The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-287-RC1, 2020


The Cryosphere Discussions
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# *Interactive comment on* "Unprecedented loss of surface and cave ice in SE Europe related to record summer rains in 2019" *by* Aurel Persoiu et al.

**Anonymous Referee #1**

Received and published: 24 November 2020

Overview of the manuscript

This manuscript investigates the changes of ice thickness of five ice-filled caves (Scarisoara, Chionotrypa-Falakro, Chionotrypa-Olympus, Crna Ledenica and Velika ledena jama v Paradani), as well as the area changes of two mountain glaciers (Snezhnika and Basnki Suhodol), all of them in Eastern Europe, during the hydrological year 2018-2019. The relatively large changes observed are associated to an anomaly in the weather (both summer and winter weather). The observations of ice changes are carried out based on in situ length measurements for the ice within caves, and with a drone for the two mountain glaciers. Weather parameters are obtained from the fol-



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lowing datasets: E-OBS (Cornes et al., 2018), NCEP/NCAR (Kalnay et al., 1996) and MODIS/Terra Snow Cover Monthly L3 Global (Hall et al., 2006).

The manuscript is well-written and illustrates that changes in weather have also effects on ice within caves. However, in my opinion, there are some major flaws that need to be improved before this manuscript is suited for publication. Below a list of general comments and specific comments for the authors in order to improve the manuscript:

General comments:

1 – Weather vs climate:

The abstract, introduction, discussion and conclusions manuscript refer in numerous occasions to “climate”. This, in my opinion, is not correct, since a study of one-year length does not reflect climate variability, and contains the high-frequency effects of the weather. Similarly, it is also erroneous to associate the observed changes of one year to climate. To “filter” the weather from the climate, the study should span minimum 10 years (e.g. Marzeion et al., 2014). Through the manuscript this should be clarified, and the word “climate” should be used minimally. Also, the areas of interest are located at really large distances within each other (up to 1000 km apart), and it is almost certain that each area of interest will have a different response to weather and climate. It can be expected that the glacier changes are not simply explained from pressure and temperature anomalies. For example, the two studied glaciers are still existing likely due to their elevation range, slope and aspect.

2 – Surface vs cave glacier:

The manuscript shows observations on two glaciarized systems: mountain glaciers and ice within caves. These two categories are rather blurry throughout the manuscript. Each type of ice is measured with different methods, but throughout the manuscript there is no distinction of them, and all the results and discussion are presented regardless of this difference. A distinction between both types of ice would make, in my





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opinion, a cleaner section of methods and results, showing (1) changes in ice within caves, with its associated method and (2) changes in mountain glaciers from UAV. Finally, in connection to the general comment nr1, the two glaciarized systems will likely have different responses to weather and should not be discussed without taking this into account.

3 – Data collected:

The manuscript uses two main kinds of observations collected in situ: (1) distance measurement between benchmarks and the ice, to measure relative changes in the level of ice in caves, and (2) comparison of UAV-based surveys. These observations lack on specific description of how they are carried out. See specific comments on questions that arise when reading the manuscript. In general, since there are rather limited studies of ice within caves, it would be worth adding some paragraphs, even some photographic material, on how these measurements are conducted.

The temporal resolution of the data collected in caves is also not clear. Are the measurements done only once a year? In this case, the temporal resolution of the data collected does not allow making statements regarding the seasonal variability of the ice, as is stated throughout the discussion.

A table showing an overview of the data collected would be really beneficial for the reader to understand the amount and main characteristics of observations done in this study.

4 – Results:

The manuscript is also lacking methodological information on how some results are calculated, which limits the study's repeatability. For example, how is the change in the level of the ice converted to a volume change?

None of the presented results contains error bars. The general reader has no sense of the robustness of the measurements (also due to the lack of description in the data





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collected), and this, in my opinion, causes a lack in scientific rigor of the results.

The section 4.1 (Ice mass balance changes) does not show any mass balance number. Neither volume change (presented for ice within caves) nor area changes (presented for mountain glaciers) is “mass balance” (Cogley et al., 2011).

The methods show that the UAV-based surveys produced Digital Elevation Models (DEMs), but these were not included in the study. Differencing of UAV-based DEMs is a robust method to infer volume changes and mass balance (e.g. Whitehead et al., 2013, Groos et al., 2019). Analyzing area changes in mountain glaciers, as opposed to volume changes, is not optimal, since the area changes are not as closely connected to climate/weather than the volume changes (e.g. Jóhannesson et al., 1989).

Specific comments

Title: "Unprecedented” is a very strong statement and the limited observations do not prove whether or not there has been any similar event in the past.

Title: I found confusing the term "loss of surface and cave ice”. Something like “loss of ice in mountain glaciers and within caves” might be clearer.

L19-24: Half of the abstract is focused on “climate”, but this manuscript does not show “climate” but “weather” (general comment nr 1).

L26: “catastrophic and unprecedented” ... again this is a really strong statement without clear evidences of it.

L26-30: The second half of the abstract is focused on model predictions and the fate of the ice within caves, but this manuscript does not show any climate model prediction at any point. Similarly, the paleoclimatic information is only mentioned once in the introduction (L50). Since the focus of this manuscript consists of bringing observations and exploiting the weather datasets, some general results should be mentioned in the abstract.





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L32-40: See general comment nr 1.

L87-88: “Ice dynamics” typically refers to ice motion and ice deformation. As I understand this is not measured in this case.

L125: This study does not show “mass balance changes” (general comment nr. 4)

L127-130: How are the distance measurement carried out? With tape, total station? What’s the estimated uncertainty of the measurements? (general comments nr. 3 & 4.)

L136-142: More details are needed for the photogrammetric set up. Did you use GCPs and/or GPS? How are the results of the photogrammetric processing, for example from bundle block adjustment? What is the expected uncertainty of the orthomosaic and the DEM? What’s the exact date of survey? (see suggestion of adding a table with observations). Why are the DEMs not used in the study? Measuring elevation difference and volume changes is much more representative to study glacier changes than measuring area changes, since the area changes are influenced by the response time of the glacier (general comment nr. 4).

L144-145: “In order to link the (. . .) parameter (. . .)” The study does not perform any robust link or correlation between parameters. Please rephrase or clarify.

L143-154: Some information about the uncertainties of the weather parameters would also be highly valuable.

L156: See general comment nr. 4. No mass balance changes are provided in the results. Please use more accurate terms, such as “volume changes”, “ice-level changes” or “area changes”.

L163: How is this volume calculated from the ice-level changes? What are the uncertainties? This also applies for the other caves (general comment nr. 4)

L164-165: “a gradual decrease of the ice volume was evident since 2014, reaching a





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minimum in September 2019 (Fig. 3)": This statement needs a stronger support than Fig. 3.

L242-244: "(. . .) resulted in the large accumulation of snow (. . .)" . . . but this is only observed by the weather datasets, right? And these datasets do not show accumulation (snow thickness), only snow distribution. Therefore, this sentence might not be correct.

L245: "led to the rapid melt of the surface snowpack" . . . again this is not observed, only suggested. Please rephrase acknowledging the lack of such specific observations, for example "high temperatures suggest rapid melting of the surface snowpack".

L248: "resulted in rapid ice accretion in caves" ... Please rephrase acknowledging the lack of such specific observations

L250: "wet late spring and summer led to rapid cave ice ablation" . . . Please rephrase acknowledging the lack of such specific observations. Check for any other occurrences throughout the discussion.

L264: Break into a new paragraph, since now you start talking about mountain glaciers as opposed to ice within caves.

L271: Please follow a logical structure of the discussion, I suggest first a discussion about ice within caves and then a discussion about mountain glaciers, but not an alternation between the two.

L298: How is this prediction done? This shouldn't be stated in the conclusions without specifying any prediction of disappearance throughout the manuscript.

L302: "our observations show..." These are not really observations done in the study, these are results from weather datasets. To me, the observations done in this study are the ice level changes and area changes.

L303-310: Again, this is the first time when the prediction of extreme weather is mentioned in the manuscript. This should not be presented in the conclusions.





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Figures

Fig. 2: Please indicate source of data in the caption.

Fig. 3: This figure showing changes in snow is heavily influenced by the seasonal differences of each picture. This needs to be properly addressed or otherwise this figure should not be presented. Comments on the caption: the figure does not show any ice. Also, the first year is 2014 and not 2016.

Fig. 4: See general comment nr. 4 about the limited use of the UAV data. Comments in the caption: "Orthomosaics showing ice surface changes (. . .)"

Fig. 5: See general comment nr. 1 and 2. The interpretation of pp change at several locations at relatively large distances and with different systems (mountain glacier vs caves with ice) is not straight-forward and it can be misleading to compare them as such.

Fig. 6: Letters (a,b...i) are missing.

Fig. 8: See general comment nr. 4. Volume changes is not the same as mass balance.

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Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-287, 2020.