocene (between ca 8 and 5 ka) were generally small in comparison to their LIA magnitudes. A general trend of increased glacier activity in Neoglacial time (after ca 5 ka) is also evident in both hemispheres, although the beginning of the Neoglacial advances may differ substantially over the regions.

Centennial glacier variability in the Holocene

- The accuracy and coverage of the records is still too low to assess the global or regional synchronicity of advances at the centennial scale with high confidence.
- At least some groups of glacier advances were clustered -- for example, the advances at 11.0-11.4 ka documented in the NH and in the tropics, the events at 9.1-9.2 ka and 8.0-8.4 ka recorded in the NH and SH.
- Glacier records presently do not provide firm proof for global synchronism through the Holocene on the centennial to millennial scale. However, the lack of such synchroneity can be also connected to the limitations of these records.

Solar and volcanic forcing and internal variability as triggers of Holocene glacier variations

- Glacier advances clustering at 4.4-4.2 ka, 3.8-3.4 ka, 3.3-2.8 ka, 2.6 ka, 2.3-2.1 ka, 1.5-1.4 ka, 1.2-1.0 ka and 0.7-0.5 ka correspond to general coolings in the North Atlantic. It has been noted that these cooler periods correspond to multidecadal periods of low solar activity, while the cluster of glacier advances at 1.7-1.6 ka does not fit to this pattern, but it does correspond to very strong volcanic eruption of Taupo (New Zealand).

- Due to covariance between Grand Solar Minima (Steinhilber et al., 2009) and large tropical volcanic eruptions (PAGES Consortium, 2013) it is sometimes difficult to separate the forcings of cooling episodes that led to glacier advances.

- Internal (chaotic) variability can also trigger climate conditions (e.g. the domination of a long lasting La Niña) that may be favorable for glacier advances in some regions.

Modern glacier retreat in the Holocene context

- There is much evidence of unusual glacier behavior in the last century (and especially in the last few decades) in many regions compared to Holocene glacier changes. The recent exposure of organic material buried under the ice since the Early to Mid Holocene in some regions is unprecedented for at least the last four to five millennia and in some areas (e.g. in the Canadian Arctic: Miller et al., 2013) possibly since the last interglacial.

- The retreat is occurring at very high rates, is almost universally global in scale and is acting during an interval of orbital forcing favorable for glacier growth, rather than degradation. This highlights the remarkable consequences of anthropogenic forcing on glaciers worldwide.

The End