Supplement: Determining SISALv2-speleothem growth rates during the Holocene

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Abstract. Speleothems are terrestrial paleoclimate archives that occur abundantly in the low and mid latitudes. They archive changes in the past hydroclimate in many ways, including the rate of calcium carbonate accumulation – their growth rate. However, determining speleothem growth rates, and in particular growth rate changes, is challenging due to speleothem inherent features such as growth hiatuses, and large and abrupt growth rate changes. Low dating resolution poses an additional problem, as the U/Th measurements that allow for precise dating are time-consuming and expensive.

Here, we analyze speleothem growth rates during the Holocene – an ideal period for method testing due to the high abundance of speleothem records in the SISALv2 database. In particular, we compare speleothem growth rates in the early (12-8 kyr BP), mid (8-4 kyr BP) and the late Holocene (4-0 kyr BP). Using synthetically-modelled stalagmites, we test the strengths and weaknesses of state-of-the-art age-depth modelling methods to determine a set of necessary requirements to quantify speleothem growth rates and growth rate changes. Using these, we find slightly higher growth rates in the early Holocene within speleothems that cover at all periods. Comparing growth rates of speleothems that cover only one of the respective periods in the Holocene did not distinguish any period of highest or lowest growth rate. Detailed regional studies and comparison to model data are used to further interpret these results. Reliably determining growth rate changes in the Holocene may help in further understanding and characterizing hydroclimate changes as archived in speleothems also beyond the Holocene.

1 Growth rate detection using different age-depth models

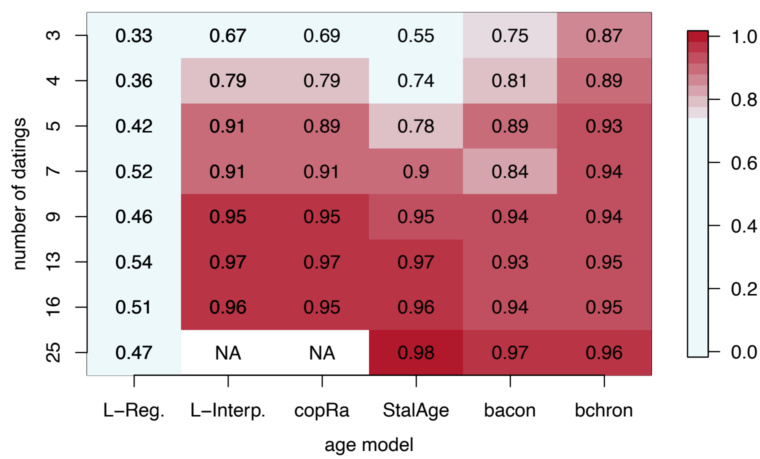

Figure 1. True positive growth rate detection: ratio of true detected growth rate changes within the same time window as the modelled stalagmites after calculating the age-depth relationship using different age-depth models (linear regression, linear interpolation, copRa Breitenbach et al. (2012), StalAge Scholz and Hoffmann (2011), Bacon Blaauw and Christeny (2011) and Bchron Haslett and Parnell (2008)). Modelled stalagmites cover 8 kyr and have 400 mm depth. Non of the case studies include hiatuses. Figure adapted from Bühler (2022).

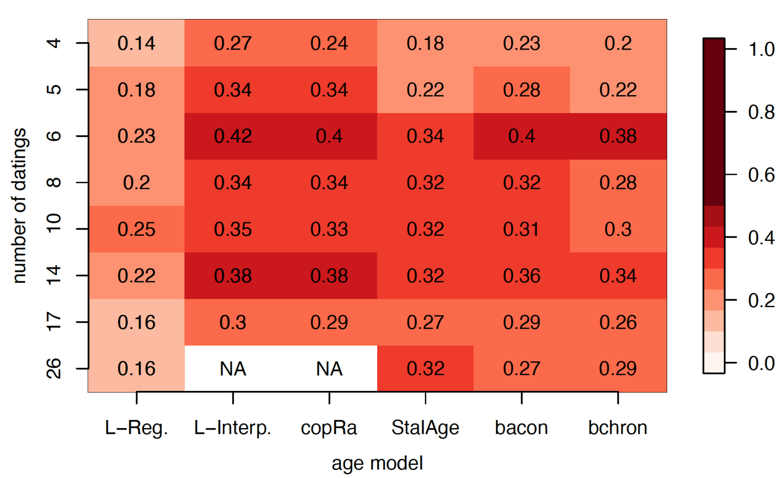

Figure 2. False positive growth rate detection as compared to Fig. 1. Figure adapted from Bühler (2022).

2 Growth rate changes in speleothems during the Holocene

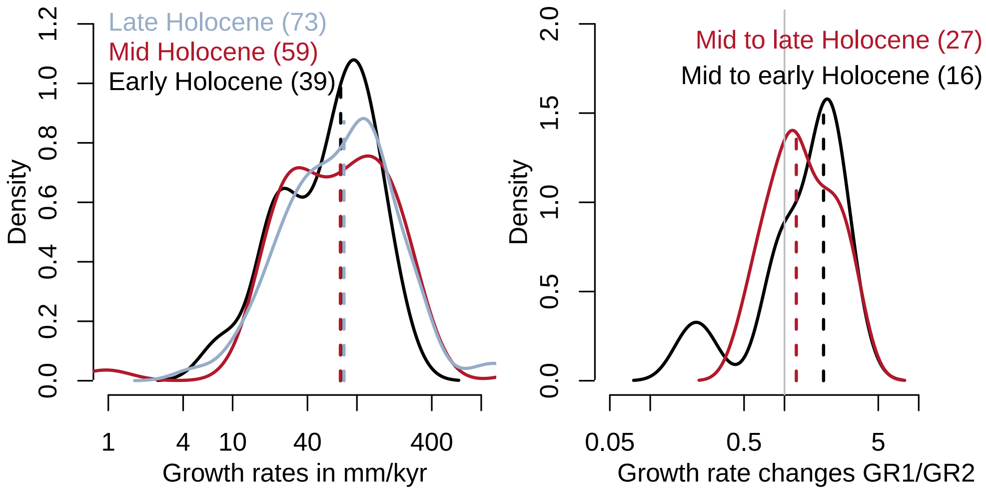

Figure 3. Left: median growth rate: Early Holocene 56 90% confidence interval (28, 84) mm/kyr, Mid-Holocene 51 (37, 88) mm/kyr, Late Holocene 68 (47, 105) mm/kyr. The number in brackets in plot indicate the number of entities used in the calculation. **Right:** growth rate changes between the time periods. Here only records with sufficient length and number of datings in two subsequent time periods were chosen. For the 11 entities available in all time periods, the Mid-Holocene growth rate is 1.95 (1.06, 2.06) times higher than in the early, and 1.23 (1.12, 1.85) higher than in the late Holocene. Growth rates are calculated as the slope of the regression using all datings and depths in one time period.

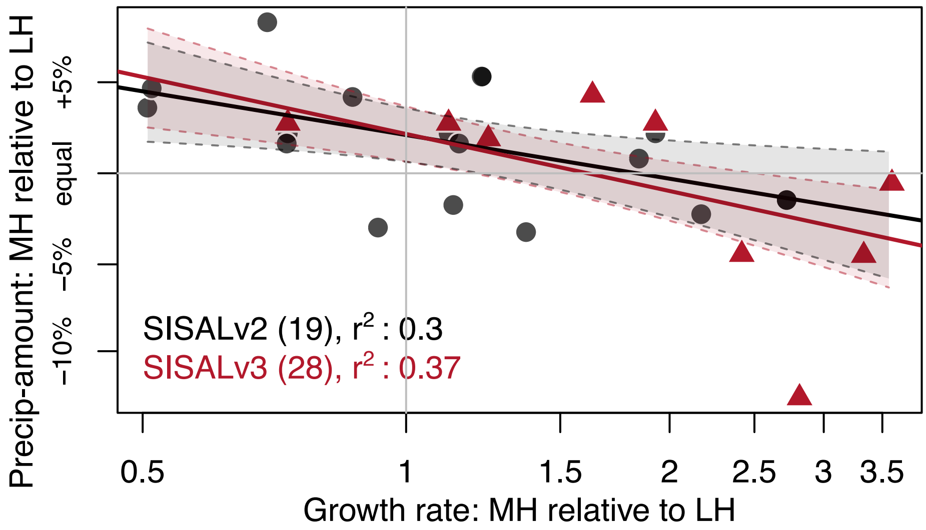

Figure 4. Speleothem growth rate changes between the Mid and late Holocene are contrasted with mean precipitation amount changes from the iHadCM3 6k run (Bühler, 2022) vs the last millennium run (Bühler et al., 2021), representing Mid to late Holocene precipitation changes. The records included in the SISALv2 database (Comas-Bru et al., 2020) are indicated by black circles, new records included in the soon to be published third version of the database (SISALv3) are marked by red triangles.

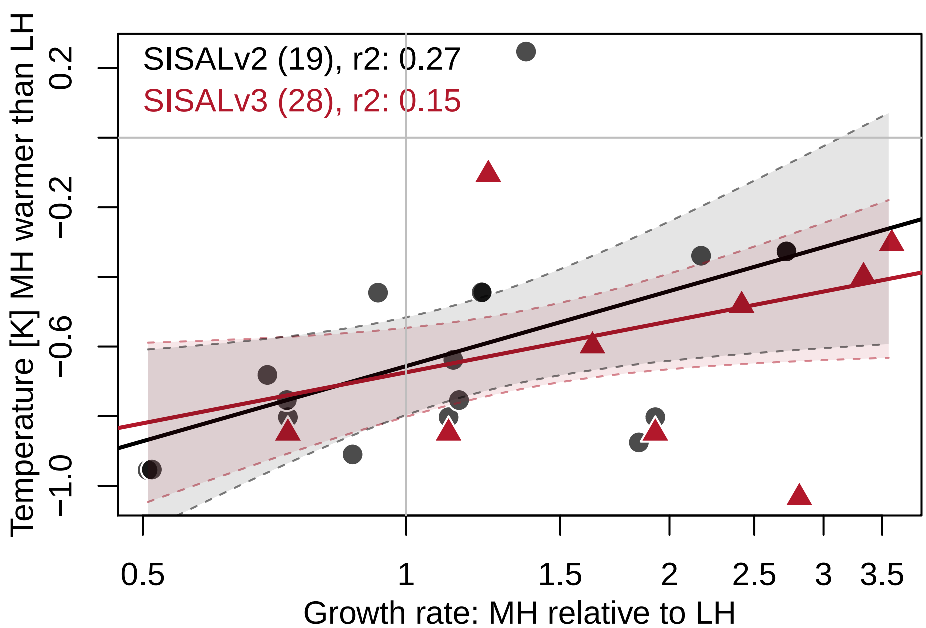

Figure 5. As Fig. 4 but for temperature changes.

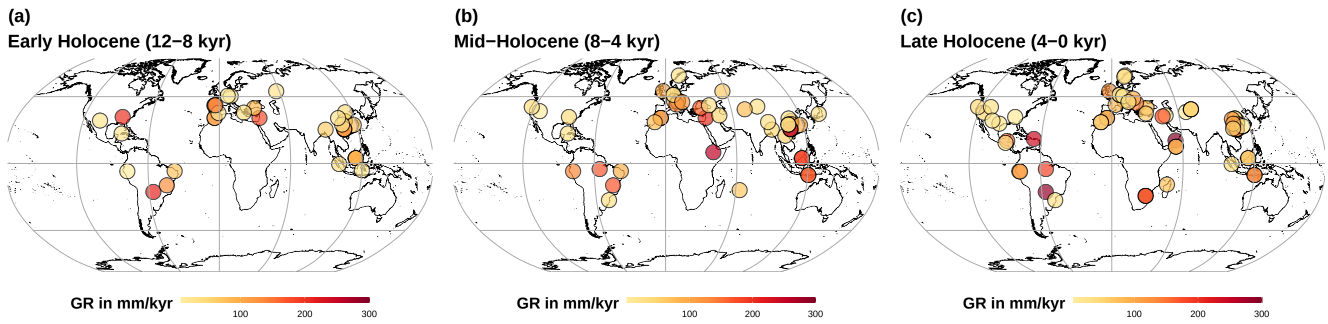

Figure 6. Growth rates of selected speleothems from SISALv2 and the soon to be published SISALv3 with at least 4 datings and a 3000 y coverage within the respective time periods.

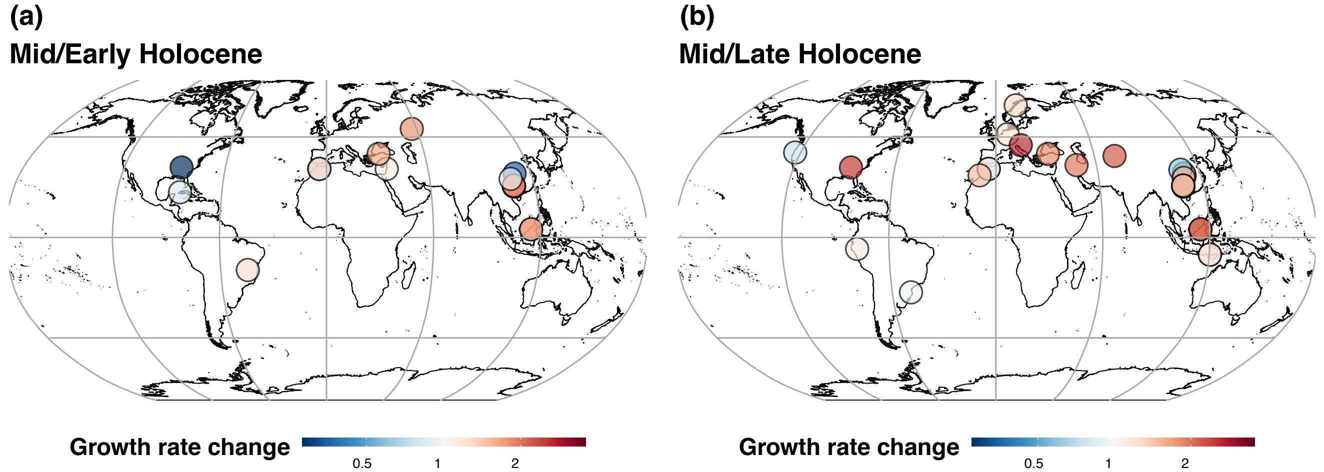

Figure 7. (a) Growth rate changes in single speleothem entities between Mid and early Holocene and (b) between Mid and late Holocene. All considered speleothems show at least 4 datings and a coverage of 3000 yr in both time periods. In both a) and b) red colors indicate higher growth rates in the Mid-Holocene compared to the respective time period.

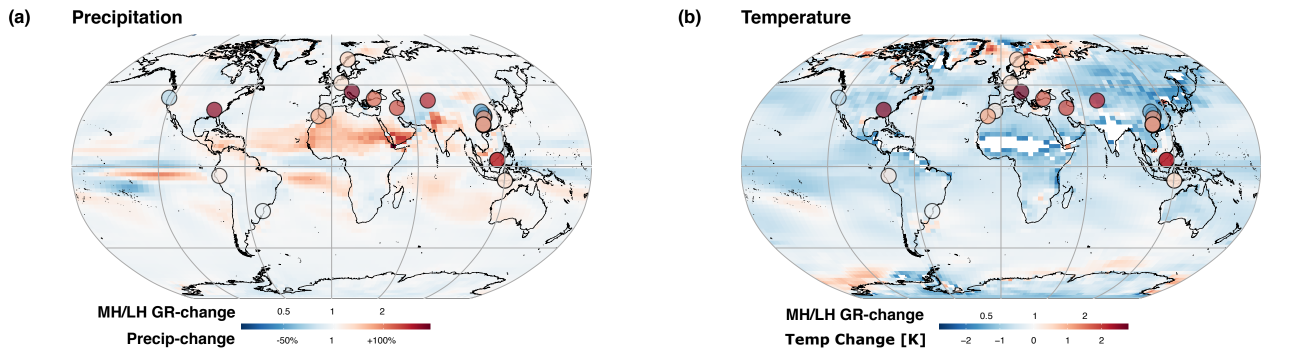

Figure 8. (a) Background: precipitation changes MH/LH from iHadCM3 forced 6k and LM run (Bühler, 2022; Bühler et al., 2021), growth rate changes of speleothems as circles above (as in Fig. 7b). (b) Same but with absolute temperature changes MH-LH. The colorbar is used for both precipitation/temperature changes as well as growth rate changes, where the axis above corresponds to the speleothem growth rates, and the axis below to the modelled climatic changes.

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