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Interactive comment on "Implications of present ground temperatures and relict stone stripes in the Ethiopian Highlands for the palaeoclimate of the tropics" *by* Alexander R. Groos et al.

Anonymous Referee #2

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General comments:

This paper presents a detailed account of current and past periglacial landforms and processes of the Bale Mountains in Ethiopia, with specific focus on relict sorted stone stripes. The latter is a very prominent feature and very unique for the tropics and mid- and high-latitudes in general. The characteristics of these stone stripes are described by detailed geomorphological mapping, UAV photogrammetry, ground-penetrating radar and 36Cl surface exposure dating. Palaeoclimatic importance are studied by collecting current ground and air temperature data and modelling a minimum air temperature depression needed to form these landforms.

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I was pleased to receive the invitation for reviewing this work, which I read with great interest. It is clear to me that the authors have gathered a highly relevant dataset, which would be a great scientific contribution about this topic. However, I agree with previous referee report of Stefan Grab that the paper is very long, in some places lacking focus and it is not always clear what the added value of certain datasets are. For example the UAV photogrammetry data – is this just a nice addition or does it actively contributes to your findings? Are grain size distributions based on this imagery as you state in your methodology? This is not clear. I understand that the authors want to describe the features in as much detail as possible, but this does not come forward in the result section of the paper, where it seems that only the geomorphic mapping, the 36Cl surface exposure dating and the temperature measurements and modelling are presented. Results from UAV data and GPR seem to be lacking/could be stated more clearly. The way the paper is written now, the temperature measurements and analysis form the core of this work and all other methods are tributary. I strongly agree with Stefan Grab's suggestions on the temperature data used in this paper. The potential presence of air circulation in the blocky material, causing substantial cooling, should be discussed. In addition, comparison with current day examples could be more elaborate and is now only briefly touched in the discussion (on p25, L6 you state there are well documented examples from the high arctic). It is also not clear to me why the example of the Falkland Islands is highlighted. Is this the only other site that shows similar inactive landforms, like the ones you observe in the Bale Mountains?

Nevertheless, I also agree with Stefan Grab that this work is highly relevant and important to publish. I therefore suggest that a moderate to major revision of the manuscript is required.

Specific comments:

- Be careful with absolute statements that are not based on clear references/data. For example: P1 L1: . . .the most prominent features. . . -> one of the most/one of the more prominent features. . . (People studying rock glaciers might disagree with your

initial statement...). P2 L17: Africa's largest alpine environment -> one of Africa's largest alpine environment (also see comment of Stefan Grab). I see that in L22 on p3 underneath study area you have a more detailed statement of this, referring to your manuscript in revision. If you stand by this statement, consider moving this information more forward in the manuscript.

- You are very brief when describing the collected UAV data (L14-20 p6). Normally, at least an error reporting should be done to indicate the reliability of your data. Because UAV data is prone to deformation, especially when using a small amount of ground control points that might not be evenly distributed. If I understood correctly, you did not incorporate ground control points to process the images, but only to georeference the final products (orthophoto, DSM). This is confusing, since normally ground control points are used to correct the geometry in the 3D modelling procedure. Therefore, consider using different terminology. I understand that this is not the focus of your paper and that you refer to earlier work. However, I still think error reporting should be included here (and might not be similar as the errors you achieved on Kanderfirn) if you want to include this data in your paper.

- The text reads sometimes confusing when you talk about temperature measurements. Please check thoroughly throughout the document that you clearly mention when you talk about ground temperature and when you talk about air temperatures. For example: In the caption of figure 1: GT and TM are both ground temperature loggers?

- P13 L13: This sentence is lacking a reference. Since you base an important part of your modelling on this value, and the resulting temperature depression, you could give more attention to where you get this value. Is this -1°C ground temperature purely theoretical (from literature)? Or is this based on other observations in other areas? In your discussion you give an example of Goldthwait 1976, where large sorted landforms are common with air temperatures of -4 to -6°. How does this stand in relationship with -1°C ground temperature? Could you compare these air temperatures to the air temperatures depression you found for the Bale Mountains? This needs some clarification

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Discussion paper

throughout the document in both methodology, results and discussion.

- Section 4.1: make sure the distinction between active and relict periglacial processes is clear. Also add this to the title, for example . . . past and present periglacial processes (needle ice is not really a landform).

- Figure 5: I agree with Stefan Grab considering the comments about Figure 5. Reporting single frozen waterfalls and needle ice observation is rather anecdotal. Could you, besides direct observation, also indicate areas where these phenomena are likely, depending on elevation, slope, aspect. . .? Do you have more observations, from for example locals? You could make different mapping categories between permanent landforms and areas were current periglacial processes could be observed. Differ between landforms and processes.

- P16 L9: Is there a clear difference in elevation (belts) between relict periglacial features and current periglacial landforms/processes?

- P17, L1: Are the scree slopes really relict? Or could present frost weathering also still contribute to these landforms that are mainly formed in the past?

- P23 section 4.3: this section could use some rewriting. L9-10 contains your topic sentence, what this part is really about, and I would move this up to the beginning of your paragraph for clarity. At the end of this section you again state that -1°C MAGT seems critical for the formation of deep seasonal frost. On what do you base this statement? (see also previous comment).

- P23: Your discussion section could benefit greatly from adding subtitles. Now the structure is not clear and different things are discussed alternatingly, not always grouped coherently. The first paragraph reads more like a conclusion/summary. I can differ the following discussion topics from your current paragraphs:

Similar periglacial landforms in other areas/comparison of the Bale Mountains to other area (paragraphs 2-4) Specific environmental settings of the Bale Mountains (para-

graph 5, but also 9 and 10) The formation of pattern ground (paragraph 6), discussion seasonal variation (paragraph 7) and sporadic permafrost (paragraph 8) Outreach and future research (paragraph 11)

Technical comments:

- The English of the paper can still be improved, especially long and complex sentence structures (e.g. multiple commas) should be avoided. Often readability already improves greatly if the sentence structure is reversed, or split into multiple phrases. For example: P2 L7-10 P3 L16-21: turn these two sentences around: The exact timing.. is unknown... due to lack of geological maps... The central Sanetti Plateau... is characteristic for the Bale Mountains. P3 L26-28 P17 L5-8

- Watch out with neglecting articles (a/an, the): P14 L25: the Sanetti Plateau, the highest peaks P20 L20: ...and the northern valleys...

- Take care of the use of hyphens: P1 L2 and P2 L28: mid- and high-latitudes

- Consider putting table 2 and figure 3 in Appendix.

- The use of allow: allow cannot be followed just by a verb, so things like “allow to establish” (L4 p12) are not correct. Allow needs either a noun or a subject and verb, like “allow the establishment of”

- Several times you refer to information that is stated later in the manuscript (for example L12, p13, L8, p15). This makes the structure of your paper not always clear to the reader. Consider moving important information more forward.

- p 17, L7: this sentence is already part of the next paragraph. Move for better structure.

- P22, L3: revise sentence, wrong use of minimal

- P23, L3: concurrently = simultaneously (?) – long sentence

- P23, L5: what = which

- P29 L27: Suggestion to add ‘modern’ and ‘co-exist’ :. . . where relict and modern, frost-related periglacial landforms co-exist..

- Spelling and grammar flaws are not all flagged, so careful proofreading is still required, keeping the above mentioned comments in mind.

- Figure captions should be clear independently from the text. Therefore, please clarify:

Figure 1: the control points, are they used for georeferencing the UAV data or for satellite imagery? GT and TM are both ground temperatures? The different figure panels require a, b, . . . so the data basis can be referenced more clearly. Consider leaving out the map of Africa indicating the position of Ethiopia and instead mention in the text that Ethiopia is positioned in the horn of Africa. The map of Africa is lacking a scale, as well as your inset of the map of Ethiopia to show the position of the Bale Mts.)

Figure 5: Consider using a different color code for active and relict periglacial forms (and general geomorphology such as landslides). The distinction between stone polygons and stone nets are not clear, use a different symbol. Make it more clear that panel D is derived from the UAV data.

Figure 8: very long figure caption. Put the information of the columns into the figure (the months for Bega, Belg, Kiremt). No need for mentioning the colours for panel b, this is clear from the column headers. Specify if this displays air temperatures or ground temperature in the figure.

Figure 9: I assume this data is from the AWS stations, mention this clearly. Specify if this displays air temperatures or ground temperature in the figure.

Figure 10: I assume this data is from your loggers, mention this clearly. Specify if this displays air temperatures or ground temperature in the figure.

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