

## Responses to Referee 1 (Andreas Kääb)

### Comment from referee, #1

This study discusses glacier-rockglacier transitions and changes over time of selected rockglaciers in the Andes of Chile. This is a very interesting and timely contribution on a less studied rockglacier area that can add to the understanding of rockglaciers and their climatic and geomorphological significance. The paper is well written and nicely illustrated. The paper could, though, benefit from a broader view and discussion of the changes seen.

### Author's response

As also suggested by the second referee, we have widened the view, scope, and discussion of our study. The overall significance of the study is better highlighted by covering the following key aspects: the spatial and dynamical interactions between glaciers and permafrost, the *in vivo* observation of rock glacier development, and how these composite landforms participate in sustaining a hybrid cryospheric landscape in which glacial and periglacial realms spatially and dynamically interact in response to climate change. The latter aspect is of particular importance in semiarid areas as the one studied here. We also insist much more on the importance of the rock glacier morphology, i.e. how it is likely to influence the surface energy balance, the subsurface heat transfers and resulting landform dynamics.

### Author's change in manuscript

See in particular the whole introduction, discussion, and conclusion.

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### Comment from referee, #2

I have however a major problem with the displacement measurements presented, which are a, or even the core of the study. For me, most of the displacement vectors look like mismatches, i.e. wrong measurements. In parts, especially on the glacier parts, it is very hard for me to imagine that there are corresponding points that are preserved and can be matched over tens of years. Without checking the original images used, it is however not possible to me to judge this thoroughly. I offer to the authors to contact me directly for further details and solving my concerns. In sum, for me the quantitative results of the study are for now under a big question mark.

### Author's response

See our General comment. The analysis has been re done completely and new figures produced.

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### Comment from referee, #3

Page 7/line 14: Which software did you use for matching?

### Author's response

Erdas was used.

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### Comment from referee, #4

7/17: did you test your DEMs for lateral offsets and higher-order biases?

### Author's response

The aerial photo DEMs were co-registered to the Geoeye DEM using common GCPs during DEM processing. The bias of the generated DEMs was tested over stable areas outside the

landforms' area, as mentioned in the Method section. Nevertheless, we did not analyse biases dependent on the elevation or geometry of the data acquisition (Nuth and Kääb, 2012).

#### **Author's change in manuscript**

p. 8, l.22-24 (in the new version): 'The same processing scheme was followed for the aerial photo stereo pairs using control points visible both on the Geoeye image and the aerial photo stereo pairs.'

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#### **Comment from referee, #5**

7/25: I don't understand fully: you used the airphoto DEMs for differencing, but they were too bad to use them for orthorectification?

#### **Author's response**

The phrase was incorrectly formulated. We rephrased.

#### **Author's change in manuscript**

p. 9, l.1-3: "The Geoeye images were pansharpened and orthorectified using the Geoeye DEM. The aerial photos were then orthorectified using the corresponding DEMs, except when no reliable DEM could be obtained (as for 1955 at Navarro); in that case the Geoeye DEM was used."

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#### **Comment from referee, #6**

8/1: better not to use 'vertical displacements' for elevation changes and thickness changes, as 'displacements' suggests that particles are moving vertically, which is not the case for the type of DEM differences you observe.

#### **Author's response**

We have replaced 'vertical displacements' by 'elevation changes' throughout the manuscript.

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#### **Comment from referee, #7**

8/12: You need to show and discuss the DEM differences on stable ground. This would be a good indicator of the uncertainty.

#### **Author's response**

See (p. 8, l. 24-26; this was already mentioned in the first version): "The vertical bias of the aerial photo DEMs was calculated by comparison with the Geoeye DEMs over flat and stable areas outside the landform studied and was removed from the subsequent calculations (see below)." The biases appear in Table 2. They were also taken into account for the interpretation of elevation changes (p. 9, l. 18-21).

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#### **Comment from referee, #8**

Show all images, not only for Presenteseracae Fig 8, so that the reader can judge by himself. Perhaps in an Appendix.

#### **Author's response**

We have included two additional figures, for Presenteseracae and Las Tetas, respectively. All original images are now visible in the article.

**Author's change in manuscript**

Fig. 6.

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**Comment from referee, #9**

11/17, and 13/27: show and discuss stable ground displacements and DEM differences.

**Author's response**

See our response to Comment #7.

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**Comment from referee, #10**

17/16 and other places: you should discuss the processes potentially involved in the rockglacier/glacier changes observed more broadly and complete. For instance, what about potential changes in debris production, debris budget, debris evacuation, glacial transport, etc.

**Author's response**

Absolutely. We developed a wider discussion in the new version of the manuscript. The composition of the discussion is now as such: 5.1. Initial landform development. 5.2. Differences between debris-covered and rock glacier areas. 5.3. Current evolution and its significance. 5.3.1. Landscape evolution. 5.3.2. Dynamical evolution. 5.3.3. Final diagnostics and future evolution of the landforms.

**Author's change in manuscript**

See the whole new discussion section in the text

**References (not cited in the manuscript)**

Nuth, C., Kääb, A.: Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness changes. *The Cryosphere*, 5, 271–290. <http://www.the-cryosphere.net/5/271/2011/tc-5-271-2011.pdf>