

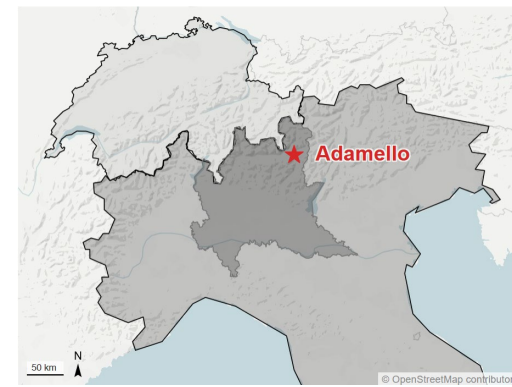


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Dating of ice cores from temperate glaciers

Significant mass loss in the accumulation area of the Adamello glacier (Italy) indicated by the chronology of a 46 m ice core

Contributors and Affiliations



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Also see:

Festi, D., Schwikowski, M., Maggi, V., Oegg, K., and Jenk, T. M.: Significant mass loss in the accumulation area of the Adamello glacier indicated by the chronology of a 46 m ice core, The Cryosphere Discuss. [preprint], <https://doi.org/10.5194/tc-2020-334>, in review, 2020.

Abstract

Dating glaciers is an arduous yet essential task in ice core studies, which becomes even more challenging for the dating of glaciers suffering from mass loss in the accumulation zone as result of climate warming.

Here, we present the dating of a 46 m deep ice core from the Central Italian Alps retrieved in 2016 from the Adamello glacier (ADA16, Pian di Neve, 3100 m asl.). We show how the timescale for the core could be obtained by integrating results from the analyses of the radionuclides ^{210}Pb and ^{137}Cs with annual layer counting (ALC) derived from pollen and refractory black carbon (rBC) concentrations.

Our results clearly indicate that the surface of the glacier is older than the drilling date by about 20 years, with the 46 m ice core reaching back to around 1944. Despite the severe recent mass loss affecting this glacier in the accumulation zone, we show that it is possible to obtain a reliable timescale for such a temperate glacier.

These results open new perspectives to examine the potential of such glaciers as palaeo-archives. With about 270 m of total ice thickness at the ADA16 drill site, this archive potentially provides access to several thousand years of local and regional climate and pollution history. Dating and investigating what parameters / signals are preserved under these temperate conditions (melt water) will be the challenging task of future work.

Motivation

Because of meltwater percolation occurring in temperate glaciers, proxies such as soluble ions and stable isotopes can be disturbed, resulting useless also for dating (by annual layer counting) when the seasonality in the signal is lost. The present-day state of signal preservation in to date still cold glaciers but more recently affected by the current warming trend needs thorough testing, and an urge exists to retrieve these valuable archives of the past before they will be permanently compromised, or even completely vanished.

In the near future, even the rather few still existing cold glaciers from mid- and low- latitudes are predicted to soon transition into a temperate state. To our knowledge, so far only few ice cores from temperate high elevation glaciers could successfully be dated (see e.g. Kang et al., 2015; Pavlova et al., 2015; Kaspari et al., 2020; Gäggeler et al., 2020). Among them, an ice core from Silvretta Glacier (Eastern Alps, Switzerland; Pavlova et al., 2015).

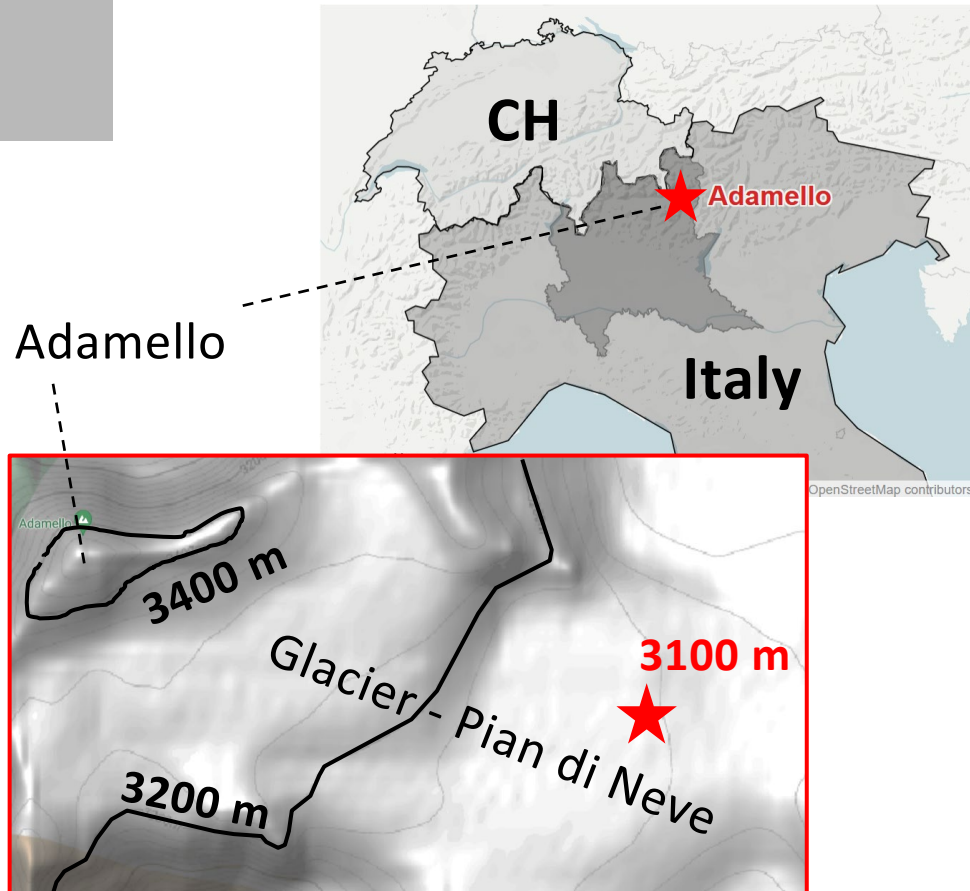
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Pavlova et al., Environ. Sci. Technol., 49(24), 14085-14091. <https://doi.org/10.1021/acs.est.5b03303>, 2015.

Kaspari et al., J. Geophys. Res-Atmos., 125, e2019JD031126. <https://doi.org/10.1029/2019JD031126>, 2020.

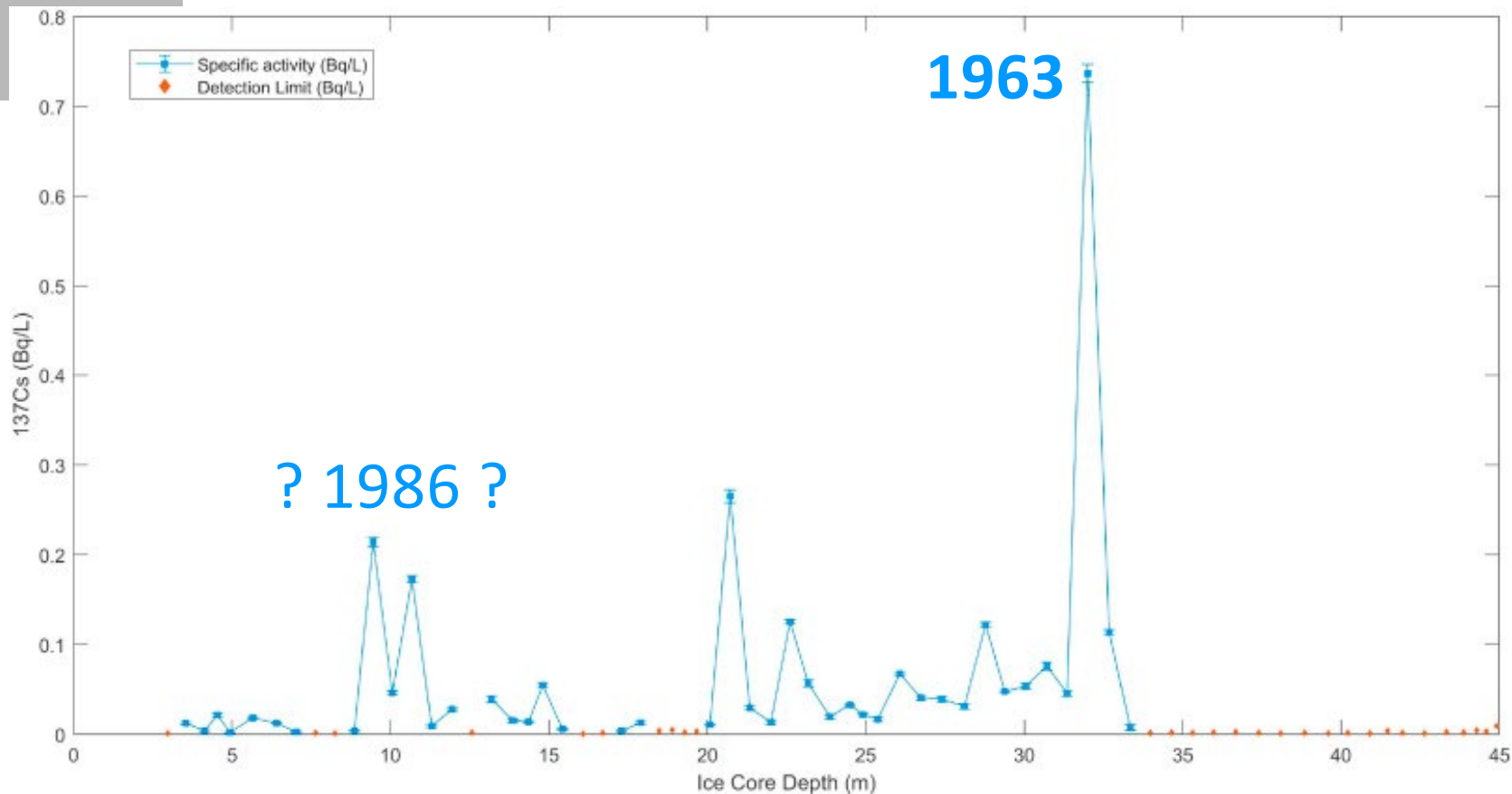
Gäggeler et al., J. Glaciol., 66(257), 447-456. doi:10.1017/jog.2020.19, 2020.

Study site



★ Drilling site

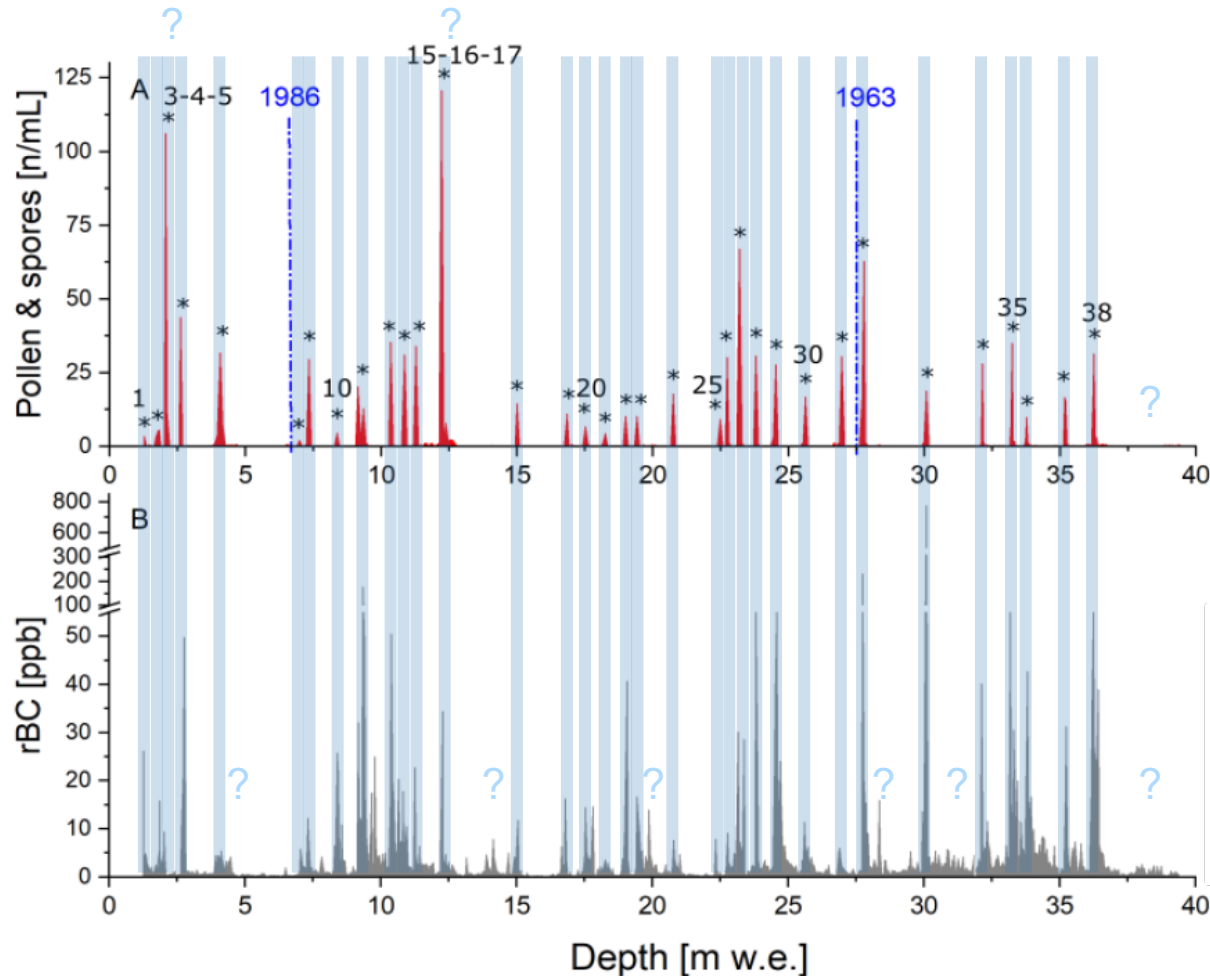
- Maps showing the locations of the Adamello and the drilling site on the glacier plateau Pian di Neve.
- The Adamello is the largest glacier in Italy with an extension of 16,3 km² but located at a relative low elevation of 2500-3400 m asl. and currently affected by considerable mass loss even in the (former) accumulation zone.
- The 46 m deep ice core ADA16 was drilled with an electro-mechanical drill in April 2016 (WGS84: 10.52 E, 46.15 N). Prior to drilling, a 3.1 m trench was excavated, removing the fresh winter snow.

Previous work – ^{137}Cs horizons ^{137}Cs profile, specific activity (Bq/L) vs. mean depth (m).

- Di Stefano et al. (2019) showed that in glacier ice ^{137}Cs is tightly bound to insoluble particulate matter inside the ice core.
- They detected a distinct peak in ^{137}Cs activity (low background γ -spectroscopy), attributed to the maximum fallout from surface nuclear bomb testing in the year 1963.
- Another, decoupled peak was hypothesised to reflect the signal of the 1986 Chernobyl accident.

Dating approach – Annual layer counting (ALC)

Pollen and Black Carbon (soot, here rBC): Relatively large particle size, attachment to other rather immobile, larger particles such as mineral dust. Previously shown to be robust parameters in terms of signal preservation even under the potential influence from melt water percolation.



- Both, pollen and rBC concentrations show a marked seasonal signal, with 34 synchronous peaks occurring throughout the ADA16 ice core.
- ALC indicates that the second peak in ^{137}Cs at 9.5 m depth (6.6 m w.e.) identified by Di Stefano et al. (2019) indeed reflects the signal of the 1986 Chernobyl accident.

1986, 1963: ^{137}Cs horizons (Di Stefano et al., 2019)

* : Counted years (Pollen & spore peaks coinciding with rBC peaks)

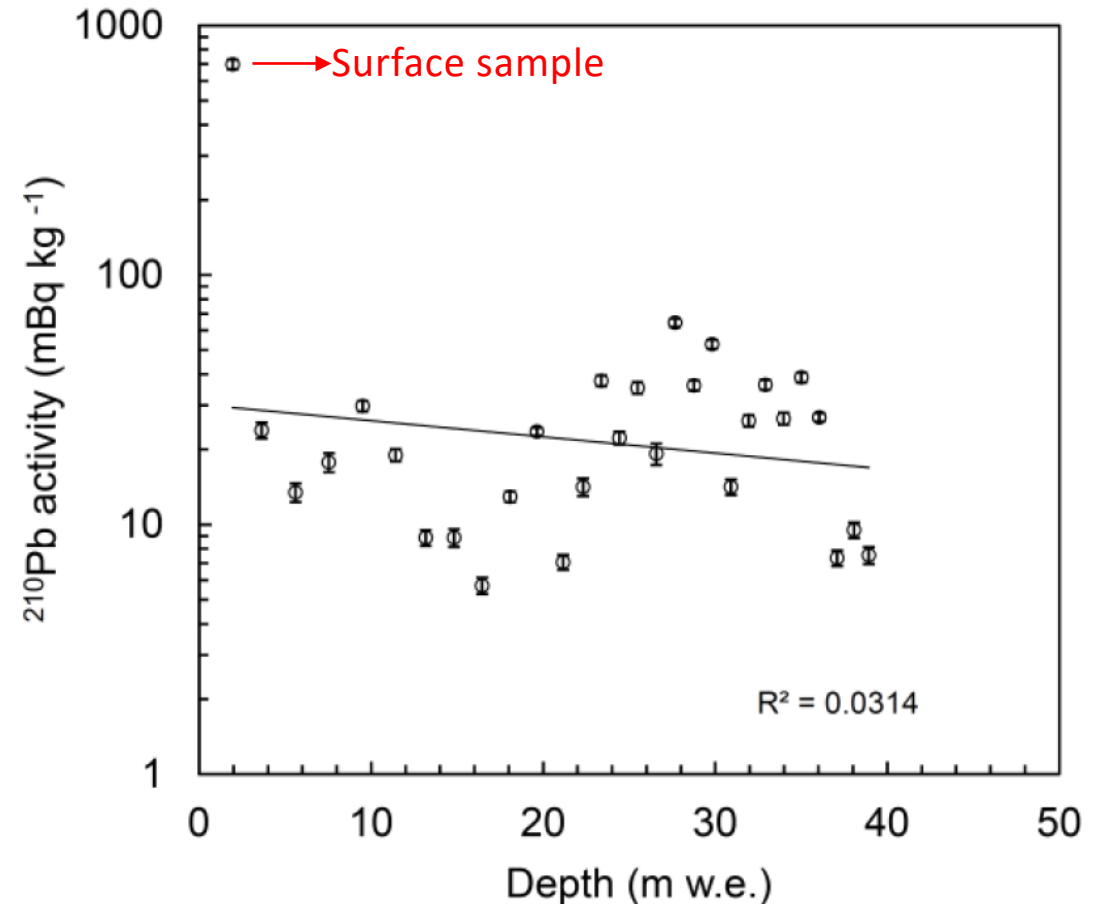
x-y-z : Multiple years in one layer (enriched, no/negative accumulation)

? : Uncertainty in the annual layer counting (ALC)

3rd independent dating method applied

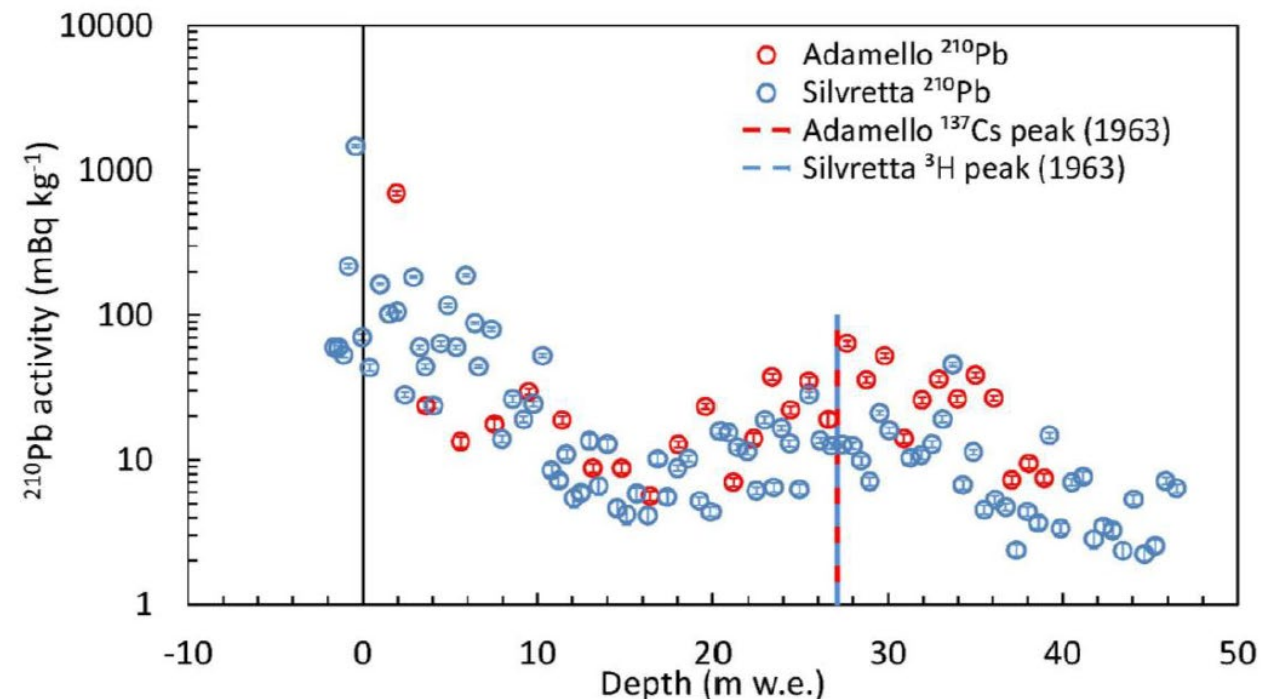
- Not a typical profile of exponential decrease with depth as expected due to radioactive decay over time ($T_{1/2} = 22.3 \text{ a}$).
- Very high activity concentration in the surface sample, typically around 100 mBq/kg in the Alps → Enrichment at surface = integrated activity of lost annual snow/ice layers: 13 annual layers lost (a lower limit estimate considering the likelihood of partial run-off).

ADA16 profile of ^{210}Pb activity concentrations.



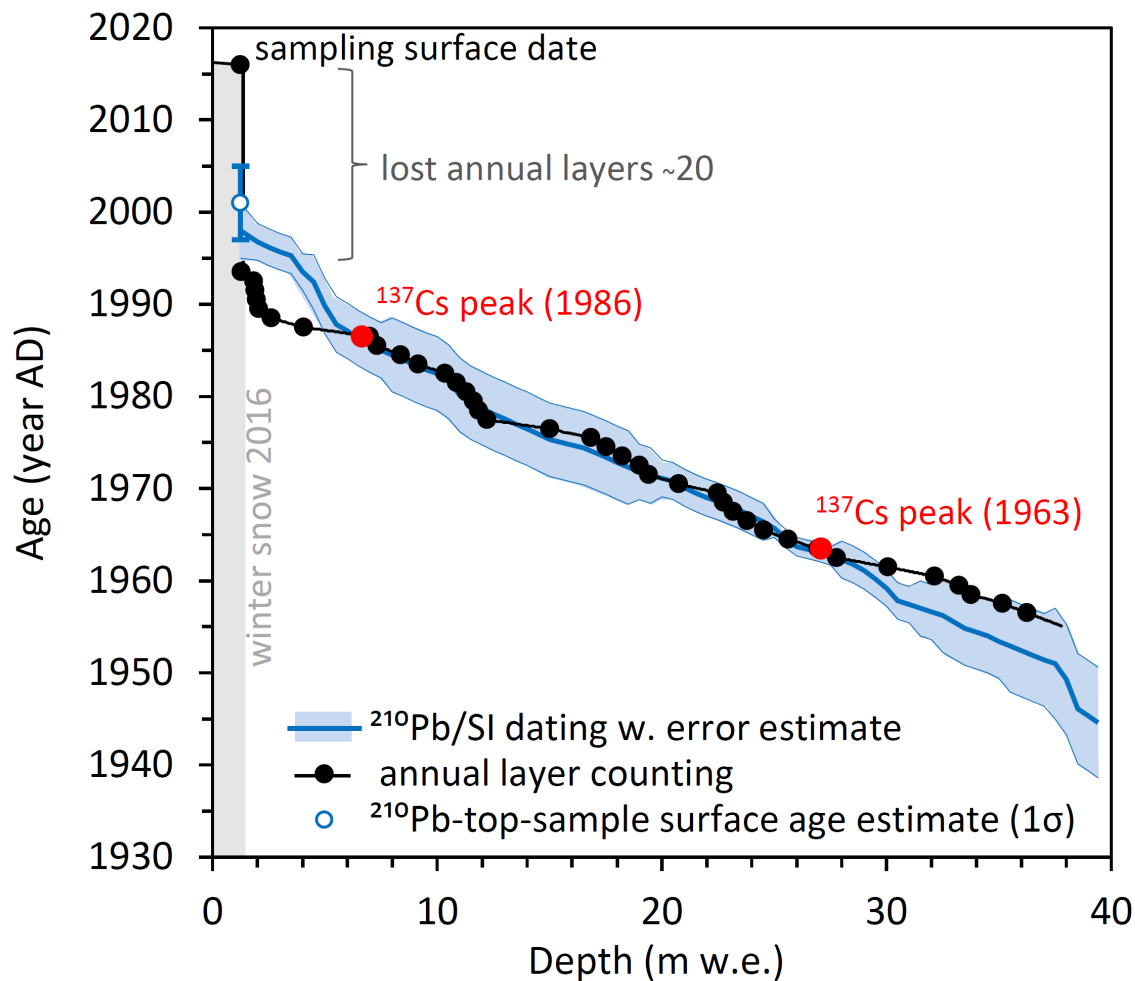
3rd independent dating method applied – confirmation of the dating by ALC

ADA16 and previously dated Silvretta ice core: striking resemblance in ^{210}Pb profile patterns.



^{210}Pb profiles aligned by shifting the Silvretta depth scale by -1.8 m w.e. to match the 1963 horizon observed in both cores.

Final dating – ALC supported by two independent methods



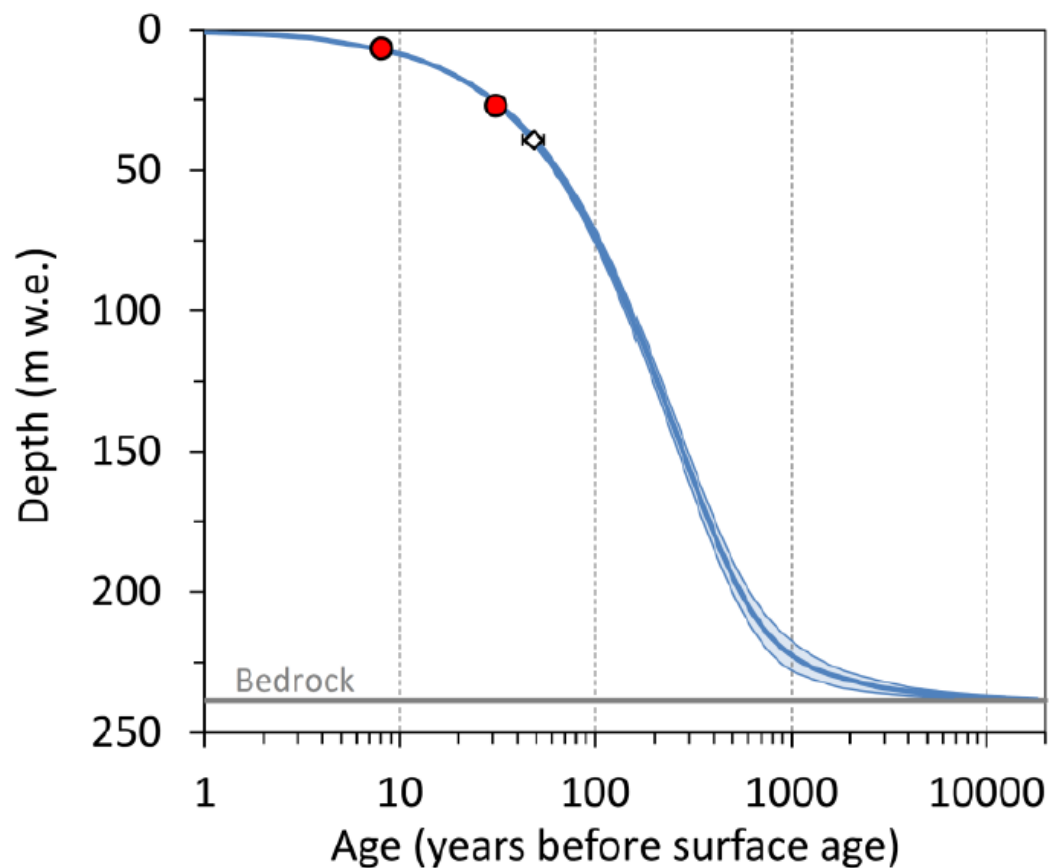
The ADA16 age-depth relationship

Independently derived from:

- (1) ALC using pollen and rBC concentrations in combination with the distinct time markers from the nuclear accident of Chernobyl (1986) and the nuclear surface bomb testing maximum (1963) identified by peaks in ^{137}Cs activity and
- (2) based on ^{210}Pb (i.e. the age-depth scale with uncertainty of the Silvretta ice core transferred to ADA16).

- **Loss of about 20 years of snow accumulation at Pian di Neve.**
- **Previous annual mean net accumulation rate of 0.8 -0.9 m w.e.**

Outlook



Rough age-depth estimate for the entire, radar defined glacier thickness of 270 m at the ADA16 drill site (1-D Dansgaard-Johnsen glacier flow model). Red dots show the 1986 and 1963 ^{137}Cs horizons used to fit the model. The estimated age at the bottom of the core is shown in addition but was not used for the tuning (open diamond). The shaded area indicates the 95% model confidence interval.



Drilling to bedrock: 7-19 April 2021

- **Potential archive covering > 1000 years of local and regional climate and pollution history.**

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