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The Cryosphere Discussions

Interactive comment on "First investigations of an ice core from Eisriesenwelt cave (Austria)" *by* B. May et al.

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Review by Anders Svensson of the manuscript 'First investigations of an ice core from Eisriesenwelt cave (Austria)' submitted to The Cryosphere by B. May, C. Spötl, D. Wagenbach, Y. Dublyansky, and J. Liebl. DOI: 10.5194/tcd-4-1525-2010

In this review, I will challenge some of the conclusions of the submitted manuscript. It is up to the authors if they find my suggestions reasonable or not.

As a Greenland ice core / polar ice sheet person I was struck by several of the statements in the manuscript:

- There are air bubbles in the ice! To me this comes as somewhat of a surprise as the formation of air bubbles in the polar ice caps are formed in the snow-to-ice transforma-

tion in the firn. Having no snow and no firn layer in the cave it is a little of a mystery to me where those bubbles originate from. In the manuscript it is stated that elongated bubbles 'are most likely formed through melting and refreezing of the surface ice'. To me this appears as a rather unlikely scenario. Indeed, in the polar regions melt layers or refrozen water is exactly characterized by containing NO bubbles (when the ice melts the air escapes and it is not reincorporated by refreezing). To me it seems much more likely that the bubbles are introduced at an earlier stage, e.g. from the ice column.

- it appears to be an assumption throughout the paper that the ice is not flowing, or at least ice flow is not really taken into consideration. Without ever having put my foot in the cave, I would assume that the ice is actively flowing. This is temperate ice almost at the melting point, which is very soft and deforms easily. If indeed, ablation and sublimation only plays a minor role for the mass balance (as you suggest?) the ice flow will be driven by the ice source, e.g. the inflow of ice through the ice column or from other areas in the cave, and ablation/melting at the edges/bedrock. If the ice is actively flowing the age of the ice at the drill site will depend not only of the depth of an ice layer but merely on the distance to the ice source. You would need estimates of the inflow of ice and a simple ice flow model to determine this. To investigate if the ice is indeed flowing one could survey the movement of marks/sticks at the surface over time, one could measure the deformation of a borehole that is kept open, or at least follow the position of the existing borehole. The non-horizontal ice floor supports the idea of active ice flow.

- Air bubbles are elongated in the upper 4 m of the ice and round in the lower parts. To me elongated air bubbles strongly suggest an active ice flow whereas round bubbles suggest ice that is 'stuck' for some reason, such as the structure of the bedrock (maybe the GPR can tell something about this?) In Greenland ice we have elongated air bubbles on the ice ridge caused by the ice deformation. In ice that 'gets stuck' round ice bubbles are likely to reform after some time due to energy minimization. Based alone on the shape of the ice bubbles in your core, I would therefore suggest that your ice drill

has penetrated two distinct sections of ice: an upper actively flowing section of 'recent' ice and a lower 'stuck' section of older ice. It would be most useful to look at some thin sections of ice to see if the ice crystals in the upper section are also elongated along with the air bubbles (which is the case in Greenland).

- there is a significant change of about 10 permil in dD at the 4 m transition zone from 'warmer' to 'colder' values, which is associated with the change in the impurity content of the ice and the change in the air bubble shape. I find it likely that the water isotopes primarily reflects climate, and thus changes in precipitation and seepage water. Just as it is the case for the oxygen isotopes of stalagmite records in the Alps, such as the Kleegruben stalagmites. Lower isotopic values correspond to colder climate and vice versa. The Holocene Climatic Optimum would be a candidate for a warmer and wetter climatic period that could be the origin of the 'warmer' isotopes. The water isotopic shift in the ERW core appears to be of the same order of magnitude as that between glacial interstadial and stadial values in the Kleegruben stalagmite oxygen isotopes.

To summarize the above, I would suggest the following scenario for the interpretation of your ice core:

- During the last glacial conditions were too dry for ice to form in the cave or the entrances were covered by glaciers (guess).

- During the warm and wet Holocene climatic optimum water/ice started to enter the cave and an ice sheet of 'warm' water isotopic values and specific impurity content was formed. Some of this ice is still present in certain locations of the cave, at least at the drill site.

- Since then there has been an actively flowing glacier in the cave more or less in mass balance. The more recent ice in the cave has a 'colder' isotopic composition and impurity content due to the colder climate and the less precipitation.

- The ice flow has removed much of the ice deposited throughout the Holocene such

that the ice core profile is not continuous in time. The ice core contains a deeper part of Early Holocene ice that is for some reason stuck there, and a younger section of more recent and actively flowing ice, while an intermediate section is missing. The different climates of the two sections in the ice core are likely also to be the cause of their different impurity content.

Unfortunately, I cannot judge how well/bad this interpretation fits with the obtained C-14 age estimates based on the limited information provided in the manuscript.

As already mentioned, it is entirely up to the authors whether or not they want to apply some of the above interpretations or not. It is certainly not a demand from my side that they are applied and with my very different background it is likely that my suggestions are not realistic.

A few specific comments:

Could you please provide a table summarizing the results of the four C-14 samples and analyses? It is difficult to extract the results from the main text. What was for example the result of the upper most sample, what exact depths were they taken, etc.

Figure captions figure 6+7: 'by filling the missing sections. . .' -> gaps are linearly interpolated.

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