

Author response to RC3

The manuscript “A comprehensive TLS-based framework for cave ice monitoring under adverse surface conditions: application at Scărișoara Ice Cave” by Šupinský et al. presents a detailed investigation of cave ice development at Scărișoara Ice Cave in Romania with focus on the methodology (terrestrial laser scanning) needed to calculate ice volumes as accurately as possible. Although this is quite a niche topic, which will likely attract less readers, I find this work interesting and think it is a nice and also new contribution suitable for “The Cryosphere”.

The manuscript clearly focuses on the methodology and I think the authors did a good job in describing their work extremely accurately. However, I think the manuscript could benefit from some additional information not specifically related to the methodology.

We thank the reviewer for the positive assessment of our manuscript and for considering the work a novel contribution suitable for The Cryosphere. We also appreciate the suggestion to make the paper more accessible to readers less familiar with ice caves, which we have taken into account. Each comment is addressed point by point below.

“Romania” should be added to the title.

We will add it to the title.

It would be helpful to describe in 1-2 sentences why their work is important and why ice caves should be monitored. Of course it is interesting to do it but what is broader value of doing it? In line 31 they mention the loss of paleoclimatic information. Is there anything else?

We will emphasise why cave ice monitoring matters beyond the paleoclimatic value already noted. Perennial cave ice is a sensitive indicator of climate change, responding rapidly to shifts in temperature and precipitation, and its accelerating loss threatens a unique and non-renewable natural archive as well as the associated subterranean environments, home to unique cave-dwelling fungal, microbial and faunal assemblages (Iepure, 2018; Purcarea, 2018).

I think most readers are not super familiar with ice caves. It could be helpful to briefly define what an ice cave is, where you can find them, how many caves are known? Are these caves touristic caves and accessible to the public? Along with this it would be nice to have a photo of the cave somewhere in the introduction part. The only photos I could find are the ones in figure 7 and these are really small. Having one or two photos at the beginning would clearly help to easier introduce the readers to the investigation area and provide a general overview.

We will add a brief introduction to ice caves and also photographs of the cave to give readers a clear overview of the site.

Ice caves are rock-hosted caves in which snow and ice accumulate to form perennial ice masses. Ice in caves can form either through snow diagenesis or water freezing, or a combination of the two. Most cave ice deposits are formed in single-entrance, descending caves, in which snow is trapped and subsequently metamorphosed to ice and/or the inflow of cold air leads to the freezing of water. Perennial ice masses can exceed 100 000 m³ in volume and 20 m in thickness, and may flow under their own weight in a manner similar to surface

glaciers. Ice caves occur mainly in the karst regions of Eurasia and North America, with rare occurrences in high mountains elsewhere (Mavlyudov, 2018), and are best documented in the European mid-latitude mountains (Alps, Dinarides, Carpathians). No complete global inventory exists, as new sites continue to be discovered while others have lost their perennial ice (Meyer, 2018). Under ongoing warming, many ice caves are transitioning from perennial to seasonal ice caves that retain ice only during the cold season (Kern and Perşoiu, 2013). Only about 20 ice caves worldwide are developed as show caves accessible to the public (Oedl, 2018), Scărișoara Ice Cave being one of them.

Can you briefly describe the main reasons for ice cave loss at Scărișoara? Rising temperatures? Less precipitation? Tourists? You talk about these things in general but it would be nice if you could provide some basic information for Scărișoara.

We will add a brief paragraph describing the two main processes leading to loss of ice: rising air temperature, translating into a lengthening of the melting season and shift from solid to liquid precipitation, leading to increased inflow of warm water and rapid loss of ice. We do not detail these too much, as they form the subject of a dedicated manuscript in progress. Monitoring of ice volume, air temperature and number of tourists did not show any connection, the amount of heat delivered by the human bodies is too small to impact air temperature (and subsequently ice volume change).

Again, I know the manuscript is already long and I don't think it should be even longer, but maybe there is a way to shorten the methodology part slightly or summarize some information/figures. I really appreciate the effort the authors put into the detailed description but for readability it might be helpful to shorten the text.

We appreciate this point. To improve readability, we will move some of the more detailed statistics to a Supplement while keeping a concise summary in the main text. We would prefer to retain the methodological description, as the completeness of the workflow is central to the transferability of the framework, but we will tighten the wording where possible.

Is the methodology suitable for monitoring in other caves? I assume yes since you have caves with similar conditions? This could be discussed towards the end of the paper to highlight the importance of the work?

Yes, the methodology is designed to be transferable to other ice caves and is not limited to caves comparable to Scărișoara, as the processing workflow was developed to handle incomplete and variable-quality data from a range of adverse conditions. We will strengthen the concluding recommendations into a clearer generalised guideline to emphasise the broader applicability of the framework.

In summary, I think the manuscript is suitable for publication in The Cryosphere after some revisions.

We thank the reviewer once again for the constructive and encouraging assessment, and for the suggestions that help us improve the manuscript's accessibility to a broader readership.

References

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