

Review of the manuscript entitled: GEOPHYSICAL MEASUREMENTS OF PERENNIAL SNOW PATCHES IN PIRIN MOUNTAIN, BULGARIA

General comments The research article enclosed aims to characterize perennial snow patches and the structure of their underlying formations in Pirin Mountains, Bulgaria, using geophysical methods, such as: Ground Penetrating Radar and Electrical Resistivity Tomography. First of all, even though this type of characterization has been done before in other parts of the world, I believe it is novel and intriguing in this context, due to the rarity of microglaciers and perennial snows on the territory of Bulgaria, despite the high altitudes. I appreciate the hard work that has been put into this study. From personal experience, it is not easy to conduct geophysical surveys on mountainous terrain, especially if it is not easily accessible as this site appears to be. Normally, I would expect more repeatability of the surveys done throughout the years in order to capture the morphological/hydrological changes that might have occurred, but given the location, this may not have been an option. However, I do have several problems with this manuscript and in this current state I would only recommend a reconsideration with major revisions. I do believe this work is publishable, but needs a bit more work on the following aspects:

1. The use of English language. Even though I often understand the message behind a sentence, it is very hard to follow sometimes. There are a lot of grammatical errors and quite often I come across sentences that could be reworded or incorporated in a longer phrase to improve the readability of the paragraph. (I will give specific examples below and in some places I attempted to rephrase some parts in order for them to read better. I should say that I only picked up some mistakes, there are definitely others that would need attention).

Thank you for your suggestions on improving the English language. We have modified the manuscript as suggested. Additionally, the language will be corrected by a colleague and a revised version will be uploaded when needed.

2. I feel like there needs to be a bit more discussion about the changes you might have seen across the 3 years of surveys. All around us, nature is changing rapidly and cold regions are often the ones that show the greatest change. You touch a bit upon some structural changes you noticed on the tomograms imaging the microglacier, but I personally feel this should be expanded enriching the content of the manuscript.

3. There are a few technical issues that I came across when reading your methods and looking at the figures, but I think these can be overlooked if only they are properly explained (I will give details below).

We are going to correct some of the figures

I will give a list of specific comments below with line numbers associated. The ones with red headings I considered to be more pressing issues that need re-

solving. When I use quotation marks I am rephrasing that bit of the text or correcting a mistake.

Specific comments Abstract 1. Line 4: rephrase as "in Europe, situated in the...". This is an example of a sentence that could have been merged into a bigger phrase to improve readability.

Done

2. Line 5: ERT stands for Electrical Resistivity Tomography

Done

3. Line 6: "next three years" implies 2021 as well. Please rephrase.

Done

4. Line 11: No issue here, just wanted to underline this is an interesting find. Like I said above, the permafrost's changes in time would be interesting to look at. This could be a continuation of this work, a basis for an ampler future project.

We are going to continue the measurements near Snezhnika but also near other perennial snow patches observed in high mountains of Bulgaria.

1. Introduction

Line 22: "The most studied perennial snow"

Done

Line 25: "size were made"

Done

Line 25: What systematic measurements ? Be specific please. Also, "were conducted".

Done

Line 25: "at the end of summer"

Done

49 Line 31: There are many types of geophysical measurements, not just the ones listed here. A probe 50 reading a soil's temperature can be thought as a geophysical measurement. Are you sure none have been 51 carried out before? You could say: "Georgievna et al., (2019) finds that geophysical measurements, such 52 as... could be useful for a better site characterization because of their...".

Line 35: "Permafrost is also a good..."

Done

Line 45: Double parenthesis after Onaca et al.

Done

Line 52: " with the GPR technique used for imaging of..."

Done

Line 58: ERT is not an acronym for electrical resistivity. ER would be, if you want to use one.

Done

Line 63: I am not sure if you need the EM abbreviation if you don't use it afterwards.

Done

58 Line 79: ERT is not just in 2D, can be in 1,2,3 D and even timelapse 3D classed as 4D in some cases. 59 Please rephrase. Line 81: Do not forget salinity!

Line 93: The last sentence is a repetition, please rephrase or remove. In addition, the last paragraph is a bit too short, normally is meant to be setting the scene to what you are about to read in the paper. Please expand. For example you have not even mentioned which geophysical methods you have used, even though you are hinting that GPR and ERT are your methods of choice.

Done

2. Methods Line 97: You can just say ERT from now on. It was previously defined in the abstract and introduction and I suspect you will be asked for a list of abbreviations too.

Done

Line 98: I do not think this intro paragraph is needed, at least not in this form. Everything you say here you repeat later on.

Done

2.1 71 Line 113: "as can be observed in Fig.2"

Done

Line 116: "in the same place over the microglacier's bed where the GPR profiles were made the previous year"

Done

Figure 2 caption: "over the years".

Done

75 Figure 2 caption: 2nd sentence should not be in a caption. 76 Figure 2: By

looking at the dates when the photos were taken, can you discuss a bit if the weather at the 77 specific time of year had an impact on your measurements? In 2017 and 2018 you went there in August, 78 whereas in 2019 and 2020 you went in October.

2.2 Line 133: "Locations are presented in..."

Done

Line 133: "Profile coordinates..."

Done

Line 134: 1-2 m seems like a rather big error to me. Can you justify that this is acceptable?

Line 135: The "relief's horizontals" ?

Done

Line 139: I really don't get why they have no topography, doesn't it skew the results? surely the 85 topography is not that similar across all radargrams. 86
Line 141: Even though I sympathise with the effort needed to perform this kind of survey, unless you 87 describe how this has impacted your results, this last sentence is unnecessary.

2.3 Line 144: "Based on other surveys..."

Done

Line 146: "when observing permafrost"

Done

91 Line 147: I know what you mean here, but this sentence needs to be rewritten. Please refer to the 92 literature. 93 Figure 3: It is not clear to me when did you make the measurements? Same day as the photos?

Line 151: "Four-electrode"?

Done

95 Line 152: What were the conditions?

Line 152: "conditions in the field"

Done

Line 154: "over the moraine ridge"

Done

98 Line 156: I feel like the information about the length of the profile should have come earlier in the section.

Line 158: "on an area without any ice and snow cover"

Done

100 Line 161-163: Last sentence sounds bad in English. I know what you are trying to say though. Please 101 refer to the literature and phrase this a bit better. For example: " In order to obtain a model of electrical 102 resistivity an inversion algorithm was used in which a starting resistivity model is iteratively adjusted in 103 order to achieve the best fit with the measured apparent resistivity values..... "

3. Results and discussion 3.1

106 Line 165: The title of this section is a bit misleading, ERT is also a type of geophysical investigation and 107 is not presented here. I suggest renaming this section to refer strictly to GPR.

Line 167: "We acquired nine radargrams.."

Done

109 Line 168: What other 2 profiles?

Line 170: "In Fig. 4"

Done

111 Line 171: Same as before, saying it was "difficult" is redundant if it has not impacted the data in any 112 way? Please expand. 113 Line 174: "The are covered by profiles..." 114 Line 175: "by snow during the previous year"

Line 180: "was used"

Done

Line 187: A suggestion. Rather than listing them in the text, you can put the velocities in the stratigraphy table. By the way, I like your idea of having a summary table.

Thank you for this idea, we moved the GPR velocities in the stratigraphy table.

Line 189: " They have no scientific meaning and are the result of technical difficulties..."

Done

Line 191: This sentence is a bit redundant. If I see the figure I know it contains those profiles, you can use this section to present the results and discuss them.

Done

Line 192: "In order to capture the discontinuities"

Done

Line 192: "between the start and end"

Done

123 Line 193: Shouldn't this change in elevation be taken into consideration?

Line 193: "In both radargrams"

Done

3.2

126 Line 215: Again, this title sounds misleading too. Isn't what you presented in the previous section also 127 about the subsurface structure? Needs renaming.

Line 217: "Located in the lower part of the investigated area"

Done

Line 217: "these horizontal profiles..."

Done

130 Line 219: In reference to the topography data: 1. You should mention this in the methods section and 2. 131 Why can't you do this for all GPR sections? please explain.

Line 223: "the apparent resistivity values"

Done

133 Line 224: how do you know those rock sizes? 134 Line 226: In reference to your claim that you are detecting marble. I don't think that is a valid assumption 135 unless is supported with further evidence, that resistivity range can cover many types of material. 136 Line 230: These variation in size are very interesting, tied to the hydrology of the area. It deserves a 137 closer look. 138 Line 238: Try to discuss and expand this, it looks as if some melting occurred. 139 Line 245: Quite a redundant sentence again. 140 Line 250: You have said this before. The interesting bit here is that they match. Please discuss how well 141 they match.

Line 253: Delete "right on the figure"

Done

Line 254: "ERT data reaches a smaller depth"

Done

Line 255: "with the area identified as a frozen zone on the GPR profiles"

Done

Line 259: Delete "even in the sunniest days of summer". I don't know if that was the sunniest day that summer...please avoid vague sentences like this.

Done

Line 263: "Snow patches were not observed"

Done

148 Line 264-266: I am not sure how these 2 sentences are relevant if you can't show any data or reference 149 any study. Page 5150 Line 271: This is an interesting point. You can expand. 151 Figure 10: It is not very clear to me exactly where do they overlap. Are the 2 tomograms at different 152 scales? 153 Figure 11: The elements of this figure are way too small, I cannot see the labels at all. Every figure needs 154 to be readable, even though you are reproducing some material you have shown before.

4. Conclusion Line 278: "and the subsurface beneath it."

Done

157 Line 280-283: I know the conclusion usually contains a bit of repetition, but you have almost copied the 158 whole paragraph from the discussion. The conclusion should be a concise version of your results and 159 discussion.

Line 285: "However, the thickness values estimated are a good base for monitoring microglaciers of this size."

Changed

Line 286: "The underlying layer is identified as a glacier bed ...and consists of rock blocks of different sizes, spaces between them being filled by ice, water and air."

Done

Line 288: "beneath the surface as surface water is rarely observed."

Done

165 Line 288: You did not discuss this conclusion in the discussion section. It is an interesting point that 166 deserves consideration.

Line 290: "From the GPR profiles situated on the lower part of the investigated area..."

Done

Line 292: "60000 $\Omega.m$, values typical for ice"

Done

169 Line 299-302: Please remove these lines as they are not supported by any

data or past studies.