Project STALCLIM Switzerland – where, how and what for?

Anamaria Häuselmann[1,2], Sebastian Breitenbach[3], Adam Hasenfratz[2], Dominik Fleitmann[1,2]

Zusammenfassung: Eines der Hauptziele des vom Schweizer Nationalfonds unterstützten SINERGIA-Programmes “STALCLIM - Multi-proxy climatic and environmental reconstructions from stalagmites from Switzerland, Turkey, Arabia and India”, ist es, mit Hilfe von Stalagmiten aus Schweizer Höhlen hochaufgelöste und gut datierte paläoklimatische Zeitreihen mit Hilfe verschiedener Analysemethoden zu konstruieren. Nachfolgend präsentieren wir eine Liste der Schweizer Untersuchungsgebiete und die beprobten Speläotheme, mit dem jeweiligen Zeitraum welche sie umfassen. Schliesslich werden erste Ergebnisse präsentiert, namentlich δ^{18}O- und δ^{13}C-Kurven von Stalagmit GEF_1 aus der Grotte aux Fées (Waadt) und von Stalagmit MF3 aus dem Alpsteingebiet (Schafsloch-Höhle, Appenzell Innerrhoden).

Summary: “STALCLIM - Multi-proxy climatic and environmental reconstructions from stalagmites from Switzerland, Turkey, Arabia, and India” is a recently SNF-funded SINERGIA program. One goal of STALCLIM goal is to construct highly resolved and precisely dated paleoclimate records from stalagmites sampled in Swiss caves by using a broad array of different analytical techniques. Here we present a list of new sampling sites and the periods covered by the recent collected samples. We also present preliminary results of stable isotope analysis (δ^{18}O and δ^{13}C) performed on stalagmites GEF_1 (Grotte aux Fées, VD) and MF3 (Schafsloch Cave, AI).

Motivation

Until now, speleothems from Switzerland were primarily used for reconstructing cave and surface evolution, valley incision, as well as seismic and neotectonic events (Fig. 1). Very few high resolution analyses of the calcite isotopic composition of the samples were done so far, although during the last 40 years speleothems have developed as important paleoclimatic archives, as proxies for changes in surface temperature and precipitation, as well as providing accurate and independent ages. We have now the possibility for radiometric dating with accuracy as good as 1 % error of the absolute age.

As speleothem deposition in any cave is primarily governed by temperature and the presence of water, they are important indicators of climatic conditions at the surface. In most caves, the oxygen isotopic composition (δ^{18}O) of speleothems is primarily controlled by variations in δ^{18}O of the seepage water and surface precipitation (McDermott, 2004), whereas δ^{18}O of precipitation is related to the source area of the moisture and the air temperature. If we consider the North Atlantic Ocean as source of precipitation for the northern Alps, the δ^{18}O values in stalagmites from these regions directly reflect changes in the mean temperature. Thus, the δ^{18}O values are more negative during lower temperatures and more positive during warm surface temperature.

Isotopic studies on Swiss precipitation reveal that variations in δ^{18}O are related to changes in surface temperatures, whereat δ^{18}O values tend to increase with rising temperature (0.71 ‰/°C at 2000 m and 0.56 ‰/°C at 500 m) (Schürch et al., 2003). Using this relationship and considering the isotopic fractionation during precipitation, δ^{18}O values of stalagmites will not only give us valuable information about the timing of climatic changes, but also deliver a first estimate of the temperature variations at the surface.

The interpretation of the carbon isotopic composition (δ^{13}C) in speleothems is more complicated. Nevertheless, in most cases, changes in δ^{13}C are the likely result from variations in soil microbial activity and vegetation.

Methods and samples

Continuous, high resolution isotope profiles are obtained by drilling along the growth axis with a micro drill, in steps of 0.1 - 0.5 mm. The isotopic composition of each sample (150 - 200 µg) is measured on a Finnigan Delta V Advantage mass spectrometer equipped with an automated carbonate preparation system (GasBench II) at the Institute of Geological Sciences, University of Bern, Switzerland. Future analyses of fluid inclusions and trace elements are planned at the University of Bern and ETH Zürich.

The stalagmites are dated using the 230Th/234U disequilibrium method (^{230}Th hereinafter). 100-200 mg of powder was taken from well determined layers and dated at the Institute of Geological Sciences, University of Bern, Switzerland, and Department of Geology and Geophysics, University of Minnesota, USA.

[1] *Institute of Geological Sciences, University of Bern, Baltzerstr. 1+3, 3012 Bern (ana@speleo.ch)*

[2] *Oeschger Centre for Climate Change Research, University of Bern*

[3] *Geological Institute, Department of Earth Sciences, ETH Zurich, 8092 Zurich, Switzerland*

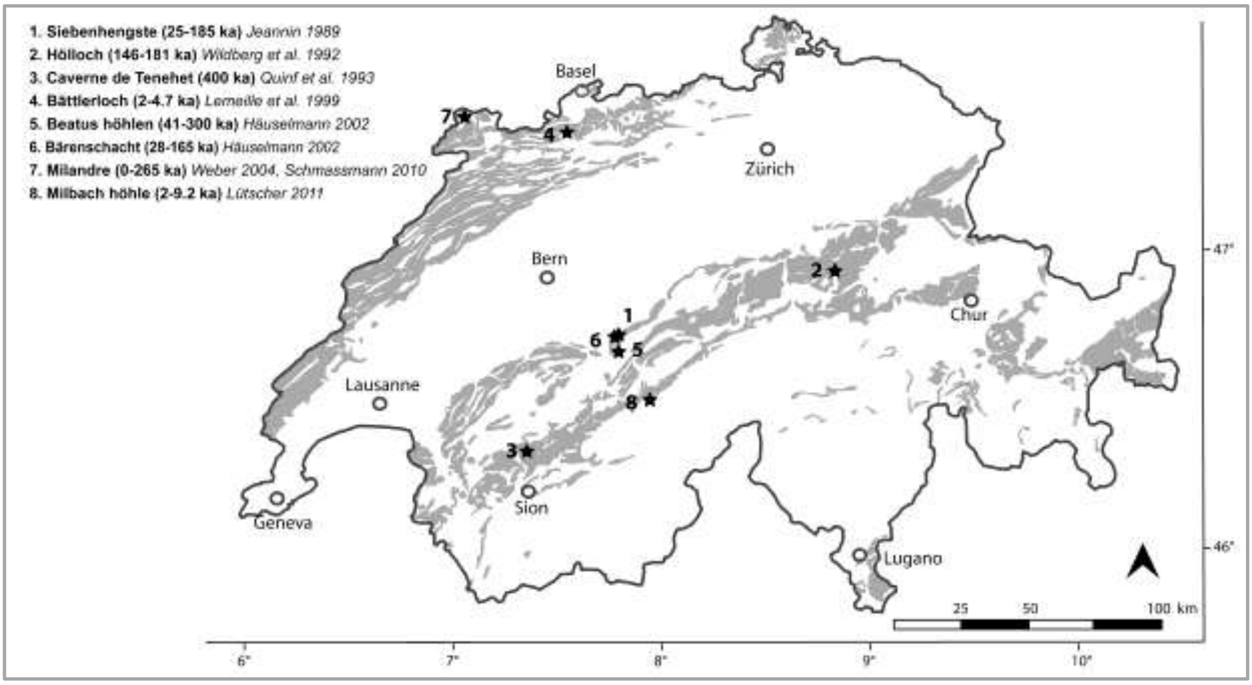

Fig. 1: Karst area in Switzerland (data from SISKA), time interval covered by speleothems studied in different Swiss caves.

Fig. 1: Karstgebiete in der Schweiz (Daten von SISKA), Untersuchungsgebiete dieser Studie und die jeweiligen Zeiträume, welche die zu untersuchenden Speläothemen umfassen.

In order to obtain new detailed paleoclimatic reconstructions, samples from the Alps (Hobbithöhle, Haglätsch, St. Beatus Höhle, Weidhöhle bei Ecce Homo and Schafsloch Cave) and the Jura Mountains (Grotte aux Fées and Milandre) were collected (Fig. 2). To identify suitable samples, "reconnaissance cores" at the base of the stalagmites were drilled and then dated. Under certain circumstances (big stalagmites or flowstone) we also drilled up to 30 cm long cores.

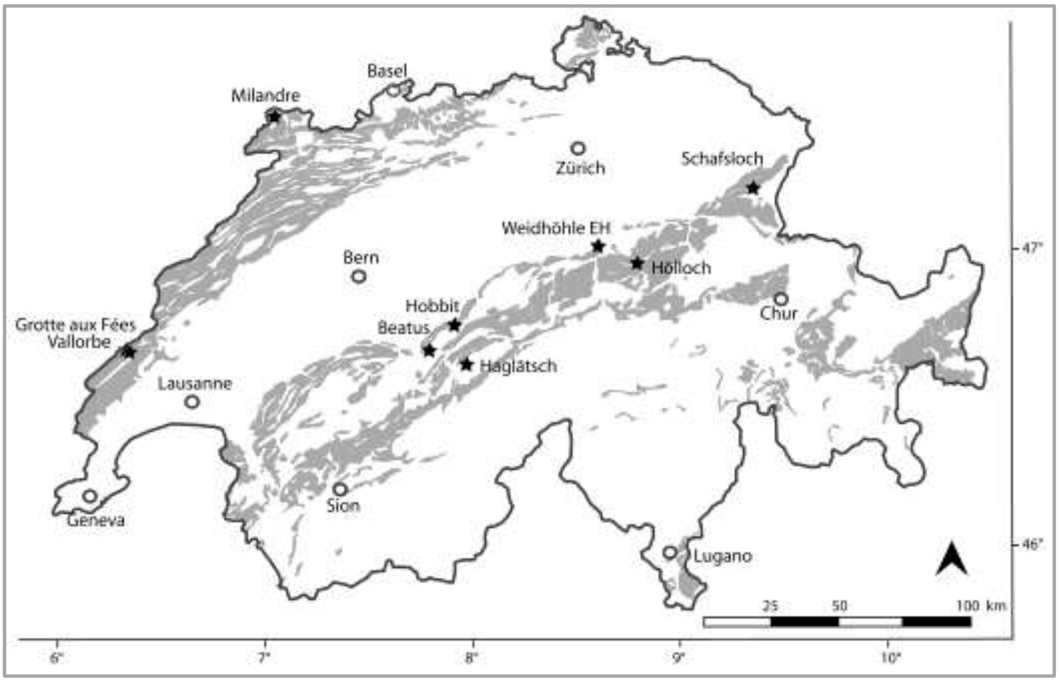

Fig. 2: Karst area in Switzerland (data from SISKA) and location of new sampled caves.

Fig. 2: Karstgebiete der Schweiz (Daten von SISKA) und die Lage der neuen Untersuchungsgebiete dieser Studie.

Cave	Alt. (m)	Sample	Type	Lenght (mm)	Period
St. Beatus Cave (BE)	690	BHN_1	stalagmite	535	Holocene
Hölloch (SZ)	740	Höll_A	soda straw	600	Holocene
Schafsloch (AI)	1890	MF_3	stalagmite	210	Penultimate glacial
Vallorbe Cave (VD)	750	Vall_1	stalagmite	700	Holocene
Vallorbe Cave (VD)	750	Vall_2	stalagmite	495	Holocene
Millandre Cave (NE)	400	M2	stalagmite	250	Late Pleistocene/Holocene
Millandre Cave (NE)	400	M6	stalagmite	1400	Holocene
Grotte aux Fées (VD)	895	GEF_1	stalagmite	695	Holocene
Hobbit Cave (BE)	2000	Ho_1	stalagmite	210	Last glacial
Haglätsch Cave (BE)	1660	HAG_01	stalagmite	230	Pleistocene
Weidhöhle bei EH (SZ)	780	WEH_1	core	300	Last glacial

Table 1: Overview of the samples in process at the Institute of Geological Sciences Bern, for the STALCLIM project-Switzerland.

Table 1: Zusammenstellung der Speläothemen, die im Rahmen des STALCLIM-Projektes in der Schweiz untersucht werden.

An overview of the samples that are now being analyzed at the Institute of Geological Sciences, Bern, is presented in Table 1. Most of the samples are suitable for paleoclimatic studies, are from stable cave environments, and are composed of dense calcite. Some samples even present annual laminations.

Active stalagmites collected from the Jura Mountains cover the Holocene and will be compared with samples from alpine caves. This will add to our understanding of the climatic variability in both regions during the last 12’000 years, following the Younger Dryas event.

Samples were collected from galleries located less than 50 m below the surface, with air flow below 100 l/s, and the feeding water dripping through a soda straw. The exception is BHN_1 from Beatus Cave, as the sample was inactive and the gallery is located 250 m below the surface.

Most of the Pleistocene samples were collected during the past years by cavers and were already broken when collected. Some were found near their growing place, and others remobilized in sediment.

Open questions regarding the timing of extreme flood events in Hölloch and Grotte aux Fées are now addressed. This can be done by dating the top of active speleothems broken by floods, and the base of new stalagmites formed after the flood. This gives us information on the timing and frequency of heavy precipitation periods or even of glacier ice melt. In addition, clay layers present in stalagmites M2 and Ho_1 provide additional information on the timing of flood events.

To reconstruct climatic oscillations at high resolution, oxygen and carbon stable isotopes were measured for 4400 samples at the Institute of Geological Sciences, University of Bern. For the construction of age models, a total of 70 ^{230}Th ages were measured at both the Geological Institute of Bern University, Switzerland and at the Department of Geology and Geophysics of University of Minnesota, USA.

A preliminary low resolution oxygen (interpreted as temperature proxy) and carbon (interpreted as vegetation proxy) isotope profiles (sampled at 5 mm resolution) of sample GEF_1 is shown in Fig. 3.

The work was extended to samples covering the late and middle Pleistocene. These reconstructions of climatic and surface evolution are needed, as other climate archives (e.g., lake sediments) are mostly eroded and, where present, are hard to date.

A very detailed analysis was made on one of the stalagmites collected by Martin Fischer from Schafsloch Cave, Alpstein (AI). Sample MF3 is a 21 cm long stalagmite, found in a sediment stack that now blocks the access to the cave. The sample covers the time interval between 130’000-230’000 years before present (Fig. 4). The temperature oscillations, both during interglacial and glacial periods, are reflected in the δ^{18}O profile. A distinct positive shift of 4.5 ‰ in δ^{18}O marks the transition from glacial into interglacial conditions at around 133’000 years before present. As δ^{18}O of local precipitation is temperature dependent (0.71 ‰ / °C), and if we apply a -0.18 ‰ / °C fractionation factor for calcite precipitation, this shift roughly translates to a 7 °C increase in mean annual temperature in the region. This estimate is in good agreement with published data from European pollen archives (Brewer et al., 2008). The midpoint of the penultimate deglaciation is placed 133’000 years before present. As published data from Asian Speleothems place the deglaciation at 129’000 years ago (Cheng et al., 2009), MF3 results emphasize the different regional climatic response to small changes in temperature. This result helps to improve our understanding of the timing and the causes of abrupt climatic changes.

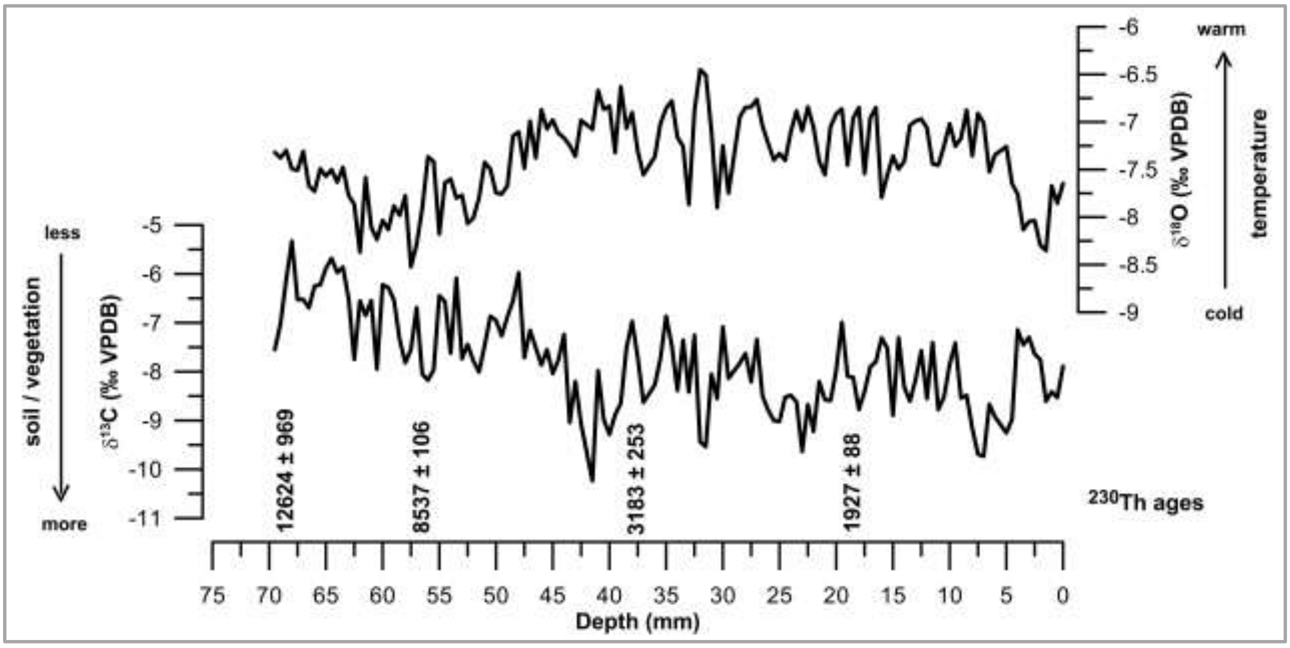

Fig. 3: Stable isotopes profile for GEF_1 (75 cm), drilled every 5 mm on the growth axis of the sample.

Fig. 3: Stabile Isotopen-Profil von GEF_1 (75 cm). Proben wurden entlang der Wachstumsachse in einer Auflösung von 5 mm ausgebohrt.

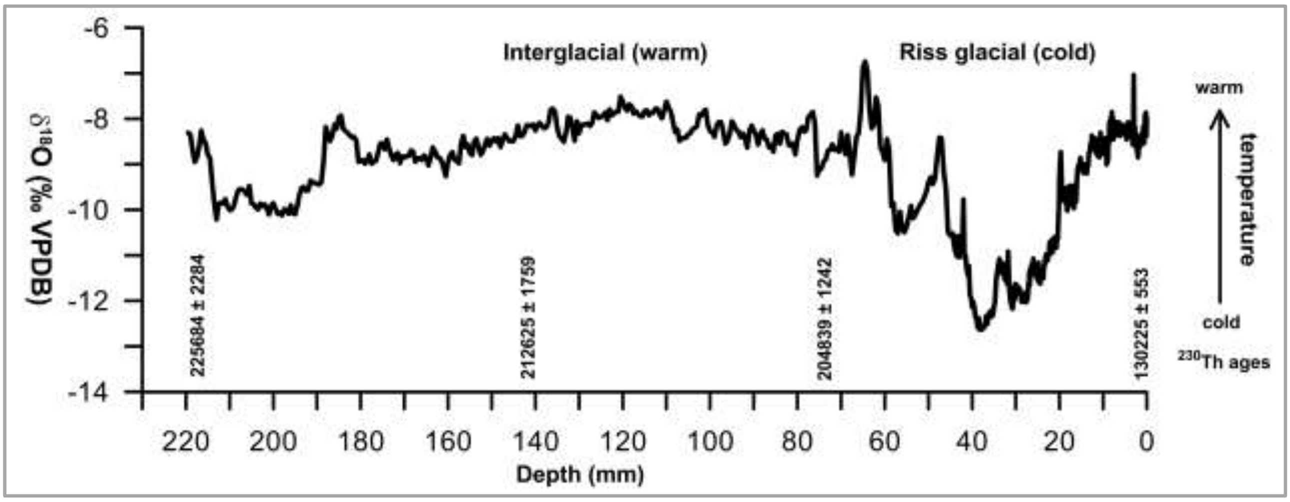

Fig. 4: Oxygen isotopic profile for MF3 (21 cm), drilled every 0.5 mm on the growth axis of the sample.

Fig. 4: Sauerstoff-Isotopenprofil von MF3 (21 cm). Proben wurden entlang der Wachstumsachse in einer Auflösung von 0.5 mm ausgebohrt.

Outlook

In the near future, detailed isotopic analyses will be performed on all collected samples. Fluid inclusion and trace element analyses are planned for sections in stalagmites that cover time periods of high scientific interest, as they provide new information about the cave and surface conditions.

Acknowledgements

The authors acknowledge the financial support of SNF Project STALCLIM (CRSI22_132646/1). We greatly acknowledge the field work support and the collaboration with the Höhlen-Gruppe Ybrig (HGY), Spéléo-Club Jura (SCJ), SGH Bern, SGH Interlaken, Höhlenclub Alpstein (HCA), Spéléo-Club de Cheseaux (SCC), Groupe d`Exploration aux Fées (GEF), Ostschweizerische Gesellschaft für Höhlenforschung (OGH) and to the Swiss Institute for Speleology and Karstology (SISKA).

References

BREWER S. et al. (2008): The climate in Europe during the Eemian: a multi-method approach using pollen data, Quaternary Science Reviews 27, 2303–2315.

CHENG H. et al. (2009): Ice Age Terminations. Science 326, 248-252.

HÄUSELMANN PH. (2002): Cave Genesis and its relationship to surface processes: Investigations in the Siebenhengste region (BE, Switzerland). - PhD thesis.

JEANNIN P.-Y. (1989): Remplissages karstiques du Reseau des Sieben Hengste. - Postgraduate diploma thesis, CHYN Neuchâtel.

LEMEILLE F. et al. (1999): Co-seismic ruptures and deformations recorded by speleothems in the epicentral zone of the Basel earthquake, Geodinamica Acta 12, 3-4, 179-191.

LÜTSCHER M. et al. (2011): Holocene glacier history from alpine speleothems, Milchbach cave, Switzerland, Earth and Planetary Science Letters 302, 1-2, 95-106.

MCDERMOTT F. (2004): Palaeo-climate reconstruction from stable isotope variations in speleothems: a review, Quaternary Science Reviews 23, 901–918.

QUINIF et al. (1993): Datation d`une stalagmite dans la Caverne de Tenehet (Wildhorn, Valais-Suisse), Karstologia 22, 2, 48-51.

SCHMASSMANN S. (2010): Speleothem-based climate and environmental reconstruction: a pilot study in the Swiss Jura Mountains, Msc thesis, Uni Bern.

SCHÜRCH M. et al. (2003): Observation of isotopes in the water cycle the Swiss National Network (NISOT), Environmental Geology 45, 1–11.

WEBER E. (2004): Etude des mouvements récents dans le karst de Melchsee-Frutt: modélisation 3D et comparaison avec la grotte de Milandre et le réseau des Siebenhengste, Diplom thesis, Neuchatel.

WILDBERGER A. et al. (1992): Datierungsversuche an Tropfsteinen aus dem Hölloch. – Proceedings of 9th Swiss National Congress of Speleology.