Author response to RC1

Referee comment

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GENERAL COMMENTS

Dear Editor,

I've read the manuscript "Multi-annual temperature evolution and implications for cave ice development in a sag-type ice cave in the Austrian Alps" by Wind et al.

I found the manuscript an interesting submission describing fully and comprehensively the microclimate of a sag-type ice cave. The manuscript fits with the purpose of the journal TC.

The manuscript reports significant information generally poorly or not addressed in the existing literature and it is, therefore, a valuable work.

Although pointed out several times and accurately described, the only "weakness" of the work relates to the lack of data calculating the impact of visitors in the cave, which is indeed something hard to quantify. This is not something that affects the quality of the paper itself but makes the findings a bit less important than what could have been achieved in a non-touristic cave.

Besides such general comments and the specific comments below, I suggest the manuscript can be published after minor revision.

Thank you very much for this encouraging review. We agree that the quantification of the impact of the cave management on the cave climate is a highly interesting point. However, other than making the reader aware of these influences, with the data we have we unfortunately cannot provide more information on this topic.

Please find the responses to the specific comments below.

SPECIFIC COMMENTS

P 2 L 30-35: as I agree with the statement "it is crucial to assess and understand the microclimatic and glaciological conditions inside ice caves and their coupling to the outside atmosphere" I suggest the innovative CFD model approach proposed by Bertozzi et al., (2019) "*On the interactions between airflow and ice melting in ice caves: A novel methodology based on computational fluid dynamics modelling" https://doi.org/10.1016/j.scitotenv.2019.03.074, 2019*is mentioned in this section.

We suggest to extend the text in the manuscript as follows (L39-41):

Furthermore, the spatial distribution and temporal consistency of these measurements are mostly insufficient to allow comprehensive analyses of the full spatio-temporal characteristics. This also limits the validation of respective numerical models (e.g. Bertozzi et al., 2019).

Figure 1: for more clarity, I suggest adding the location of the stakes even in the elevation view (lower panel)

We will adapt the figure accordingly.

P 5 L 106 (also related to **P20 L 416-419**): I understood that, as you mentioned, it is really hard to quantify the effects of artificial snow input inside the cave, but can you be more specific about this process? I see that some information is retrievable from Fig. 8 and some are explained in the discussions but maybe you can add some more if known. For example: is the snow input affecting all the areas homogeneously or just near the entrances, how often does it happen usually, just in late winter? Has the artificial snow input ever been quantified at least in snow thickness at a stake to have a vague idea of its impact (maybe referring to some of the Figure 8 values)? Is the shovelling process documented every time or the listed markers are just some of them?

The snow is brought in through the upper entrance and accumulates as a snow cone in the main ice-bearing chamber (Eisdom) as well as through the lower entrance where it fills the space below the staircase and feeds a secondary ice body. Figure 1 shows the areas with snow and the position of the stakes of which only Stake A (not further used in this study) is directly affected by artificial snow input.

Regarding the amount and the timing we can only work with respective notes by the local cavers. Thus, the markers in Figure 8 have been read from the guest book of the hut next to the cave documenting the timing of artificial snow input into the cave. This information is reliable, but the quantity of snow input was never documented.

We suggest to add the following sentences in the text (L 106): "*The snow is brought in through the upper entrance accumulating as a snow cone in the main ice-bearing chamber (Eisdom) as well as through the lower entrance where it fills the space below the staircase and feeds a secondary ice body (Fig. 1). Although these activities are documented, proper quantification of the effect of the artificial snow input on the cave ice mass balance is not feasible. Regarding stake measurements, only stake A was directly affected by the artificial snow input and thus not used in this study.*"

P21 L 430-437: I feel that having a range of values from other stakes and T sensors would enrich the discussions of this work and improve the eventual future comparisons with other studies using this methodology in different caves. I understand that stake B and T29 were used as references for deriving the DDF as they are more robust. Is there a chance that some other T sensors and stakes are used for calculation of shorter DDF periods and then compared with the reference values that you already mentioned? If stake B is affected by the artificial snow input, are there other stakes that can be less affected by snow shovelling and therefore can provide additional data in the discussion of DDF findings?

The combination of stake B with logger T29 was chosen not only because it is the longest continuous series, but also because the two measuring points are closest to each other (~2 m distance). Moreover, stake B was rarely affected by the artificial snow input as is known from the regular readings in spring an autumn. Following the comment we report the so far not shown degree day factors using other stake-logger combinations (Table 1). The values range from 0.6 mm °C $^{-1}$ day^{-1} up to 5.9 mm °C $^{-1}$ day^{-1} with the highest values resulting from combinations with T36. This temperature logger is furthest away from the stake measurements and represents a thermal regime which is less relevant for ice developments in the main chamber.

Table 1: Degree day factor (DDF) in mm °C $^{-1}$ day^{-1} calculated from different logger-stake combinations for the available periods (see Figure 8).

logger \ stake	A	B	D	E
T29	2.2	1.9	1.4	0.6
T30	1.9	2.2	1.7	0.9
T36	5.9	5.1	4.0	1.7