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The Cryosphere Discussions

Interactive comment on "Forecasting temperate alpine glacier survival from accumulation zone observations" *by* M. S. Pelto

Anonymous Referee #1

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General Comments

The author discusses field and satellite-based observations for small, alpine glaciers in the Cascades and Wind River Range in the western US. A methodology is proposed to use remotely sensed imagery to classify whether a particular glacier is in an unhealthy state or not. I think the paper should eventually be published, but it will require major revisions before it is acceptable in The Cryosphere. While the paper is generally well written, there is a disconnect between what the paper promises (forecasting temperate alpine glacier survival) and what the paper actually delivers (a description of features apparent in the field and on remotely-sensed imagery that indicate a glacier is experiencing negative mass balance). I expand on some of the major points that the author should consider in a revised format of the paper below; I also provide a list of minor

comments and editorial suggestions.

a) One of the major weaknesses of this paper hinges on the use of terminology. The use of the term 'forecast' commonly implies that there has been some assessment as to the skill of the prediction. As far as I can tell, however, only Table 1 provide an evaluation as to the fate of a glacier. Exactly how the author determined this score for 'Survival Forecast (SF) – yes or no' is not clear. Is it based on some empirical relation between the magnitude of thinning and percentage change area change, ELA rise, etc? Also, what does 'survival' actually mean? The author states on pg. 326 (lines 25-27) that the goal of the paper is to, 'develop a simple method of forecasting temperate alpine glacier survival utilizing ...'. To most, the term 'survival' would imply the glacier will continue to exist as a glacier (last more than a year and flow in response to gravity). On pg. 328 (line 13), however, the author suggests conditions for a glacier that include thinning in the accumulation zone, strong negative mass balance, and decline in the accumulation area of the glacier would make it 'unlikely to survive in anything like its present extent'. The reader thus is left wondering what the author means by the terms 'survival' and 'forecast'.

If the author retains the term 'forecast' then I think he should at least provide some test cases that verify that the methodology works. Much time is spent discussing glaciers in equilibrium and non-equilibrium conditions. Yet these terms are highly dependent on the time scale under question so that a decade of negative mass balance (non –equilibrium) causes the glacier to adjust its accumulation zone and overall geometry to reach as new steady-state (equilibrium) condition. An example of this transient behavior is the initial adjustment of glaciers to the end of the Little Ice Age. Much of the non-equilibrium changes the author describes for the glaciers in the Cascades and Wind River Range undoubtedly occurred for these same glaciers at the end of the Little Ice Age. Yet, the glaciers continued to survive and they largely equilibrated with climate during the period 1945-1977. Thus, they adjusted their accumulation areas to reflect a geometry that was better suited for climate during the 20th century. I can also

think of many glaciers where the criteria used by the author to forecast survival in this study (margin recession and emergence of rock in accumulation zone) occurs today. However, these glaciers are hundreds to thousands of square kilometers in area so immediate death is unlikely.

I'm not doubting that many of the glaciers described in the paper will disappear if the climate continues to warm. However, stating that a glacier is unlikely to survive is vague and doesn't provide the scientific community, resource managers, or policy maker with any assessment about when these glaciers will disappear.

The author has an opportunity to quantify the estimated volume loss of these glaciers based on changes in the accumulation area ratio (see the recent paper by Bahr et al., 2009 – 'Sea-level rise from glaciers and ice caps: A lower bound'; doi:10.1029/GRL036309). This may provide some useful data for the glaciers of this study. Bahr's study also recognizes the importance of the accumulation zone.

b) The methods section is incomplete and does not appear to be consistent with the results section presented in this paper. The author first discusses the use of repeat profiling on the glacier to assess changes in surface elevation. Data sources for this analysis are from USGS maps and field visits. How were field surveys completed? What were the probable error terms in both data sources? These profile data are never really discussed again (or shown graphically). Why not? The methodology using satellite imagery does not contain enough details for a reader to assess whether changes in glacier length or area are outside the error terms of the analysis. How were the satellite images ortho-rectified with only four ground control points?

c)The author should consider additional variables that may explain why particular glaciers appear to be thinning in their accumulation zones. Some variables that come to mind include aspect and slope. I suspect that many of the larger glaciers of this study are vestiges of Little Ice Age glaciers, and so the glacier surface is gentle with some protruding bedrock (e.g. Figure 10). My hunch is that many of the glaciers predicted

to survive have steep surface slopes, and so these ice bodies have already completed most of their dimensional changes from climate of the Little Ice Age.

Specific Comments:

Abstract

– Line 7-8. See comment (a). Term 'survival' needs to be properly defined for the purposes of the paper.

- Line 10-15. I don't agree that this technique will tell us that a glacier will survive or not. See discussion in (a) about the end of the Little Ice Age.

Introduction

- Pg. 325, line 15, '..resource management than' – do you mean 'then'? Also, see point about the need to quantify volume loss or loss through time.

- Pg. 325, line 22. I disagree. The lack of a consistent accumulation area will lead to a new geometry (smaller and possibly steeper ice surface). If the ELA rose above the head of the glacier and stayed there, then yes, the glacier is doomed.

- Pg. 326, line 8-10. Costly measurements, but many do these sorts of studies on remote, large glaciers.

Delineating the response...

- Pg. 328, line 2. Glacier's accumulation zone (possessive). I don't follow the logic of this statement. Why does use of area change ignore viability of a glacier's accumulation zone?

- Pg. 328, line 20. Use 'I' since it is a singled authored paper.

- Pg. 329, line 18. Data are plural. 'These data'.

- Pg. 330, line 11. What spatial resolution ? 2.5 m, 5 m?

- Pg. 331, line 12. What is a 'large, persistent accumulation zone'? You told us earlier that the AAR was 20, so it did persist. Suggest 'the accumulation zone was considerably smaller than the area required for equilibrium blanace'

- Pg. 331, line 25. I don't understand this sentence.

- Pg. 332, line 17. Some more details required how we know this ice was stagnant. Where there flow measurements?

- Pg. 333, line 15. Verbiage could be reduced in this sentence and others in manuscript where lists of glacier names are presented (don't need to write out Glacier after each name, e.g. 'Rainbow, Sholes, Easton glaciers' – note lowercase 'g' since you refer to many proper names).

- Pg. 333, line 19. This sentence is incomplete.

- Pg. 333, line 22. I still don't know what your method really is (see point a)

- Pg. 334, line 4. Awkward sentence. Revision needed.

- Pg. 334, line 25. Again, this terminology is problematic and the statement at face value is incorrect. If the glacier has no accumulation zone for many years, it will die. An inconsistent accumulation zone happens each year depending on net mass balance of that year. A repeatedly small accumulation zone below the area required for equilibrium balance will cause the glacier to adjust its dimensions to accommodate the new climate state.

References:

- Check the references. Several topographical errors.

Tables and Figures:

I'd rather see a figure or two that quantifies some of these apparent accumulation area changes (area of perimeter change (including internal rock) in accumulation area vs.

slope, aspect, etc.) There are too many comparison images.

- Table 1. Many Column names are not listed in the Table caption. - Figure 2 caption. 'balance' not 'balances' - Fig 4. Dotted line not apparent in printed copy of manuscript.

Interactive comment on The Cryosphere Discuss., 3, 323, 2009.