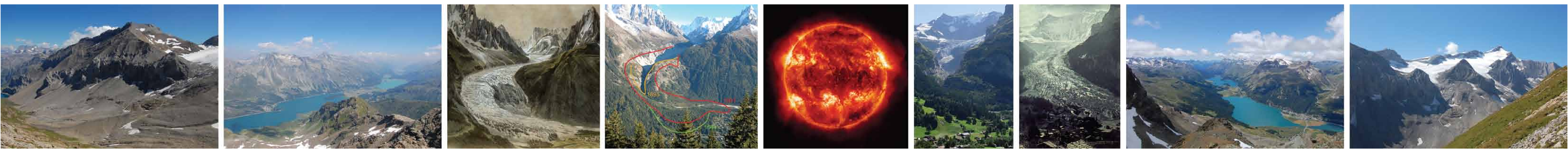
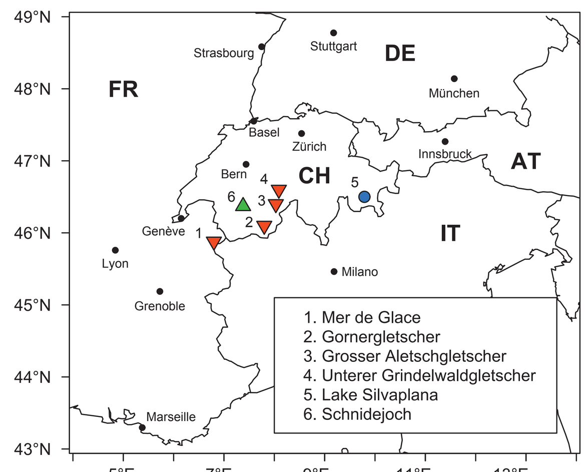
Alpine climate during the Holocene: a comparison between records of glaciers, lake sediments and solar activity

S. U. Nussbaumer,[1,2,3] F. Steinhilber,[4] M. Trachsel,[1,2,5] P. Breitenmoser,[1,2] J. Beer,[4] A. Blass,[4,6] M. Grosjean,[1,2] A. Hafner,[7] H. Holzhauser,[2] H. Wanner[1,2] and H. J. Zumbühl[1,2]

[1] Institute of Geography, University of Bern, Bern, Switzerland, [2] Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland, [3] Department of Geography, University of Zurich, Zürich, Switzerland, [4] Swiss Federal Institute of Aquatic Science and Technology, Surface Waters, Dübendorf, Switzerland, [5] Bjerknes Centre for Climate Research, Bergen, Norway, [6] Colenco Power Engineering, Wasserbau und Umwelt, Baden, Switzerland, [7] Archäologischer Dienst des Kantons Bern, Bern, Switzerland

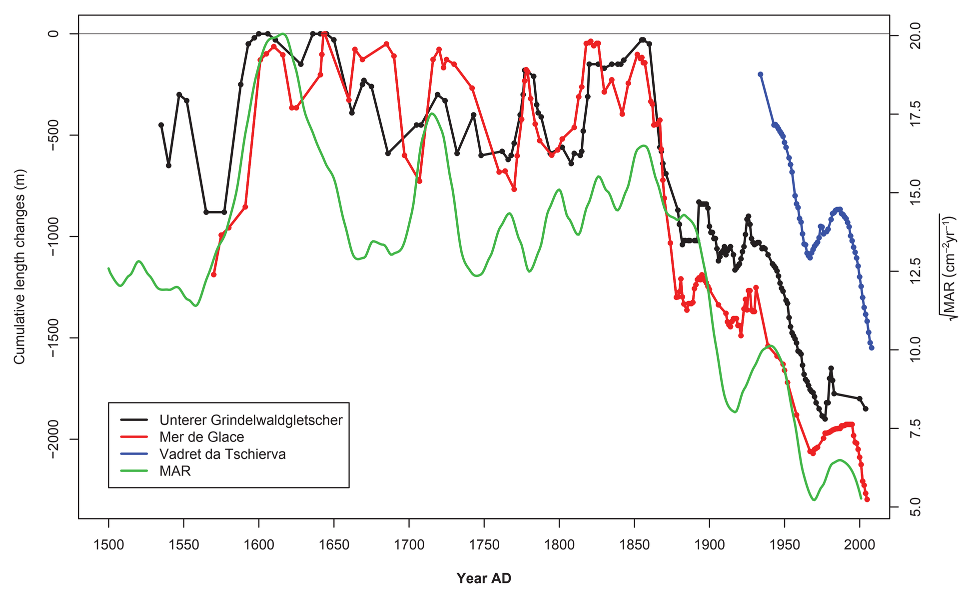


The recent improvement of Alpine glacier length records and climate reconstructions from annually laminated sediments of Alpine Lake Silvaplana gives the opportunity to investigate the relationship between those two data sets of Alpine climate.

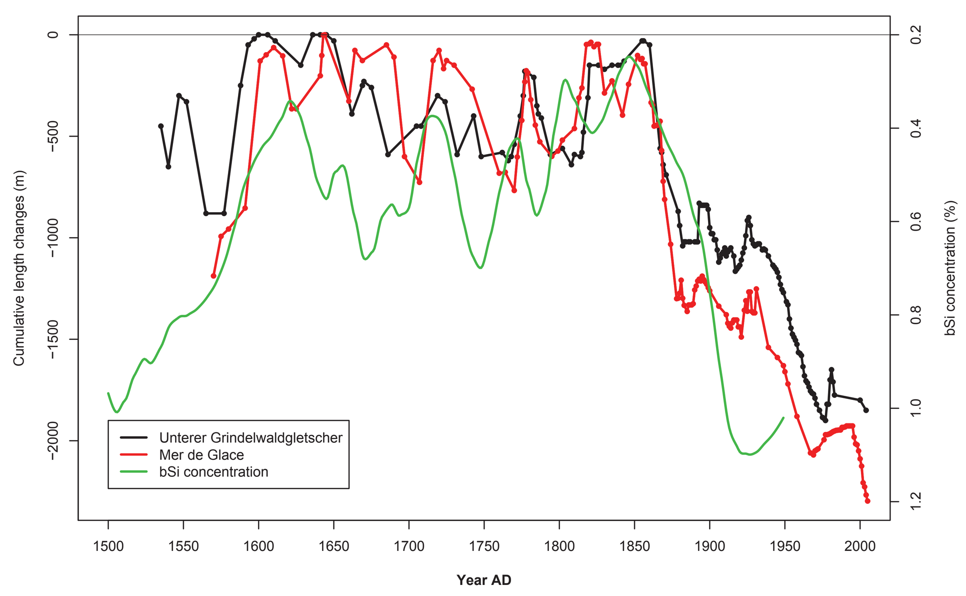


Mer de Glace and Unterer Grindelwaldgletscher are among the historically best-documented glaciers in the world, Lake Silvaplana has one of the best-studied sediment records and represents a situation where glacier input is registered in lake sediments.

Locations of the study sites in the European Alps.



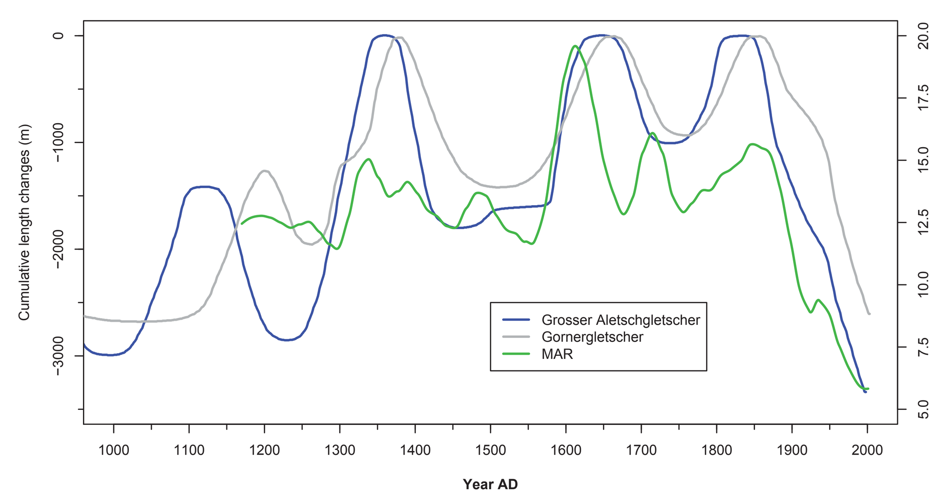
Comparison of Alpine glacier length changes and mass accumulation rates (MAR) in Lake Silvaplana during the past 500 years.



Comparison of glacier length changes and biogenic silica (bSi) concentration in Lake Silvaplana during the past 500 years.

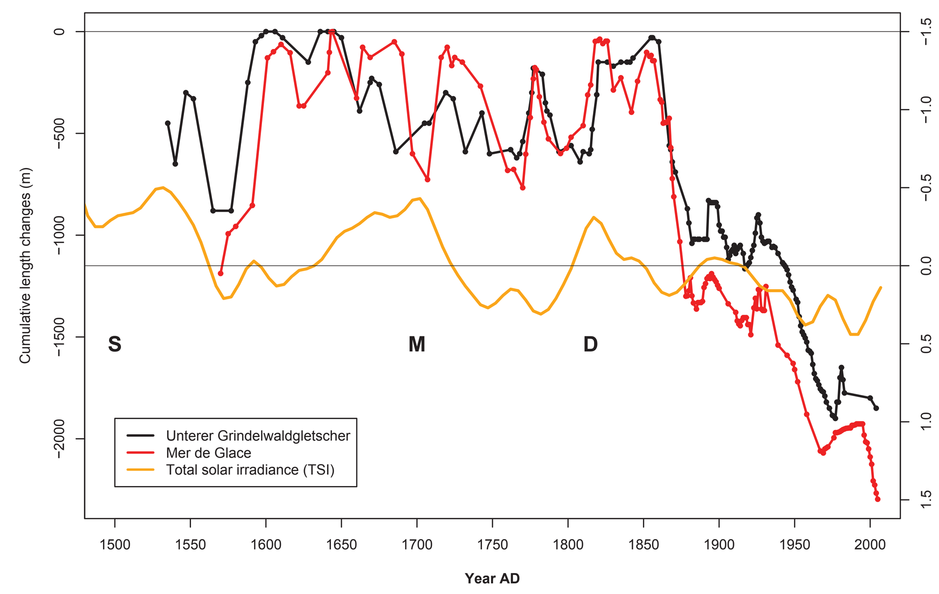
Mass accumulation rates (MAR) and biogenic silica (bSi) concentration are largely in phase with the glacier length changes of Mer de Glace and Unterer Grindelwaldgletscher, and the records of glacier length of Grosser Aletschgletscher and Gornergletscher.

There is a very good agreement between the glacial signal extracted from Lake Silvaplana sediment records and the independently reconstructed glacier variations during the last millennium.

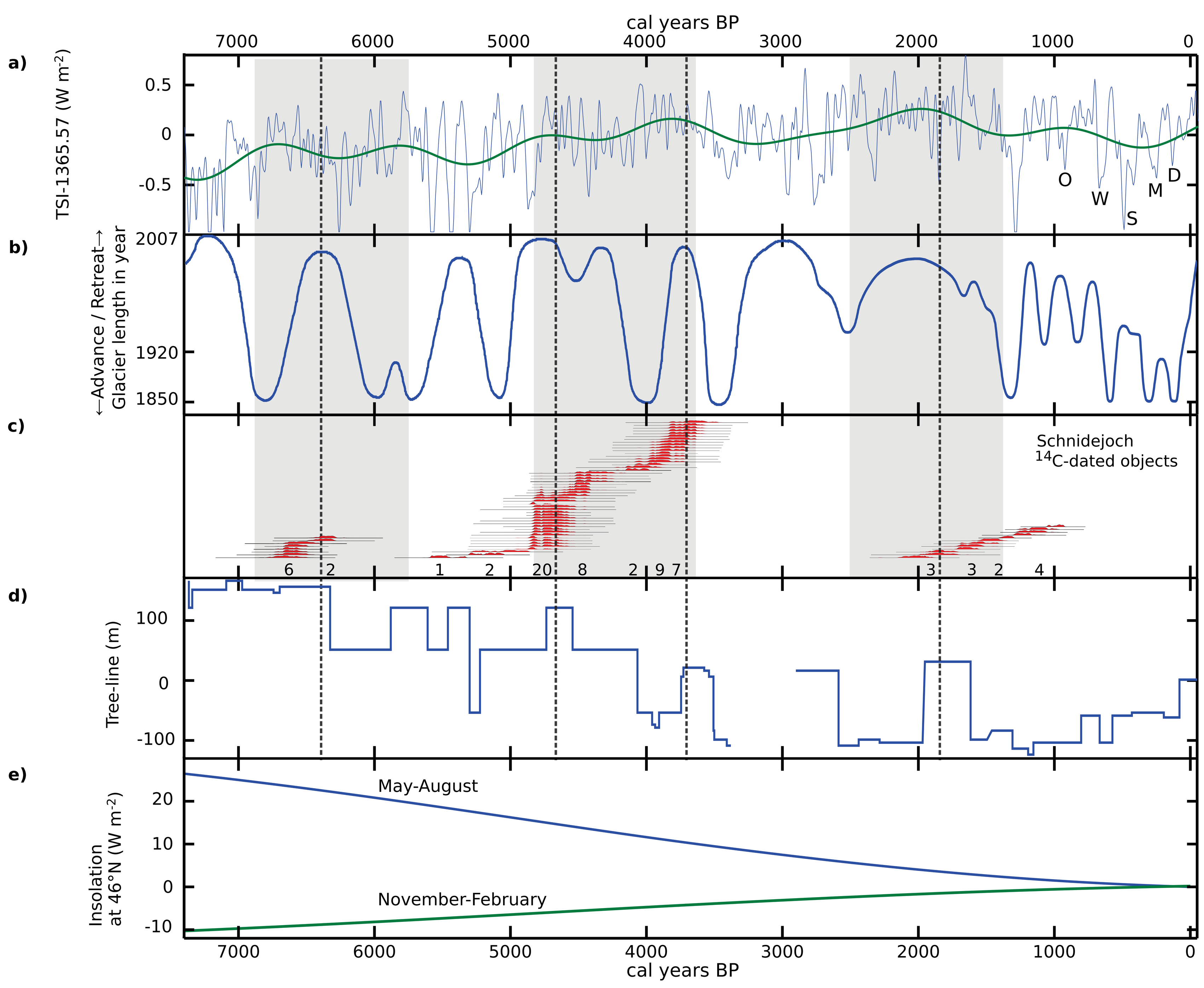


Comparison of long-term glacier length variations with mass accumulation rates (MAR) in Lake Silvaplana.

On short timescales (500-1000 years) the influence of the Sun cannot be easily detected in Alpine climate change, indicating that in addition to solar forcing volcanic influence and internal climate variations have played an important role.



Comparison of glacier length changes relative to the LIA maximum and solar activity (total solar irradiance; TSI) during the past 500 years.



We find that the Sun has had a major impact on the Alpine climate variations in the long-term, i.e. several centuries to millennia. Solar activity varies with the Hallstatt periodicity of ca. 2000 years. Hallstatt minima are identified around 500, 2500, and 5000 years BP.

The relationship between solar forcing and glacier variations is clearly visible on the long-term, millennial scale fluctuation during the mid- to late Holocene. Alpine glacier advances in the late Holocene were stronger and more prolonged due to reduced orbital insolation in boreal summer (changed orbital forcing as an important background effect).

Comparison of different Holocene climate indicators. Grey bars: Hallstatt cycle maxima. Hallstatt cycle maxima are observed around 6200, 4500, and 2000 years BP, and today.

a) Total solar irradiance curves (grand solar minima: Oort, Wolf, Spörer, Maunder, Dalton).

b) Alpine glacier length curve, calibrated.

c) Archaeological findings at Schnidejoch: calibrated radiocarbon dates given as probability distributions and number of samples.

d) Tree-line in the central eastern Alps relative to today. Today the tree-line is at 2245 m a.s.l.

e) Mean orbital insolation at 46°N in boreal summer (May-August) and winter (November-February) relative to today.

Contact: samuel.nussbaumer@geo.uzh.ch

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