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The Cryosphere Discussions

Interactive comment on "Longitudinal surface structures (flowstripes) on Antarctic glaciers" *by* N. F. Glasser and G. H. Gudmundsson

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We would like to thank the reviewers for their thoughtful and constructive reviews. Below we give a point-by-point answer to all the issues that they have raised. Our responses are in red type.

We will take all these points into consideration in the final version when we submit the revised manuscript.

Anonymous Referee #2 Received and published: 28 February 2012 This paper introduces longitudinal surface structure maps for a small number of ice streams and isolated valley glaciers in four regions of Antarctica. The paper presents hand digitized maps of flow stripes from a series of Landsat and Terra Aster images. After a rather

convoluted introduction the maps are presented in turn before key observations are presented. The lines drawn on the maps show, in places, dendritic like patterns of flow convergence, with in other areas significant flow divergence and widening stripes. It is not possible to indicate exactly where these occur as there are no lat/long coordinates on any of the maps and images. However, the patterns shown are more complex than the text suggests, casting some doubt on the observations.

We have added graticules with lat/long coordinates to all the maps.

I am surprised that manually digitizing these stripes is either the quickest or most accurate way to make interpretations. Is there no pattern recognition software that would allow this to be done, quickly, easily and without human interpretation? Such an approach would also allow quantification of stripe widths and lengths.

As a research group we have experimented with the use of pattern-recognition software (using Definiens Developer, formerly known as e-cognition) to map glaciers surface structures, including crevasse patterns, but we have found it to be of limited use. The algorithm works by comparing adjacent pixel values and establishing patterns of light and dark pixels but the problem is that it also picks up every situation in an image where there are light and dark pixels in close proximity. Also, although it looks distinct initially, the change between light and dark pixels on a 'ridge' is gradual when you look closer, so it is difficult to interpret where the 'ridge' began prior to commencing automatic feature extraction. So, we have to go through every image and manually select areas that we believe to be longitudinal surface stripes. Thus we have always come back to manual digitizing and found this to be superior.

I am also surprised that no modelling is presented. The 2nd author has conducted more rigorous modelling studies of similar features. The models presented are simple cartoons.

One of the main objectives of this paper is to show that the model presented by the second author (Gudmundsson) does not explain the origin of most flow stripes seen

in Antarctica. Gudmundsson's model is only applicable to flow stripes generated by flow over bedrock undulations, whereas as we show in the paper, most flow stripes are generated at the confluence of two ice streams. No additional modelling work is needed to support this conclusion.

Specific comments:

Page 3086, Line 25-27: be specific about the glaciers – you name the Lambert Glacier but not the Ferrar.

The glaciers are now named here.

Page 3087, Line 1-6: This is somewhat strange to read – the material is repetitious of the abstract and somewhat out of place.

Lines deleted. Page 3087, Line 21-22: Sentence lacks context and detail.

Reworded

Page 3087, Line 27: This discussion of possible cause seems out of place. The previous part of the paragraph does not state that these structures form in any particular way.

Rewritten

Page 3087, Line 28: Why not use the continuum mechanics phrase?

The term 'streakline' is a descriptive term describing what (we believe) these features are, whereas 'flowstripe' is a name that we give to these features. We cannot exclude the possibility that later research will show that some of the flowstripes are in fact not streaklines.

Page 3088, Line 6: This line starts the discussion of cause/explanation – move comments in paragraph above down to here.

We have re-written the Introduction to separate description from interpretation.

Page 3088, Line 4-16: This section seems under-developed. More needs to be made of current theories of formation.

We have re-written the Introduction to separate description from interpretation.

Page 3088, Line 17: Back to description here, before causal discussion at the end of the paragraph.

We have re-written the Introduction to separate description from interpretation.

Page 3089, Line 2-21: Back to explanation here with a summary of the theories put forward earlier in the introduction.

We have re-written the Introduction to separate description from interpretation.

Page 3089, Line 6-7: This could be interpreted in many ways – to suggest folding as the only mechanism goes against the discussion of the 'streakline' from earlier in the introduction. I do not believe that the assertion of folding is warranted or substantiated in this context. Overall the introductory paragraphs are poorly constructed. There is a feeling that they are rushed and not really ready for submission. The authors should revisit them and order them so that description and possible process are in separate paragraphs and follow logically from each other.

We have re-written the Introduction and given it a new structure to separate description from interpretation.

Page 3090, from Line 11: Again, structural comments – why are we getting a description of field sites mixed in with the results?

Sentence moved.

Page 3090, Line 18-20: There is a discussion of shadows here. What is the sun angle and sun direction on the images? The lines on the maps do not run at a consistent angle, so the amount of shadow is not a good indication of vertical dimension. Do the authors have 2 or more images of the same area with different sun angles and

elevations to explore shadowing further? The authors may end up mapping a very different set of features if different sun angles highlight different features.

For Landsat scenes it is possible to extract the sun elevation and sun azimuth at the scene centre and corners from the metadata for each scene. These vary slightly from scene to scene but sun elevation is around 36 to 37o with sun azimuth around 60o (i.e. illumination is from the NE). We have experimented with multiple images and found that the sun elevation and azimuth do not make a huge difference, as the "ridge and trough" geometry shows up at different polar sun elevation and azimuth. Where present, we have also used meltwater features to look at the "ridge and trough" geometry because meltwater ponds occupy the low points between ridges and find similar results.

Page 3090, Line 21: All elevations need to be better justified. The authors do not present a DEM so these numbers are not well justified or field truthed.

Rewritten

Page 3092, Line 4: Remove word ubiquitous – you present a limited sample of glaciers and ice streams here.

Word removed

Page 3092, Line 9: Define what is meant by a hierarchical network.

Rephrased

Page 3092, Line 14-16: There is a discussion regarding flow stripe preservation through ice falls. Do the crevasses extend through the ice thickness (a true ice fall) or is this just a zone of extensional flow with crevassing in the surface ice. If the former I might expect horizontal displacement between ice blocks, so the potential for flow stripe blocks to be offset and upon compression incorporated into other flow stripes. Such conditions would not meet the criteria for streaklines.

We have removed the term "ice fall" as we cannot demonstrate that the crevasses

extend through the ice thickness (as in a true ice fall) and replaced this with the term "heavily crevassed zones".

Page 3093, Line 5: No evidence at the scale of the imagery presented (with 15 m grid cells).

Rephrased.

Page 3093, Line 21: Remove 'it is clear that'. Also why not show this – there must be velocity data available for many of the glaciers and ice streams here. SAR imagery would indicate broad compressional/extensional regimes of flow.

Words removed.

Page 3094, Line 9-11: There is some contradiction here with the folding mechanism proposed in the introduction. I am more convinced by this argument than the folding one. Page 3095, Line 20-30: This is introductory material that should be in the causal mechanisms section of the introduction.

This text has been moved to the Introduction as suggested, but words that pertain to the testing of this hypothesis have been retained here.

Table 1 is largely in the introduction – I am not convinced it is required here.

We believe that Table 1 is a useful summary and would prefer to keep it here. It fulfils the purpose of clarifying terminology and does not duplicate the text of the Introduction.

Table 2 is redundant. The two x's could be explained in a short line of text.

We agree and have removed Table 2.

The most disappointing aspect of this paper is that little is inferred about any changes in the causal mechanisms that might be inferred from the data. If velocity changes through time then patterns and structure might be expected to change. Are any changes detected that cannot be easily explained? These stripes are a palaeo record

of flow. It is likely that in order to explore this and make full use of the study a more rigorous way of pattern recognizing the stripes would be required to quantify the process.

To answer this criticism we would need to survey the whole of the Antarctic continent, which is clearly a different job and therefore a different paper. We are very interested in extracting information about past changes using flow stripes, but here our main objective was a different one, i.e. to present and test ideas of the origin of flow stipes.

Interactive comment on The Cryosphere Discuss., 5, 3085, 2011.