Northern Spain temperature constrained by speleothem isotopes and fluid inclusion water isotopes during the abrupt oscillations of the last deglaciation period

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EGU General Assembly 2021

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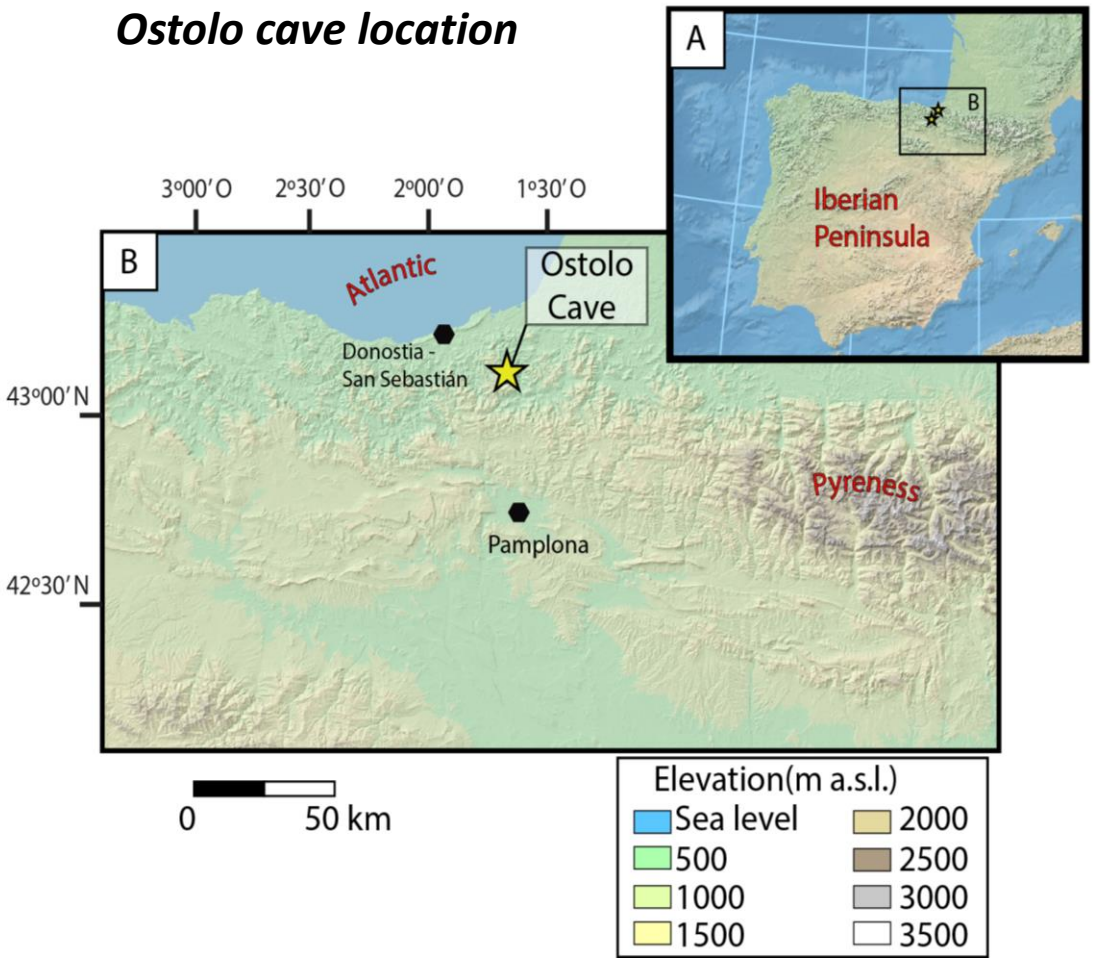
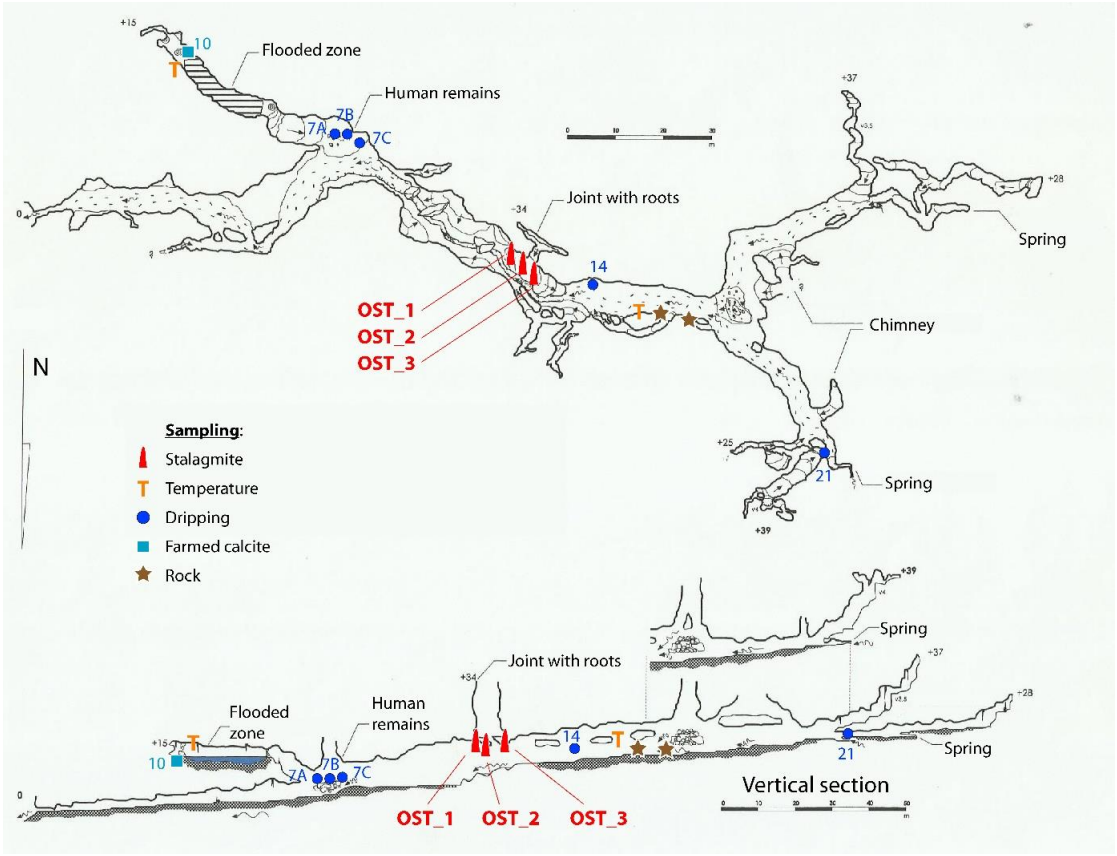
Ostolo cave location



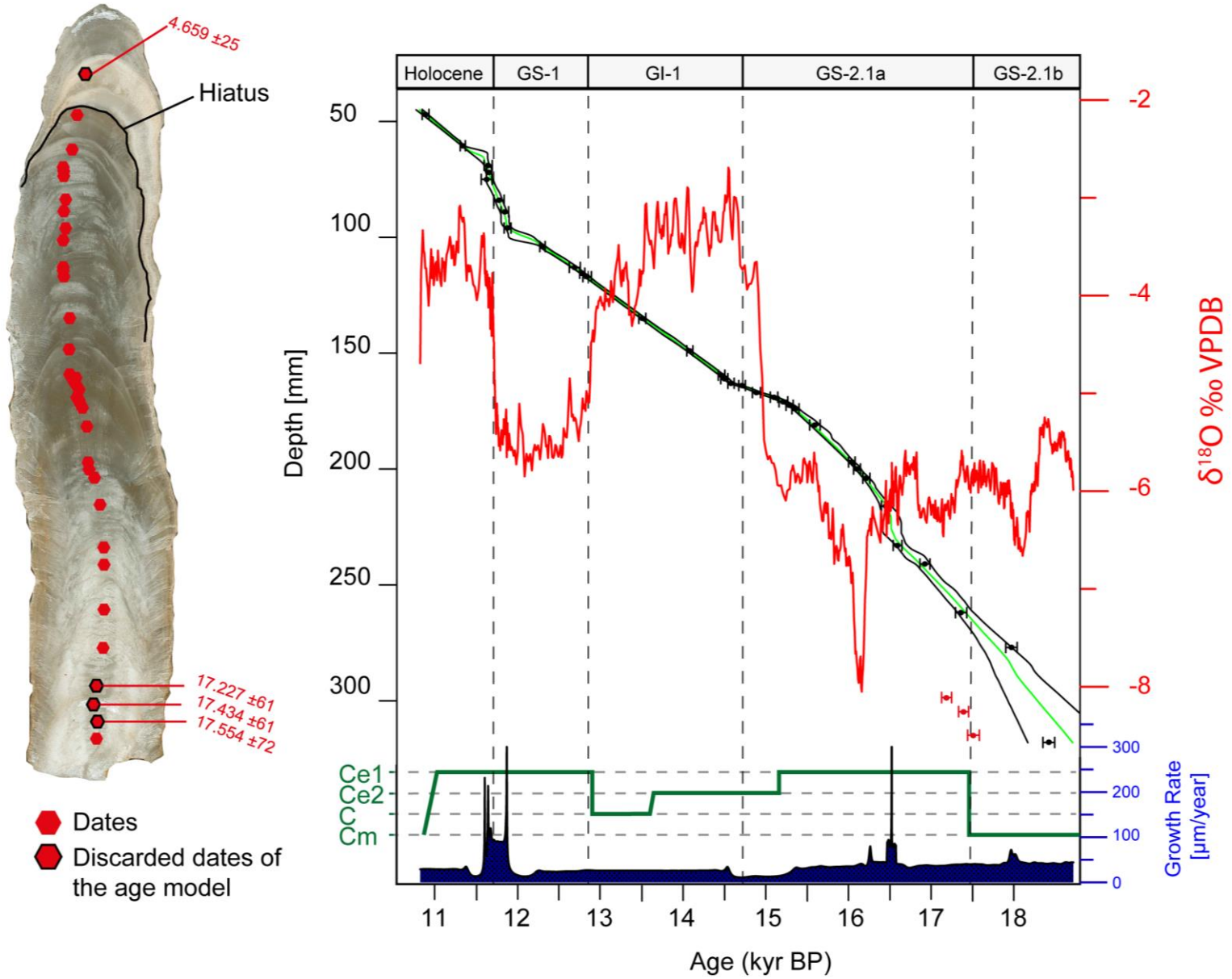
Topography and stalagmite sampling sites




Entrance Ostolo Cave


Ostolo Cave Gallery

OST-2

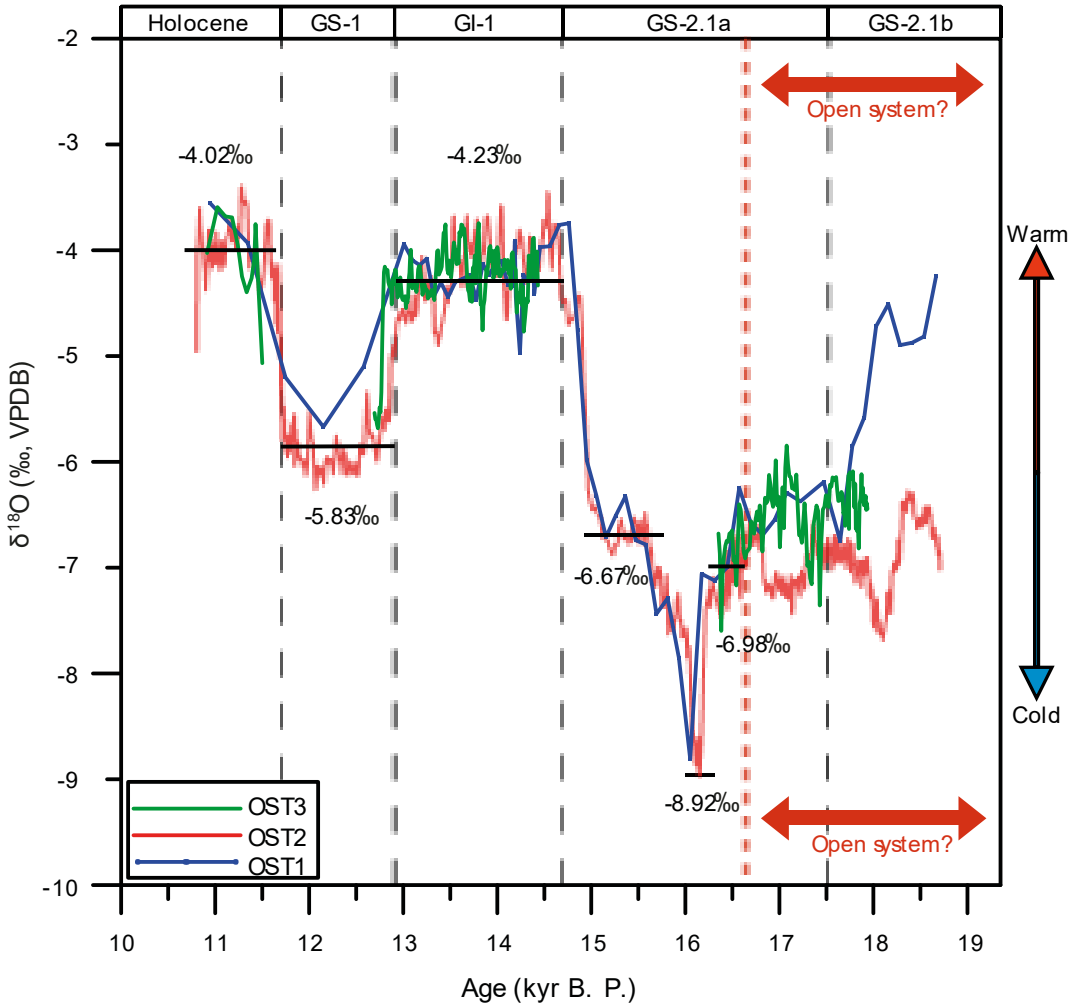


Methods and Results

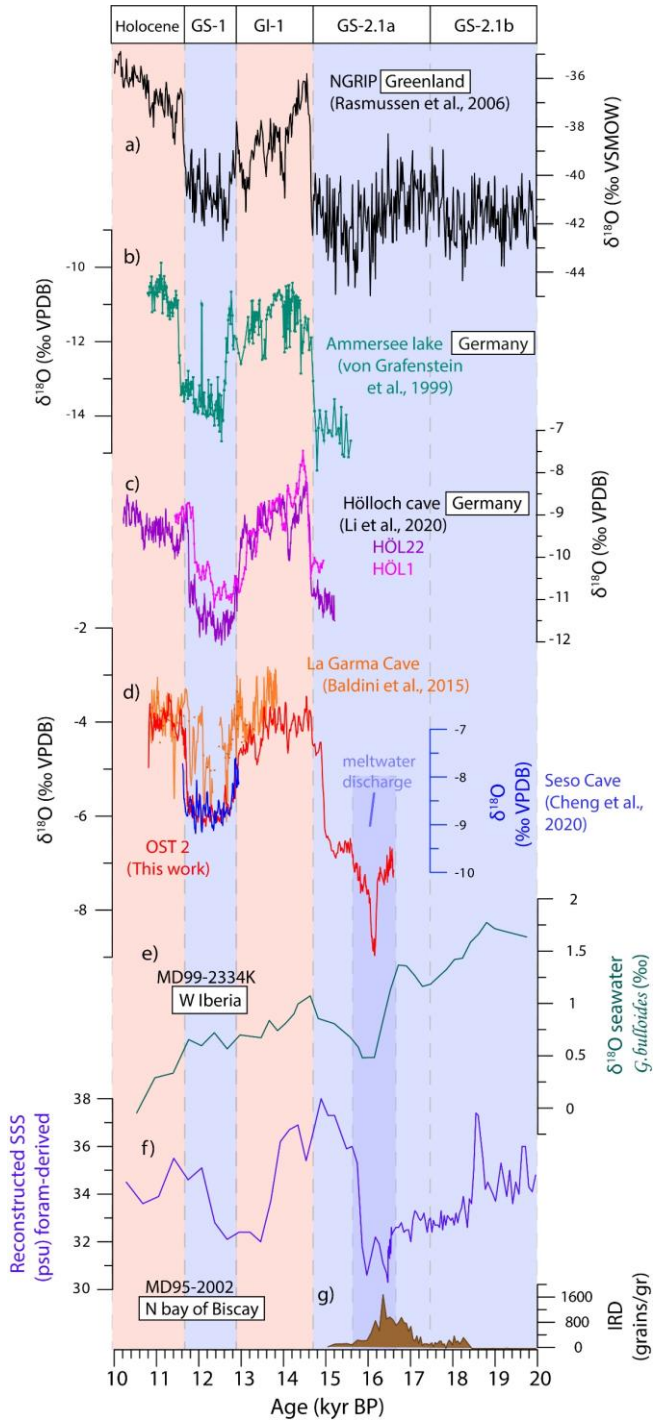
Three stalagmites (OST1–OST3) were extracted from Ostolo cave and analyzed for their petrography, stable isotope composition, and U-Th age.

The uranium content of these stalagmites is extraordinarily high, ranging from 10 to 80 ppm. This, together with low values of Th, resulted in highly precise U-Th dates.

δ18O replicated record



Low (High) δ18O values in cold (warm) periods
Low correlation in the bottom – Open system?



Comparison with other continental and marine records

- Light δ18O values were observed during stadials (GS-1 and GS-2.1a), and heavier values were observed during warm events (GI-1 and Holocene), thus indicating a dominant air temperature control on this signal

- An exceptional light δ18O excursion centered at 16.2–16.0 kyr B.P. is interpreted to reflect the major phase of HE1 iceberg melting reaching the Iberian Peninsula, which drastically changed the δ18O composition of regional precipitation.

- The exceptional high quality of the Ostolo chronology and its clear δ18O signal support a deglacial ocean-atmosphere connection that rapidly transferred high-latitude changes toward southern Europe.

Crushing of the crystals and analysis of the fluid inclusions

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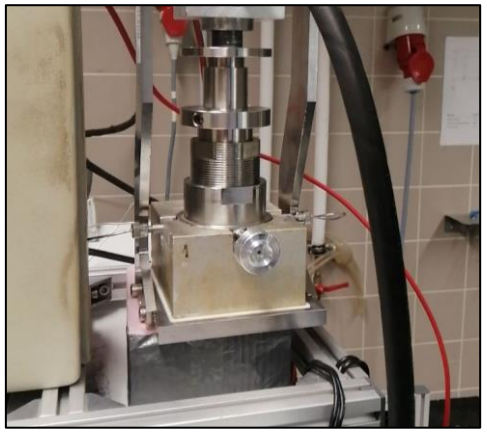
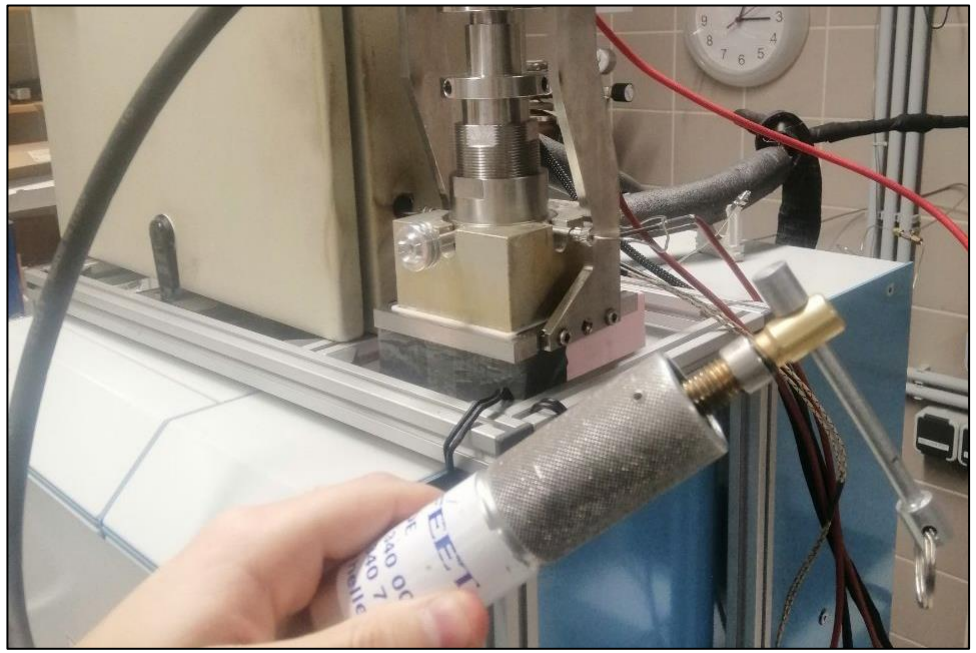
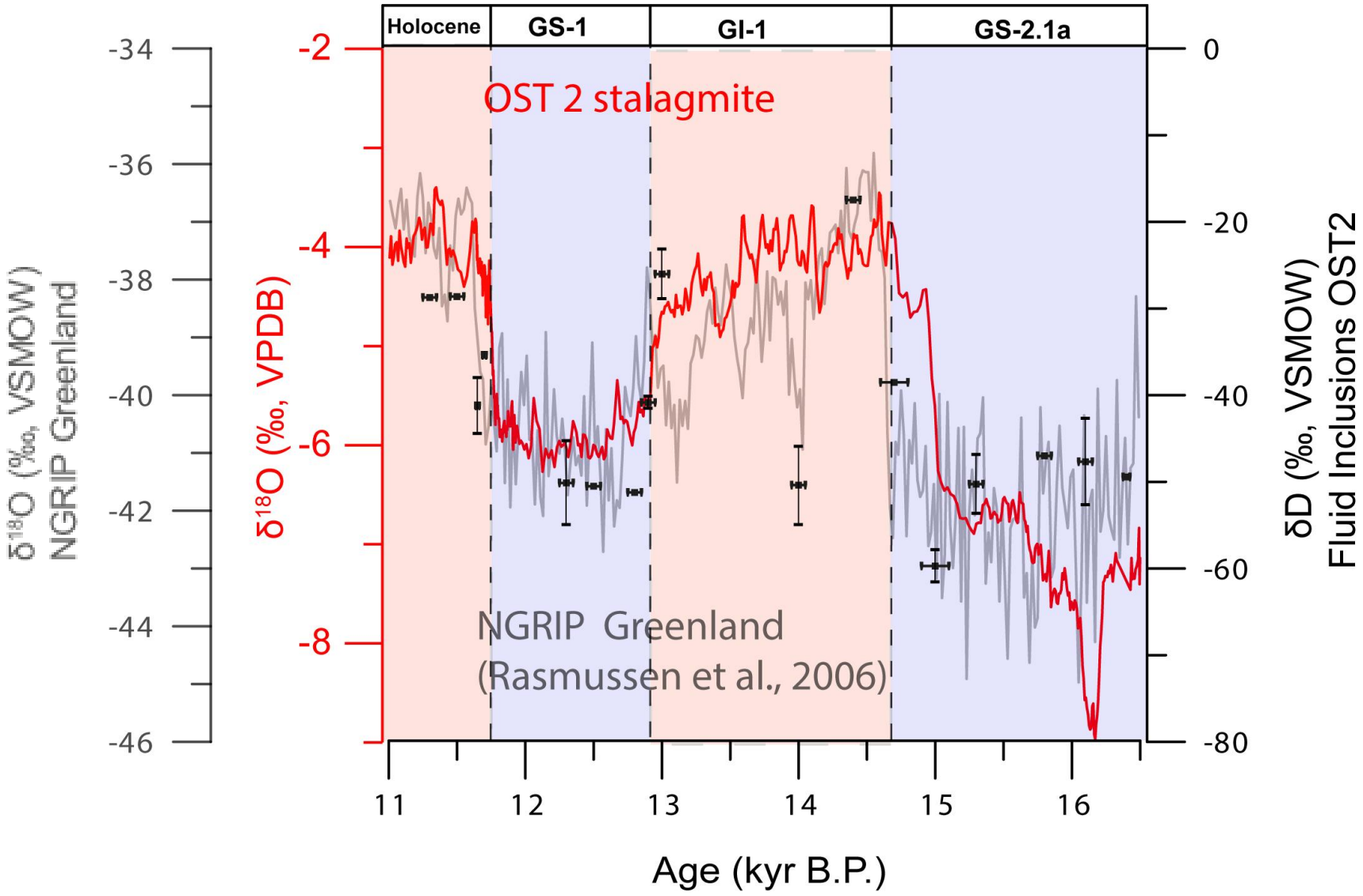


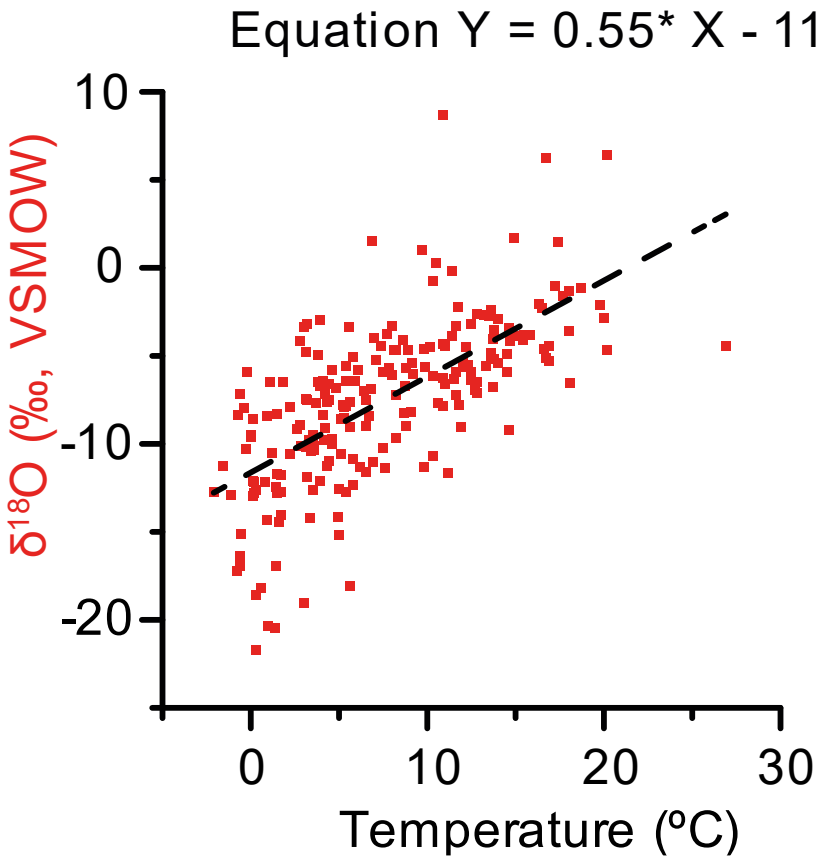


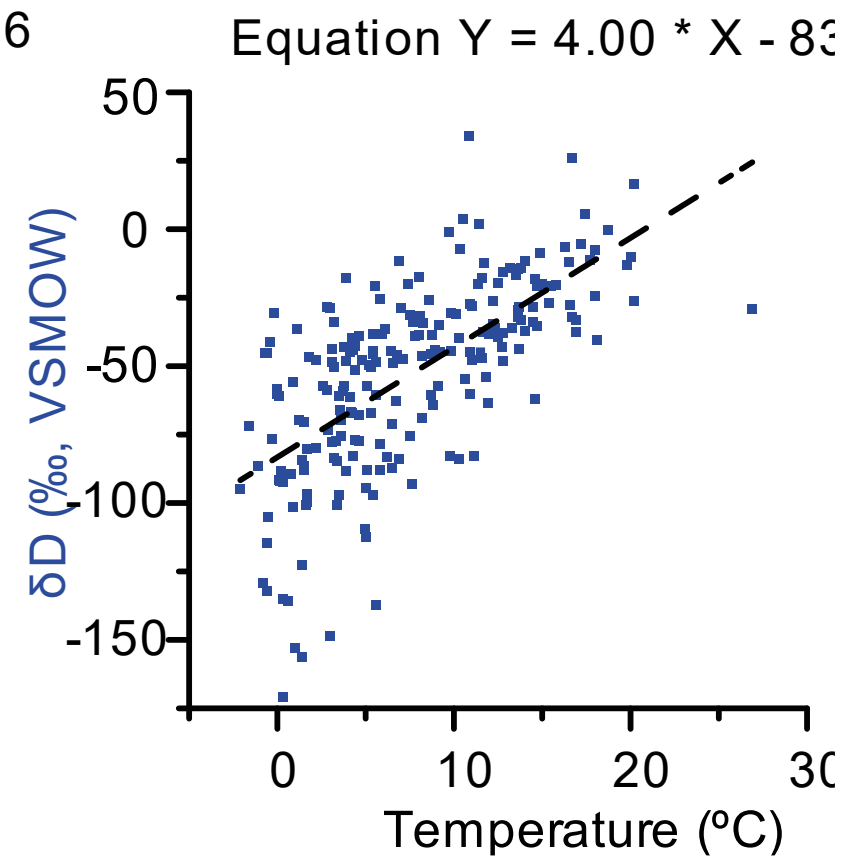
Fluid inclusion results



- 17 different fluid inclusion δD results.
- Not all results could be replicated (insufficient amount of water or lack of sample to crush).
- Light δD values were observed during stadials (GS-1 and GS-2.1a), and heavier values were observed during warm events (GI-1 and Holocene).
- The light δ18O (speleothem) excursion centered at 16.2–16.0 kyr B.P. is not present in the δD values of the fluid inclusions at this time interval.
- At 14 kyr B.P. there is a δD value which does not correlate well with the values of δ18O (speleothem). This value correlates well with a light excursion in the NGRIP record.

Transfer function to obtain paleotemperatures





- The dataset to define a transfer function consist in the change of temperature and the values of δ18O and δD in rainfall samples that were collected from July 2017 to June 2019 (n = 216) at the interpretation center of "Las Güixas" touristic cave in Villanúa* (112 km to the east form the Ostolo cave). Similar climate scenario.

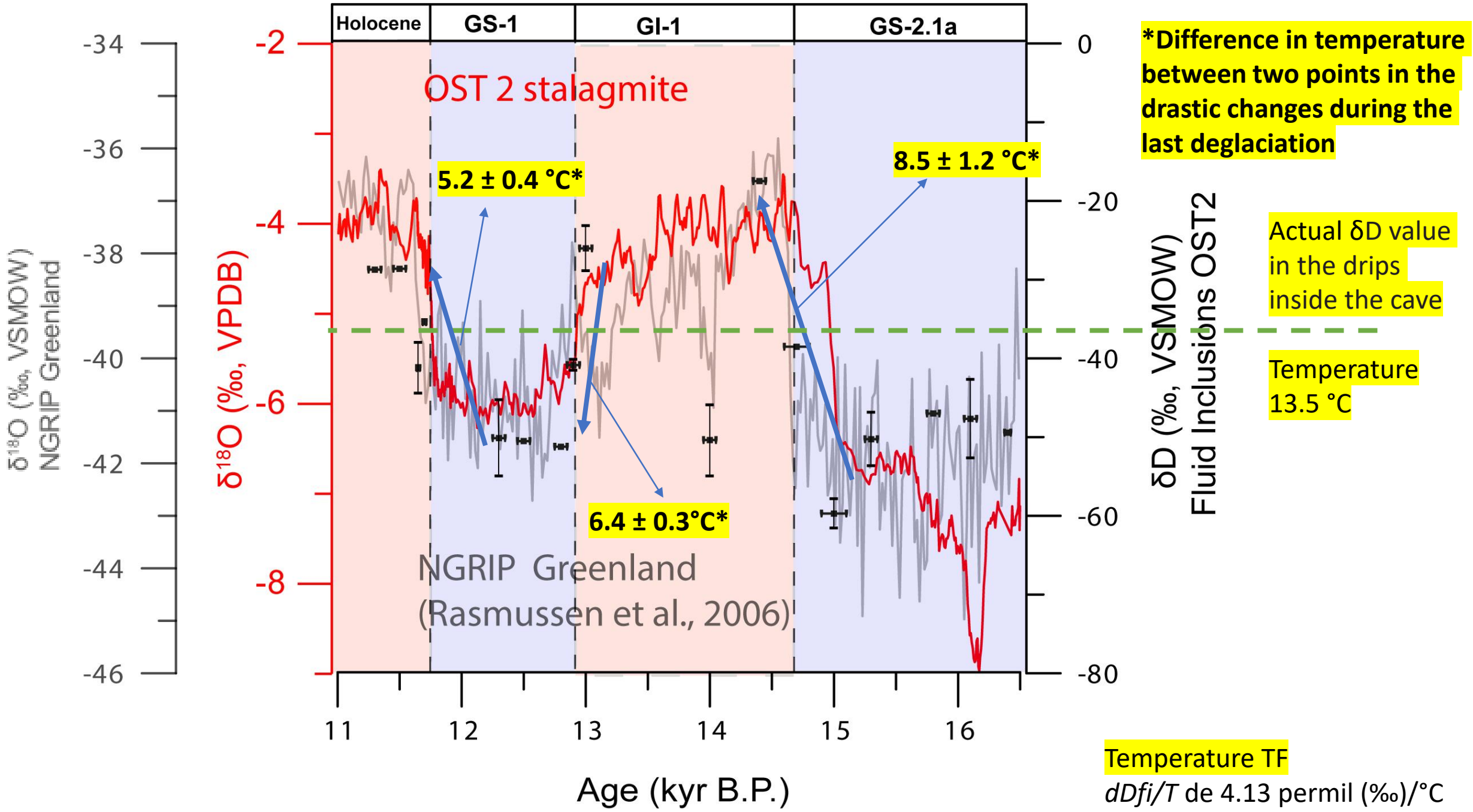
- The dependence of the δ18O values with the temperature is 0.55‰/°C

- The linear correlation between δ18O and δD for this samples has a value around 7.5. Therefore, for the transfer function we use a value of 4.13‰/°C (0.55x7.5).

Temperature TF

δD(fluid inclusion)/*T* of 4.13 permil (‰)/°C

*Giménez R, Bartolomé M, Gázquez F, Iglesias M and Moreno A (2021) Underlying Climate Controls in Triple Oxygen (16O, 17O, 18O) and Hydrogen (1H, 2H) Isotopes Composition of Rainfall (Central Pyrenees). Front. Earth Sci. 9:633698. doi: 10.3389/feart.2021.633698



***Difference in temperature between two points in the drastic changes during the last deglaciation**

Actual δD value in the drips inside the cave

Temperature 13.5 °C

Temperature TF

dDfi/T de 4.13 permil (‰)/°C

Conclusions

- The δ18O speleothem record and δD (fluid inclusions) from Ostolo cave provides a unique opportunity to accurately date the abrupt millennial-scale climate oscillations of the last deglaciation for the first time in southern Europe.

- Low [High] δ18O (speleothem) and δD (fluid inclusion) values during cold [warm] periods of the last deglaciation

- Apparently the δ18O record in stalagmites is not influenced only by temperature: proof of this is the differences that exist with the δD record (directly influenced by temperature). The major phase of HE1 iceberg melting reaching the Iberian Peninsula (which drastically changed the δ18O composition of regional precipitation) may explain the difference seen between 16.0 and 16.2 kyr B.P

- In our first approximation working with fluid inclusions the variations in temperature during the drastic changes in the last deglaciation seem to be exaggerated (Problems with the transfer function?). This because marine and continental records report temperature changes of about 5 to 6 °C between the different drastic changes that occurred during the last deglaciation period (GS-2.1a, GI-1, GS-1 and the Holocene).