Speleothem growth and δ13C as proxies of last glacial glacier coverage and thermo-dynamical states in the Alps

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1 - BACKGROUND

- Studying the last glaciation is crucial to better understand relationships between climate and glacier response.
- Thus, in recent years, transient ice model (Parallel Ice Sheet Model, Winkelmann et al. 2011) simulations of the European Alps glacier evolution (0-120 ka) were conducted (Seguinot et al. 2018, Jouvet et al. in rev.).
- **This is the first attempt to compare these ice model simulations with speleothem data.**

2 - METHODS

2.1. Speleothem proxies

- We use speleothems from caves located at different altitudes in the Alps (**Fig. 1**).
- First, we compare **speleothem δ13C with simulated ice thickness.**
  → We set the min. host rock δ13C of −1 ‰ (Buggisch and Mann 2004) as threshold for soil presence/absence (**Fig. 2**).

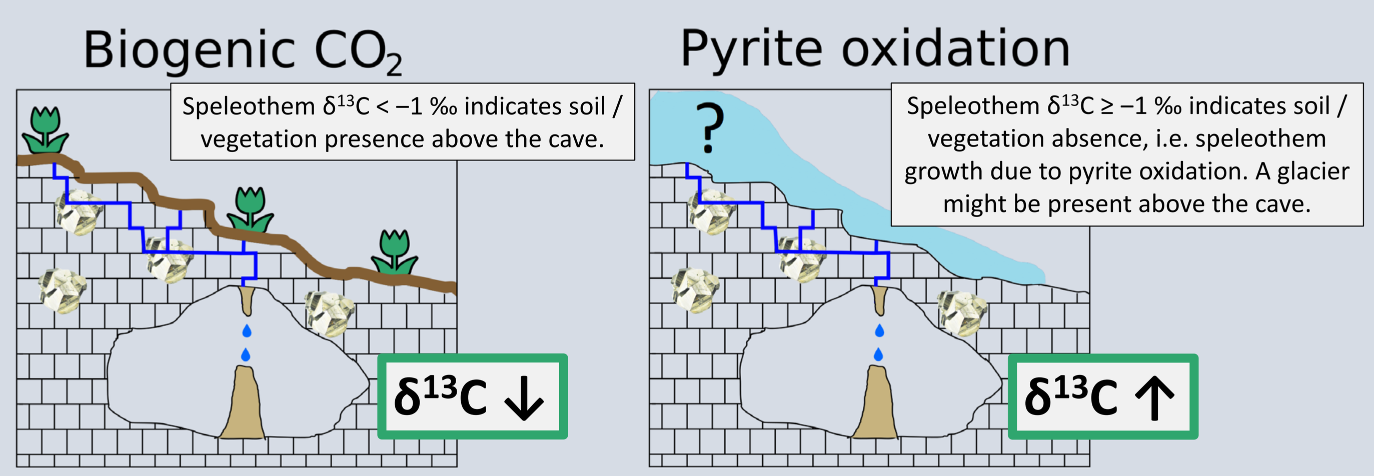


Fig. 2: Sketches describing the external conditions we infer from speleothem δ13C: water can become acidic due to dissolution of biogenic CO_2 in the water (left) and due to pyrite oxidation (right).

- Second, we compare **speleothem growth with simulated pressure-adjusted T at the glacier base** → T needs to be close to 0°C, because only a warm-based glacier allows water infiltration into the karst and, thus, speleothem growth.

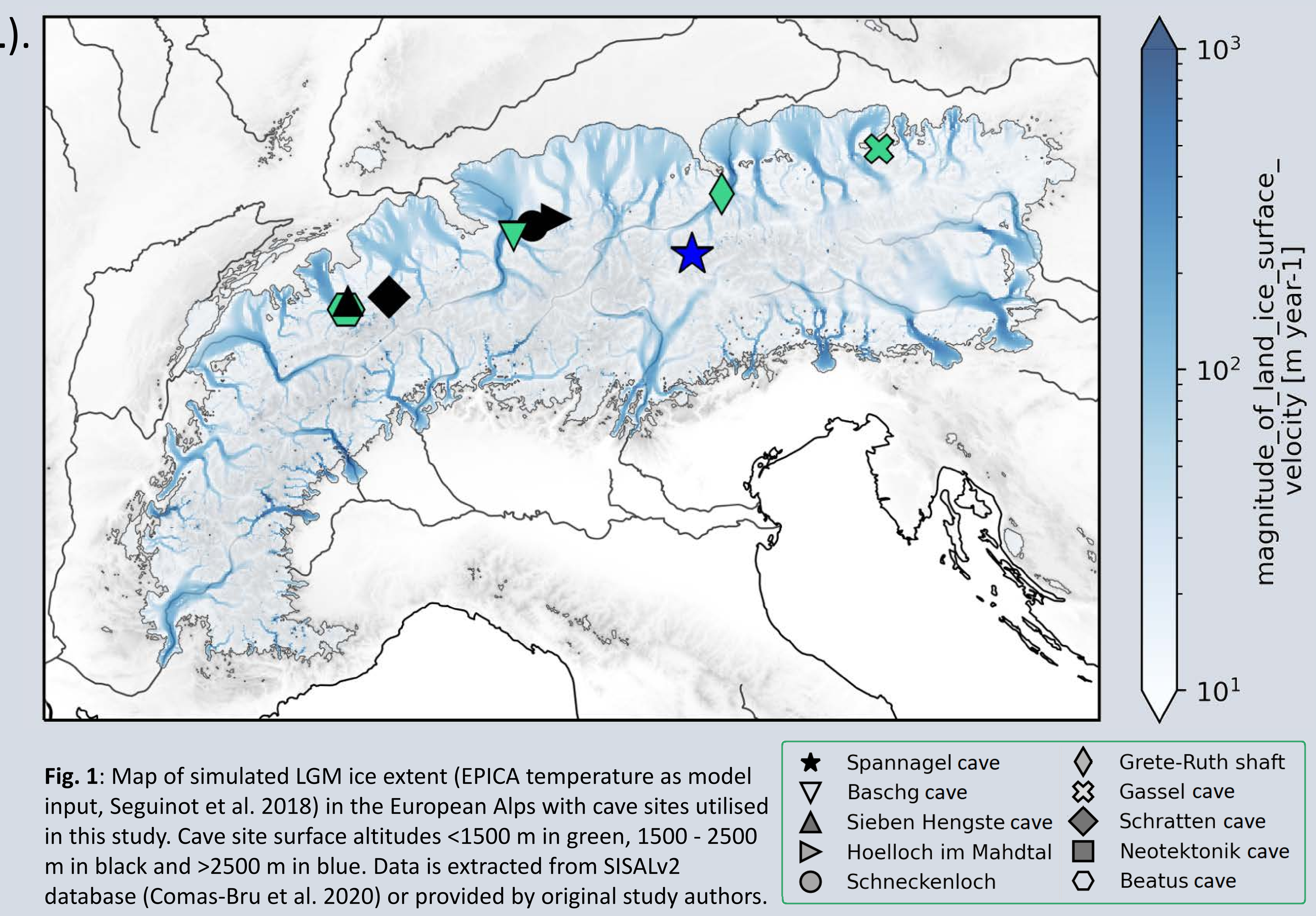


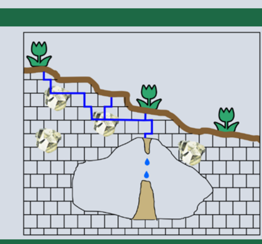
Fig. 1: Map of simulated LGM ice extent (EPICA temperature as model input, Seguinot et al. 2018) in the European Alps with cave sites utilised in this study. Cave site surface altitudes <1500 m in green, 1500 - 2500 m in black and >2500 m in blue. Data is extracted from SISALv2 database (Comas-Bru et al. 2020) or provided by original study authors.

2.2. Model simulations

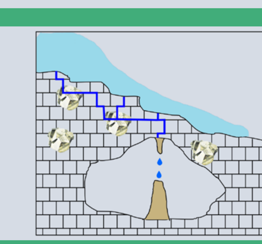
- We focus on the glacial period (12-115 ka).
- Seguinot et al. (2018) used a distortion of present-day climate based on different T proxy records (NE Atlantic $U^{k'}_{37}$-SST, Martrat et al. 2007; Antarctic ice core [EPICA] δD-based T, Jouzel et al. 2007) as transient forcing.
- Jouvet et al. (in rev.) used modelled palaeoclimate based on the EPICA T record (Jouzel et al. 2007) as transient forcing.
- We consider a location as being glaciated when simulated ice thickness is > 20 m (results are similar when using > 5 m).

Four scenarios:

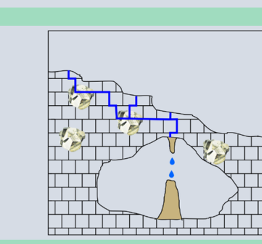
Model-data agreement #1: δ13C < −1 ‰ & ice thickness ≤ 20 m



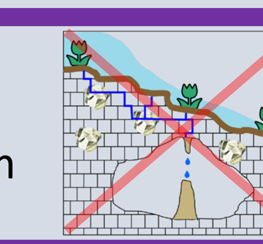
Model-data agreement #2: δ13C ≥ −1 ‰ & ice thickness > 20 m



Model-data agreement #3: δ13C ≥ −1 ‰ & ice thickness ≤ 20 m



Model-data disagreement: δ13C < −1 ‰ & ice thickness > 20 m



3 - RESULTS

3.1. δ13C vs ice thickness

- Most speleothem δ13C data agrees with model results (model-data agreement #1 to #3, **Fig. 3**).
- For simulation runs using NE Atlantic SST as T input, we find model-data agreement for >95 % of data points.
- For EPICA T-driven simulations only about 80-85 % of the points agree.

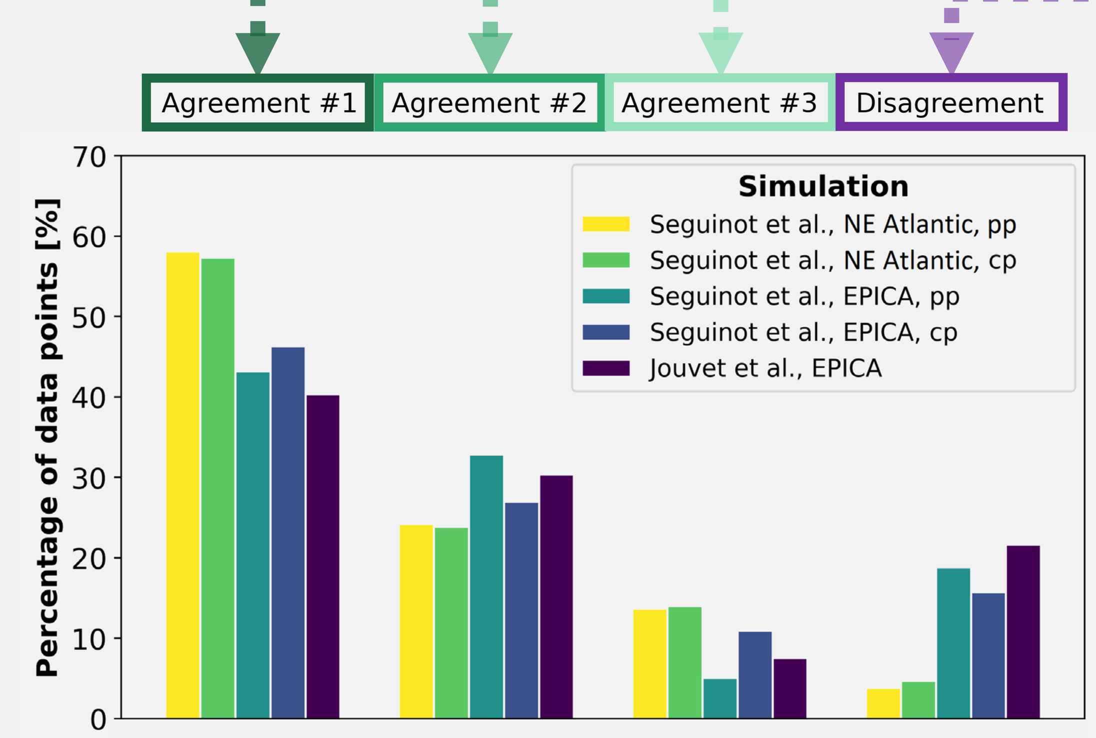


Fig. 3: Percentage of speleothem δ13C values indicating each of the four scenarios. cp = constant precipitation amount, pp = T-adjusted precipitation amount. T = temperature.

3.2. Growth vs T at glacier base

- We compare data which is showing model-data agreement #2, i.e. for which the model indicates glacier coverage and speleothem δ13C indicates soil absence, with simulated pressure-adjusted temperature at the glacier base (**Fig. 4**).
- EPICA T-driven simulation of Jouvet et al. (in rev.) and NE Atlantic SST-driven simulations of Seguinot et al. (2018) show the best agreement in terms of basal ice temperatures.

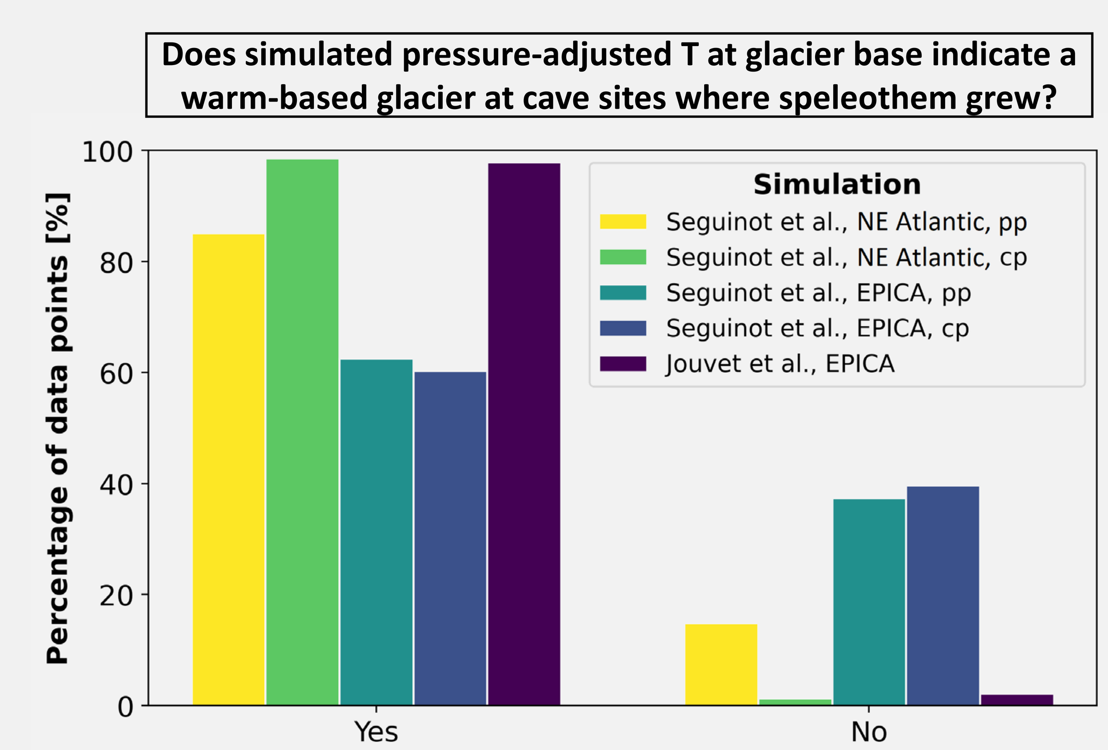


Fig. 4: Percentage of simulated pressure-adjusted temperature at the glacier base indicating a warm-based glacier (T ≥ −1°C, left) and a cold-based glacier (T < −1°C, right) for periods of speleothem growth, where model and δ13C data shows model-data agreement #2. cp = constant precipitation amount, pp = T-adjusted precipitation amount. T = temperature.

4 - CONCLUSIONS

- Here we demonstrated that speleothem growth and δ13C can serve to assess the performance of last glacial cycle glacier models for the Alps. They provide unique data to validate modelled glacier reconstructions in a transient manner considering that these models were mostly assessed for the Last Glacial Maximum before.
- First results indicate that using the Northern Hemisphere temperature signal (NE Atlantic SST) as model input leads to better agreement of simulations with speleothem data than using the Antarctic ice core temperature proxy in terms of both simulated glacier coverage and thermo-dynamical states at the base of the glaciers.

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