Short manual

The code is intended to run on speleothem data covering the last glacial (+120-20 ka BP). It will use all available data in SISALv2 (https://researchdata.reading.ac.uk/256/ , Comas-Bru et al., 2020), however, only those records which appear meaningful to us with respect to time coverage and proxy resolution. Within those data the code searches for rapid transitions, which resemble Greenlands Dansgaard Oeschger events. The basics of the methods are described in the appendix below.

This is how to run the code:

- Download and install Julia and an appropriate editor (e.g., Atom, Juno, VS-Code)
- Save each file of this GitHub directory in a directory of our choice on your machine
- Everything is prepared for a test run – so, run the program

[If some packages are not installed, do so by: *using Pkg*; *Pkg.add("Plots")* for the Plots package

In this first run the sisalv2 data base will be downloaded and unzipped. Make sure for an internet connection]

This is how to run the code with your data choice of appropriate SISALv2:

- Replace the default test data set with your evaluation of the SISALv2 data or add individual records, you deem appropriate to use from SIASL by providing entity_id, entity_name and your evaluation of the direction of the d18O change (1/-1 – from more negative stadials to less negative interstadials/vice versa)
- Run the program again

This will be your output:

All used d18O records from individual speleothems will be plotted with DO events highlighted and set into context with those from NGRIP (Rasmussen et al., 2014). Those are named 'TimeSeries_<entity_name>.pdf'. Another set of pdf files, named 'Dd18O_<entity_name>.pdf' show all detected DO events zoomed into the 300 years before and after each transition.

You will also receive four summing-up figures, which are also saved as *.pdfs in your working directory. O of those four pdfs do the summing up with respect to all detected events for all speleothems and the other two with respect of individual cave sites. In addition, there will be a "stack_offset_events.csv" file, which contain the timing of the detected transitions and the interstadial minus stadial proxy record difference for each detected event for each speleothem.

Finally, there is a *.png file popping up, which gives a global overview.

[Please note: all d18O differences in all file types refer to changes in the speleothem carbonate! Not to drip water or precipitation! One has to account for a temperature-dependent fractionation between carbonate and water!]

##

Appendix

Method:

As previously shown, e.g., for Greenland ice cores, transitions from stadial to interstadial conditions are more abrupt and larger (e.g., Rasmussen et al., 2014) than the transitions from interstadials to stadials. Thus, we focus on the offset during the beginning of a DO event. For the detection of transitions, the data set is linearly interpolated to annual temporal resolution first. This is necessary as the temporal resolution of some proxy records might be low.

Then the method uses two neighbouring windows of a certain temporal length in which the respective mean is calculated and the difference of both average values is computed. Those two windows are shifted through the interpolated proxy time series. Extrema in the difference between both windows point to strong changes in the original time series, which occur in response to those rapid climate shifts.

This method reliably finds the onset of DO events for the NGRIP ice core record using a window length of 150 years for each record (Rousseau et al., 2017). However, for unequally spaced original stalagmite data and their generally lower temporal resolution, this time window appears too small and 200 years is used instead. Nevertheless, a robustness test, using time windows of 150 and 250 years length, results usually in similar output.

The resulting curve of the difference of both neighbouring windows provides the mean of finding stadial-interstadial transitions. However, not each local maximum or minimum of the difference curve is a stadial-interstadial transition. To evaluate, if an extrema is a stadial-interstadial transition we apply a timing constraint. The time period of interest is defined as the duration between one transition and the next nearest one (Fig. 1) as defined in the NGRIP record (Rasmussen et al., 2014). This time window is centred on the stadial-interstadial transition of interest and is enlarged by the 2-sigma age error of the proxy record occurring at this period (Fig. 1). The largest extreme value of the difference curve in this time window is then used as the time point of a stadial-interstadial transition.

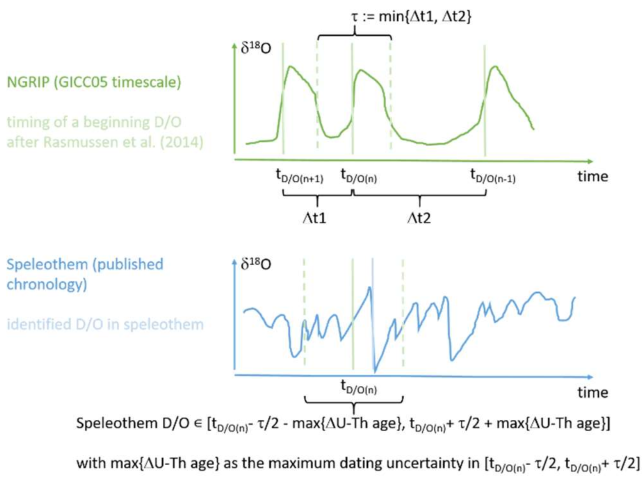

Fig. 1: *This sketch illustrates the choice of the time period within which our method is allowed to detect a stadial-interstadial transition. The half width of the nearest neighboured stadial-interstadial transition as identified in NGRIP (top figure, green dashed lines) is enlarged by the age errors of the*

proxy record (bottom figure, green dashed line) and centred around the time point of the individual event as defined in the NGRIP record (solid green lines in top and bottom figures).

References

Comas-Bru, L., Rehfeld, K., Roesch, C., Amirnezhad-Mozhdehi, S., Harrison, S. P., Atsawawaranunt, K., Ahmad, S. M., Brahim, Y. A., Baker, A., Bosomworth, M., Breitenbach, S. F. M., Burstyn, Y., Columbu, A., Deininger, M., Demény, A., Dixon, B., Fohlmeister, J., Hatvani, I. G., Hu, J., Kaushal, N., Kern, Z., Labuhn, I., Lechleitner, F. A., Lorrey, A., Martrat, B., Novello, V. F., Oster, J., Pérez-Mejías, C., Scholz, D., Scroxton, N., Sinha, N., Ward, B. M., Warken, S., Zhang, H., and SISAL Working Group members: SISALv2: a comprehensive speleothem isotope database with multiple age–depth models, Earth Syst. Sci. Data, 12, 2579–2606, https://doi.org/10.5194/essd-12-2579-2020, 2020.

Rasmussen et al. (2014), A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: refining and extending the INTIMATE event stratigraphy, Quaternary Science Reviews, 106, 14-28.

Rousseau et al. (2017), (MIS3 & 2) millennial oscillations in Greenland dust and Eurasian aeolian records–A paleosol perspective. Quaternary Science Reviews 169, 99-113.