Reply to Referee #1

I have reviewed the manuscript “Impact of natural parameters on rock glacier development and conservation in subtropical mountain ranges. Northern sector of the Argentine Central Andes” by Forte et al. with interest. The authors provide a new inventory of rock glaciers and protalus rampart for subtropical mountain ranges in the northern sector of the Argentine Central Andes. The authors mainly describe the characteristics of the inventory and finally apply a statistical approach (frequency ratio) to investigate controlling factors. The topic is of interest for The Cryosphere and the statistical analysis demonstrate that elevation, lithology and aspect are also dominant controls for subtropical mountain ranges.

We would like to thank Referee #1 for emphasizing the importance of the rock glacier and protalus rampart characterization and distribution surveys in subtropical mountainous areas.

Nevertheless, my review pointed out a number of serious scientific issues, which are listed in the following general comments and in the following detailed comments section. In my point of view, these points must be carefully addressed before the manuscript can be considered for publishing in a high-level journal as The Cryosphere. Thus, I suggest reconsideration of the manuscript after major revisions.

The general and detailed comments had been carefully addressed and we would like to thank referee 1 for the contributions.

GENERAL COMMENTS

1- The authors provide a new inventory of rock glaciers and protalus rampart and use it for further analysis. The inventor y bases on a singular survey and therefore can be used to describe the occurrence of rock glaciers and protalus rampart, but not to describe the development and conservation which is the intention of the authors (see title, abstract and elsewhere).

In the first general point, Refree1 presents our work, details the general points and makes a first significant observation. Then emphasizes the use of the terms "development" and "conservation", and suggests that we should use the term "occurrence" of rock glaciers and protalus rampart, since our descriptions are limited to that concept. The authors consider that the existence of rock glaciers and protalus rampart are indicators of processes for the development and / or conservation of these landforms. However, we have discussed the proposal again and we will consider limit the use of these terms in the body of the manuscript (title, abstract and others) as Referee #1 has suggested and to raise in the conclusion and discussion the use of these terms more clearly in order to avoid confusion.

We have considered to name the paper: *¨The influence of environmental variables on rock glaciers occurrence. Argentine Central Andes north sector¨*

2- The authors formulated the overall aim of the study, but a clear research question in the introduction is missing. An overall clear structure would facilitate reading the manuscript.

In the second point out that although we have formulated a clear research question, it is not clear in the introduction. In this regard we have decided to improve it, in order to facilitate the reading of the manuscript.

The research question is How do some environmental variables influence the occurrence of rock glaciers?

3- The rock glaciers and protalus rampart inventory for this region is novel. The resulting inventory database includes basic descriptive information, localization, physical parameters and a classification (dividing rock glaciers into active, inactive and fossil). The generation of the inventory and inventory database need to be explained in more detail. A validation and uncertainty assessment are missing and would be very important, because the statistical approach bases on it. Especially the detection and classification leaves a lot of room for interpretation. Further it is not clear how the observed features are assigned to protalus rampart or rock glaciers (what are the criteria for distinction?)

We appreciate the consideration of the new scientific information for this region. As for the inventory and database methodology, we recognize that in the manuscript we do not detail enough the way in which manual mapping and digitization was performed. This was due to the existence of a large number of scientific articles based on digital mapping with optical satellite imagery.

- For the rock glacier and protalus rampart Identifying and mapping, was mainly considered geomorphological criteria's, making observations with satellite images and a detailed field control.

- Rock glaciers are distinctive geomorphological landforms, easily identifiable through satellite images with a high spatial resolution (Wahrhaftig and Cox, 1959; Haeberli, 1985; Roer and Nyenhuis, 2007). These may extend from the rock wall, outward and downslope with a moderated slope and a frontal talus with a pronunciated slope. Above the rock glacier surface could be develop furrows and ridges or collapsed structures associated to ice melting can be developed. Intact rock glaciers were differed as active and inactive, using geomorphological criteria as the degree of furrows and ridges development, among others. Active rock glaciers present a better development, also these are characterized by exposure of fine debris at the talus front and large block accumulation at the talus bottom. Other geomorphological criteria used was the angle of the frontal talus slope, which is major on active rock glacier. The existence of vegetation, collapsed structures and flat surfaces are characteristics of inactive rock glaciers. In the Figures 1 and 2 there are two examples of active and inactive rock glaciers mapping.

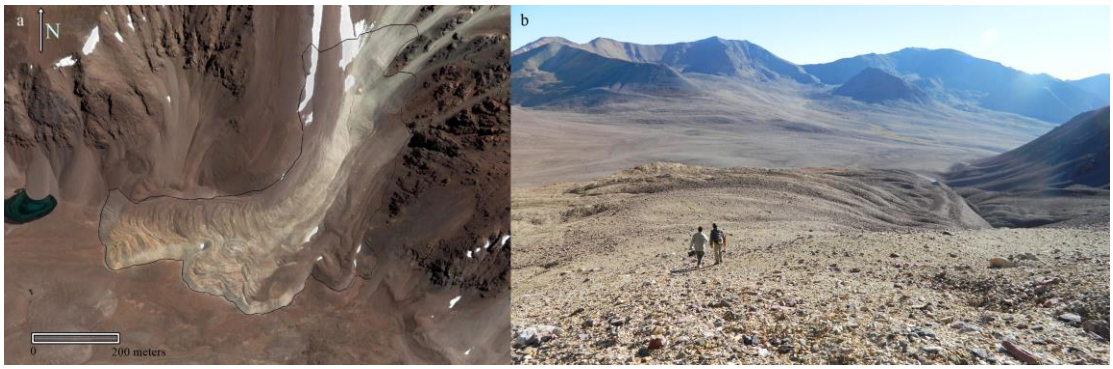

Fig1: a- Active rock glacier mapping. Geographic coordinates: 31° 9' 45" S and 70° 12' 50" W

b- Field Control. Furrows and ridges over rock glacier surface. Two people as scale.

Fig. 2: a- Inactive rock glacier mapping. Geographic coordinates: 31° 2'45"S 70°15'50"W. b- Field Control. Low frontal talus slope and a depressed general structure.

- Fossil or relict rock glaciers have lost all their ice content and indicate current environmental conditions unfavorable for their development. They have the same shape as rock glaciers but their surfaces are completely devoid of periglacial processes, and looks completely depressed. Vegetation development on its surface is common, and the frontal talus is usually underdeveloped or even could been disappeared.

- Protalus Rampart have been considered an expression of mountain permafrost creep and, as such, they may be considered as embryonic rock glaciers (Barsch, 1996). Therefore the criteria to distinguish them is their dimension. These are smaller than a rock glacier. Generally the width is greater than the length and their surface, practically, does not have furrows and ridges development.

For each mapped landform, was considered as the upper limit the root zone where is produced the abrupt slope change between the rock wall and the rock glacier or protalus rampart surface. While, for the lower limit, was included the lower part of the frontal and lateral talus of the rock glaciers or protalus rampart.

About the database, these included basic descriptive information (basin, satellite and sensor used, type of rock glacier and lithology of the bedrock); localization (latitude and longitude) and physical parameters (Elevation, Slope, Aspect and Potential Incoming Solar Radiation).

- The type of periglacial landform are rock glaciers and protalus rampart. Rock glaciers have three categories are: fossil, active, and inactive.

- The lithologies of the bedrock categories are nine units. The information was obtained using a geologic map based on the Geological and Mining Service of Argentina Republic publications (SEGEMAR, 2008).

- Elevation, slope, aspect and incoming solar radiation were obtained using a digital elevation model provided by ALOS Palsar with 12,5 x 12,5 m spatial resolution. Dataset: ASF DAAC 2015, ALOS 140 PALSAR_Radiometric_Terrain_Corrected_Hi_res; Includes Material © JAXA/METI 2007. Accessed through ASF DAAC, https://www.asf.alaska.edu 16 May 2016 DOI: 10.5067/JBYK3J6HFSVF.

- A detailed field control was conducted on the basins of the Frío, Embarrada, Los Patos Norte and Bagres rivers and near the Salinas river draining. Were observed 128 rock glaciers and 187 protalus rampart, representing a percentage of 73 % of the amount of rock glacier and a 80% of the total protalus rampart existing in a study area. Field geomorphological studies allowed a better characterization of the periglacial landforms, especially to detect vegetation, collapse structure, springs and others geomorphological structures and processes above the periglacial landforms observed.

According to the suggestion of referee 1, we added an uncertainty assessment description about the rock glacier and protalus rampart inventory. Identification, classification and mapping was performed by two different people for the same study area.

- First, we analyze that all the rock glaciers and protalus rampart have been mapped (n: total amount). Person A has identified n_a= 415 and person B has identified n_b= 398 landforms. The average of both values is n_m= 406.5 with a variance = 67.24 and the standard deviation = 8,2. The results were manually compared and the criteria were discussed in detail. Finally the total number of rock glaciers and protalus rampart acording is 405 with an accuracy of +/- 8.2.

- Second, we describe the uncertainty for each kind of landform (TABLE 1).

TABLE 1: uncertainty assessment for each kind of landform.

Type of landforms.	n_a Person A	n_b Person B	average	variance	standard deviation	Acording number
active rock glacier	53	49	51	4	2	49 +/- 2
inactive rock glacier	62	60	61	1	1	61 +/- 1
fossil rock glacier	66	60	63	9	3	64 +/- 3
protalus rampart	234	229	231,5	6.25	2,5	231 +/- 2,5

4- The description of the statistical analysis should be extended and formulated more clearly. Please ensure that the mathematical variables are unique and correctly defined.

The frequency ratio analysis is a methodology commonly used and well known among researchers of the subject, so the authors believe that it is clear in the text and referenced properly. However, we will add a goodness of fit of our statistical model, as the referee 2 suggest.

5) The discussion section is much too short and should be extended adequately. There are many open questions: How do rock glaciers in subtropical mountain ranges differ from other regions? How reliable/robust are the results of the statistical analysis? And many more.

The discussion section will be improved, as Referee #1 suggests. Among the questions mentioned in their comments, we believe appropriate to include:

- *How do rock glaciers in subtropical mountain ranges differ from other regions?*

The study area is located in a subtropical situation, about 1.000 km at south of the Capricorn Tropic, therefore the sun's rays fall on the earth's surface obliquely during all the year, with irregular distribution in the potential solar radiations values.

This phenomenon is clearly observed in the important influence of slopes orientation (aspect) on the rock glaciers occurrence, with a remarkable major development and conservation on south facing slopes.

- *How reliable/robust are the results of the statistical analysis?*

We would include the inventory uncertainty analysis

- *Concepts about rock glaciers development and conservation.*

In the present work and in agreement with previous surveys (Brenning et al., 2007; Johnson et al., 2007; Esper Angillieri, 2010) is demonstrated that in similar environmental conditions (morphometric and climatic) there are differences in the rock glaciers behavior and responses. We attribute that the lithological characteristics are directly influencing the behavior of the periglacial landforms.

In this context, concepts of rock glaciers conservation and development are differentiated. There are lithologies that favor the rock glacier development, these lithologies are apparently the same that later favor the degradation of these landforms. A large number of intact rock glaciers exist on these lithologies. Instead, there are other lithologies where rock glaciers develop with more difficulty. However, over these the periglacial landforms seem to be preserved for much longer facing environmental changes. Over these last ones, a smaller number of intact rock glaciers is developed but there are a greater amount of active than inactive rock glaciers.

We think that to discuss and understand how different variables influence periglacial systems is fundamental to understand the processes and behavior of these landforms facing different environmental scenarios.

6- There is a lot of potential to improve the figures with regards to content, graphics and readability. Try to make the content of the figures and the relation between the subfigures clear. Try to avoid repetition of figures (e.g. Fig. 2 and Fig. 3: the relevant pictures are shown twice). I suggest to reduce the content in figures. Putting the maps providing physical parameters and geology in a figure with several subplots facilitates comparison. Try to use appropriate char t types and to avoid duplicated information visualization (e.g. bar char t and table) unless there is real advantage. A consistent style of the figures with less color, better color selection (e.g. colorbrewer2.org) and clear color definition would improve the quality. Be aware of the quality of the figures and the readability of text. Par ts in Fig. 1, 3, 4, 6 and 7 are non-readable and need to be guessed

Comments and suggestions about figures are considered appropriate by the authors and they are thankful.

7- Language and consistency: I'm not a native speaker myself, but spell check and language check would be very helpful. Further be aware of inconsistencies in word/term choice, citing (e.g., p.2, l.4: who is Schrott H.?) and definitions (e.g., mostly rock glacier and protalus rampart are distinguished, but sometimes combined or mixed up.

We found the mentioned mistake on p.2, l.43, the right reference is Schrott, L. We want it to be clear about the differentiation between rock glaciers and protalus rampart, so we will improve any confusion identified in the manuscript.

DETAILED COMMENTS

p. 1, l. 1: The title does not clearly reflect the contents of the study (see General Comment 1)

This has been answered in the first general point.

p. 1, l. 11: Rock glaciers can be a part of periglacial environment, but the occurrence is not necessary and there are many other features.

We agree with this statement, however we believe, like others (Barsch D., 1996, Haeberli et al., 2006; Azócar et al., 2016), that the rock glaciers occurrence is a direct indicator of mountain permafrost and as is the most representative and easily identified periglacial landforms, could be considered as a proxy of current periglacial environment state. However, in order to improve reading, we change the sentence:

This paper presents a detailed rock glacier inventory used in determining how some environmental variables influence the rock glaciers occurrence.

p. 1, l. 25: Using an inventory based on a singular survey, how do you know that the rock glacier conservation is mainly controlled by lithology?

We appreciate this question to clarify the idea. Our affirmation ¨rock glacier conservation is mainly controlled by lithology¨ is based on observations about the rock glaciers distribution over each lithological units identified. As explained in the fifth general point, we observed that above some lithologies are an important amount of intact rock glaciers developed (active and inactive in similar numbers), while over another lithologies there are more active than inactive rock glaciers. We propose that in the second case the lithological characteristics have major capacity for rock glaciers conservation than the first case.

This idea will be explained in the discussion, and in order to improve reading, we change the sentence in the abstract:

The statistical analysis shows that elevation, lithology and aspect are the most influencing factors for the active rock glaciers occurrence.

p. 2, l. 39: If you mentioned the study area, you would already emphasize that there is no existing inventory/study for your study site.

The suggestion is appreciated. We add the following sentence:

In the study area there is no existing previous rock glaciers inventory.

p. 2, l. 46: How do you know the state of the periglacial environment? A time series of observation/inventories would allow to investigate the evolution.

Our intention is to suggest that the state of a rock glacier (active or inactive) is related to its interaction with the environment.

p. 2, l. 46: Glaciers have a reaction time to climate change of up to several decades

We agree with this comment. Our intentions were to express that rock glaciers responded with a major delay than glaciers. We briefly modified the sentence to improve it

Unlike glaciers, rock glaciers show a greatest delay in response to climate change and are conditioned by different parameters which control the velocity and degree of development, preservation and/or degradation.

p. 2, l. 48: I would rather use degradation instead of deterioration

The suggestion is appreciated (see the previous response)

p. 2, l. 54: Is this relevant for this study?

The intention was to characterize the different kind of rock glaciers, with the purposes of understood what references and concepts we are using.

p. 3, l. 67: SW = south west?

Yes, we are going to change SW for south west, as Referee1 suggests.

p. 3, l. 68f: Change order, first inventory, then statistical analysis...

The suggestion is accepted. By suggestion of the referee 2, a new statistical method is added that complements our conclusions. We could reorder the paragraph as follow:

This paper presented a novel rock glacier inventory in the northern sector of the Argentine Central Andes, specifically, the watershed areas of La Salina river, including Frío, Los Bagres and De Las Salinas river basin. The relationship between spatial rock glacier distribution and environmental variables as

climatic, lithology, topographic and morphometric were analyzed, using a frequency ratio and logistic regression as statistical methods.

p. 3, l. 77: This needs to go to the discussion.

The suggestion is accepted.

p. 3, l. 80: Study site?

We consider that Regional Setting is the best way to describe this section because the study area is described from different perspectives.

p. 3, l. 84: Is there a reference?

Subsecretaría de Recursos Hídricos (2002). Atlas Digital de los Recursos Hídricos Superficiales de la República Argentina CD-ROM, Buenos Aires.

p. 3, l. 89: Rephrase this sentence

We propose as an alternative: The climate of this region is influenced by the South American Arid Diagonal.

p. 4, l. 98: Why is the accumulation of glacier mass relevant? Or do you mean rock glacier?

In this sentence we try to describe de regional situation but is not relevant to this work and could be skipped.

p. 4, l. 104: I would use rather “shaped” than “modeled”.

The suggestion is accepted.

p. 4, l. 115: As you are only considering lithology and not geology, shorten this paragraph.

The suggestion is accepted. The new paragraph would be: *The structural, topographic, stratigraphic and geological aspects are highly dependent on the geometry of the Wadatti Benioff zone (Smalley and Isacks, 1990), where the interaction between Southamerican and Nazca tectonics plates take place.*

p. 5, l. 122: confirmed?

Yes, in the study area, eo-Palaeozoic are conform by strongly deform sedimentary rocks (Amos y Marchese 1965; en Caminos 1979). It is intrude by carboniferous plutonic rocks with granodioritic to tonalitic composition (Ramos, 1999). The Neo-Paleozoic sedimentary sequences are very widespread in Frontal Range and are characterized by Upper Carboniferous and Lower Permian marine rocks (Amos y Rolleri, 1965).

Amos A.J. y Marchese H.G. 1965. Acerca de una nueva interpretación de la estructura de Carbónico en la Ciénaga del Medio, Estancia Leoncito, Sud de Barreal, San Juan. Revista de la Asociación Geológica Argentina, 20 (2): 263-270.

Amos A.J. y Rolleri E.O. 1965. El Carbónico Marino en el Valle Calingasta - Uspallata (San Juan - Mendoza). Boletín e Informaciones Petroleras, 368: 1-23

Caminos R. 1979. Cordillera Frontal. 2° Simposio Argentino de Geología Regional Argentina, Academia Nacional de Ciencias 1: 397-453. Córdoba

Ramos V.A. 1999. Plate tectonic setting of the Andean Cordillera. Episodes 22(3): 183-190

In the manuscript only the following bibliography will be added:

Caminos R. 1979. Cordillera Frontal. 2° Simposio Argentino de Geología Regional Argentina, Academia Nacional de Ciencias 1: 397-453. Córdoba.

p. 5, l.137ff: This paragraph is hard to read and it is not clear what the date of physical inventory is.

The suggestion is accepted. The new paragraph will be:

The rock glaciers inventory has been framed within the corresponding hydrologic system. Drainage network and watersheds mapping was made using a digital elevation model provided by ALOS Palsar with 12,5 x 12,5 m spatial resolution. Rock glaciers identification, mapping and inventory were based on Satellite Multi-spectral and pancromatic Images provided by Terra/ASTER; CBERS2B/HRC (only pancromatic); Sentinel 2 and SPOT5/HRG2. The landforms were manually (on-screen) digitized as vectors, using the projection UTM zone 19 south and WGS84 datum, based on geomorphological information. As date for mapping, was used the autumn of 2016 due to the diversity and good quality of the images available. A detailed field study was performed on 128 rock glaciers and 187 protalus rampart, representing 77,7% of the total amount of studied periglacial landforms in the study area.

In this section will be added a detailed description of the considered criterial to identify and classificate each landform (see General Comment 3)

p. 6, l. 149: It is not described how the protalus ramparts are distinguished from the rock glaciers.

The suggestion is accepted. We will add this description in this section. The descripion *has been answered in the third general point.*

p. 6, l. 174: What is a "medium" elevation? Do you mean "median" or "mean"?

We were referring to ¨mean¨. The observation is appreciated, the text has been modified.

p. 6, l. 177: What is a "attitudinal distribution"? Do you mean "altitudinal distribution"?

Yes. Observation is appreciated, and has been modified text.

p. 6, l. 178: Why do you have 5 classification?

The study area was divided into 4 main categories (altitudinal belts). The aim is analyzing the rock glaciers altitudinal distribution. The sentence has been modified as follows:

For analyzing the rock glacier's altitudinal distribution, the study area was divided into 4 main altitudinal belts based on the mean, minimum and maximum rock glaciers elevations.

p. 7, l. 180: For me it is not clear how you calculate a mean aspect. Please explain in more detail.

Mean aspect represent the cardinal point towards which it inclines a determined surface.

In a first step the aspect cartography was obtained in SAGA and Gv GIS, using Travis, et al (1975) algorithm over ALOS PALSAR DEM. This was calculated in radian to prevent mistakes or confusion with degrees values, because it is not possible to do a direct average. For example: If we calculate an average between 1° (north) and 355° (north) the result will be 178° (south).

About this, the WGMS (Paul et al., 2010) suggests a method using maps of sine and cosine calculated from the aspect grid. So in a second step, was obtained the sine and cosine maps. In a third step, was calculated for each rock glacier and protalus rampart the mean sine and mean cosine aspect. The fourth step was to calculate the arc tangent for these new attributes of the database. And the final step is converting the results obtained in the previous step (in radians) to degrees to facilitate the interpretation and visualization of the results. Then were made with the medium aspect in radian and then was calculated the arc tangent and is obtained the medium aspect values. Finally we turn radian values in degree and then the numbers degree value are turn to letters which indicated the cardinal point (Table 2). Finally, the numerical values (in degrees) are converted into letters according to Table 1 (see Fig. 7 in the The Cryosphere Discussion paper). The aspect is present as 8 values: N, NE, E, SE, S, SO, O, NO, a logic classification just for simplify the visualization.

Table 2: Aspect (degree - classification)

Degree:	Valour
N	0-22,5
NE	22,5-67,5
E	67,5-112,5

SE	112,5-157,5
S	157,5-202,5
SO	202,5-247,5
O	247,5-292,5

p. 7, l. 187: Could you please explain in more detail how you calculate the potential incoming radiation?

The calculations for annual potential solar radiation was carried out in SAGA GIS, using ALOS PALSAR DEM, a sky view factor map derived from dem, aspect, slope and latitudinal situation (solar declination and position) and two grid with latitude and longitude information in degree. The calculations were performed for a full year, every 7 days in periods of 1.5 hours and the chosen solar constant was 1.367 W/m2. This constant is the value assigned by the World Radiation Reference Centre (WRRC) proposed by the WMO (World Meteorological Organization). The measuring unit for output radiation raster is watt-hours per square meter (W.hr/m^2).

You can find more information about the Command-line at the website: http://www.saga-gis.org/saga_tool_doc/2.2.5/ta_lighting_2.html

p. 7, l. 188: How do you know the "vapour pressure"?

The water vapour pressure grid is an optional input and we didn´t use it. But in the process the program ask about the most relevant atmospheric effects and have three available choices: Height of Atmosphere and Vapour Pressure; Air Pressure, Water and Dust Content or Lumped Atmospheric Transmittance. We ponder the first option, so the program uses a default command.

p. 7, l. 190: Please explain more precisely.

The frequency ratio analysis is a methodology commonly used and well known among researchers of the subject, so the authors believe that it is clear in the text and referenced properly. We have included another method, such as logistic regression to accounting for the influence of each predictor.*(*see Appendix 1, in Referee 2 responses*)

p. 7, l. 196: For your analysis, you should consider the different classes (e.g. i) of all parameters (e.g. j). Try to use appropriate naming (e.g. classes, parameters, . . .) here and elsewhere in the manuscript.

The suggestion is accepted.

p. 7., l. 202: Language.

We improved this sentence: ¨The study area covers about 630 km^2, showing an important development of periglacial landforms. Rock glaciers occupied 3,25 % of total area (Fig. 3)¨

p. 8, l. 207ff: Why 4 belts? The characterization (seasonal frost belt, unstable periglacial environment, . . .) is not only caused by the altitude. And how do you get the boundary values of the belts?

We agree with Referee #1 that the characterization we have given is not only caused by the altitude, however the rock glacier occurrence on this work is considered as a sensor of the periglacial environmental situation. And to study the influence of elevation, we divided the study area into 4 main categories (belts) based on the mean, minimum and maximum heights of the rock glaciers. The aim is analyzing the rock glaciers altitudinal distribution.

p. 8, l. 222: What is a "slope gradient"? Why do you combine rock glaciers and protalus ramparts here and distinguish them elsewhere?

Thank you for your suggestions. We were referring to mean slope.

To facilitate reading we separate the values, as suggested by Referee #1:

The mean slope in active rock glaciers has minimum values of 11,2%, maximum of 28,5% and averages of 18,9%. The mean slope in inactive rock glaciers has minimum values of 8,5%, maximum of 26% and averages of 18,5%. The mean slope in fossil rock glaciers has minimum values of 3,9%, maximum of 31,3% and averages of 12,7% and protalus ramparts mean slope has minimum values of 4,5%, maximum of 48,8% and averages of 4,5%. This shows that a very high slope (greater than 30%) is not related to rock glacier occurrence (Fig. 6).

p. 9, l. 244: Could you show the rock glaciers which are in the altitudinal range 3868-4225 m a.s.l., aspect between 113 ◦ and 247 ◦, slope between 11 and 19 ◦ as well as "Oligocene to Lower Miocene – Intrusive Rocks" lithology? Are these parameters in combination most appropriate?

Thanks to Referee #1 for this suggestion. Finding the place with best conditions for the rock glacier occurrence is possible because it has been worked in SIG platform and each categories and their subdivisions are clearly identified in the database. Therefore, by filtering variables can be found rock glaciers or protalus rampart in different situations.

According to the ratio frequency analysis, the better conditions to rock glacier occurrence are:

- Elevation: Between 4048 and 4225 m.a.s.l.

- Lithology: Oligocene to Lower Miocene Intrusive Rocks and Permian to Triassic - Vulcanosedimentary rocks.

- Aspect: 158-202 degree (South)

- Slope: Between 11 and 19 %

- Potential Solar Radiation: Between 856789 and 1839402 [WH/m^2]

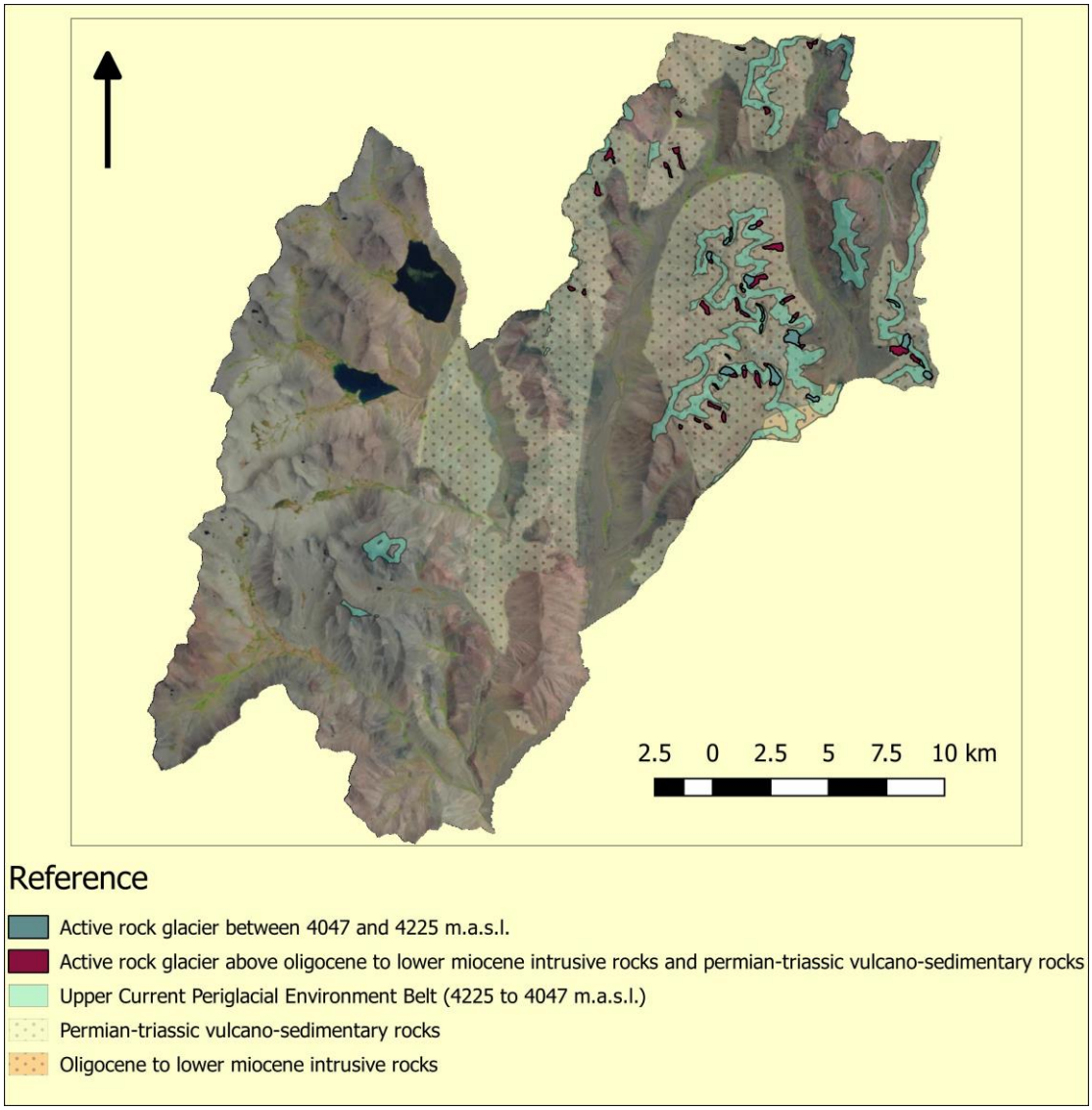

Fig 3 : Active Rock glaciers above the most favorable lithology and elevation, according to the frequency ratio method

p. 9, l. 245: Do you now include protalus ramparts or not?

Not, the frequency ratio (Fr) analyses was performed only over active rock glaciers

p. 9, l. 255: This study shows the affect of the different parameters only for rock glaciers and protalus rampart and not for periglacial landforms in general.

The suggestion is accepted

p. 9, l. 261: Again, how are you able to provide information on development and conversation of active rock glaciers using an inventory of a singular survey?

The suggestion is accepted and in this sentence we are going to limit to said occurrence.

p. 9, l. 262: What is with the first belt of before?

The study area was divided into 4 general belts. Belt 3 (Current Periglacial Environment Belt) include areas between the lower and upper active rock glacier elevations. To improve the analysis of active rock glacier distribution, this belt was divided into three parts: lower, middle and upper current periglacial environment belt (elevation intervals: 3.690-3.868; 3.868-4.047 and 4.047-4.225 m.a.s.l.)

p. 10, l. 264: Are inactive rock glaciers really an indication that no permafrost occurs?

Inactive rock glaciers are not an indication that no permafrost occurs, in fact they are intact rock glaciers. However, they are considered as permafrost degradation indicators.

p. 10, l. 276: Variable, parameter or factor? Try to be precise and consistent with terms.

The suggestion is accepted and appreciated.

p. 10, l. 291: This is a new result and should not be presented the first time in the conclusion. Further, I doubt that the accuracy is such high that you can distinguish 10 m of difference.

We accept the suggestion of mentioning these values in the result section with a major emphasis. Is important to mention that the digital elevation model used has a resolution of 12.5 meters.

p. 11, l. 295: Where/how do you determine the aspect?

In order to improve manuscript understanding, in Fig. 7 we have tried to expose the irregular distribution of landforms on different slope orientations.

We accept improve the sections of method and results in the aspect calculations (see previous response).

p. 11, l. 297: Again new result . . .

The suggestion is appreciated, however we think it is not a new result, we only mention the geographical situation of the study area (located about 1.000 km at south of the Capricorn Tropic)

p. 11, l. 304: What does "(n:15)" mean?

n= number of rock glaciers

p. 11, l. 313: Do you consider geology in your analysis?

We accept change geology by lithology

p. 12, l. 321: Again try to be consistent, even in the References. Once "Arenson, L." and once Arenson, L. U.".

The suggestion is accepted and has been modified text.

p. 17, Fig 1: Different coordinate systems are used in the different subfigures. There is an error in the coordinates (subfigure left). What is the meaning of the colors? How do the subfigure left and the subfigure top right fit together? Legend of subfigure top right is non-readable.

Comments on Figure 1 are grateful, we accept the criticism and will improve the points mentioned by Referee #1.

We use different coordinate systems in the different subfigures because we work with UTM projection, but to facilitate the readers location we transform the main image into geographic coordinates.

We detected the error in the coordinates (subfigure left), we appreciate the observation.

The colors represent different basins and sector of the study area, and are not relevant for this work. Figure 1 would improve considering this point.

p. 18, Fig. 2: Where were the pictures taken? What is the relevance of the picture top right?

We have decided, according to general comment 7, that this figure can be merged with figure 3. And we will improve the points mentioned by refree1.

p. 19, Fig. 3: Try to use better colors to indicate the periglacial landforms. The pictures in the middle right are the same as in Fig. 2. Try to use appropriate chart types and to avoid duplicated information visualization (e.g. bar chart or table, but not both). Legend in subfigure bottom right is non-readable.

The suggestion is accepted.

p. 19., Fig. 4: Protalus ramparts and rock glaciers are almost not visible and the different landforms are almost not distinguishable from each other. Subfigure bottom right is non-readable.

The suggestion is accepted.

p. 20, Fig. 5: It is very difficult to take advantage of the colors in the legend ob subfigure top left

The suggestion is accepted.

p. 21, Fig. 6: What are the high and low values of the slope map (subfigure top left)? Subfigure top right is non-readable.

The slope range is between 75 and 0%. We will add the values and improve the figure.

p. 21, Fig. 7: I suggest to emphasize the spider chart.

The suggestion is accepted.

p. 23, Tab. 2: I would suggest to use histogram to visualize the data of this table. How are the classes defined? Sometimes, the classes are not the same as in the Figures/text.

We accept the suggestion to use histogram to visualize the data of this table. The classes are the same in the Figures/text.

p. 24, l. 470: I guess this should show an example how the values in the column are calculated. Please try to use appropriate variable names (same as in Eq. 7) and give an explanation.

The suggestion is accepted.