PRIFYSGOL ABERYSTWYTH UNIVERSITY

Canolfan Rhewlifeg
Sefydliad Daearyddiaeth
a Gwyddorau Daear
Prifysgol Aberystwyth
Ceredigion SY23 3DB
Cymru, DU

Centre for Glaciology
Institute of Geography
and Earth Sciences
Aberystwyth University
Ceredigion SY23 3DB
Wales, UK

Professor Bryn Hubbard
Director: Centre for Glaciology

Tel: +44(0) 1970 622783 Fax: +44 (0)1970 622659 Email: byh@aber.ac.uk

RE: RC C883

26.08.2014

We write in relation to the manuscript 'Glacier-like forms on Mars' submitted for publication in The Cryosphere. We thank reviewer 1 (Michael Khun) for their expert comments and summarise our response to each suggestion that was raised below.

Comment (unedited)	**Response**
Reviewer 1 (RC C883: Michael Khun):	
This paper is very carefully written, but it would gain from a brief summary of physical condition on Mars relevant to the existence of glacier-like forms, their lifetime, movement, mass and energy balance. What are typical values of pressure, temperature, gravity, what are the daily and seasonal variations of solar irradiance and surface temperature?	We now summarise this information by adding the following to the Introduction of the revised manuscript: *"Although, in common with other interpretations of Mars' surface features, we adopt a model based on terrestrial analogues, several fundamental controls over martian glaciation contrast sharply with those on Earth. For example, Mars' gravity, at ~3.7 m s^{-2}, is less than 40% of Earth's. Mars' surface temperature varies between ~-130 and +27 °C, with a mean of ~-60 °C (Read and Lewis, 2004), ~75 °C lower than on Earth. Finally, the partial pressure of H_2O in Mars' near-surface atmosphere is ~1 μbar, making the planet's surface ~1000 times drier than Earth's."*
There are so many similarities of glacier-like forms and moraine-like ridges with their terrestrial counterparts that the reader is tempted to think in terms of glaciers and moraines without the cautious "-like".	While we agree that the visual appearance and morphometry of GLFs show strong similarities with terrestrial glaciers, there is still some uncertainty relating to e.g. their composition, thermal regime, mass balance and dynamics (e.g., see Short Comment C1422). We therefore prefer, for now at least, to retain the '-like' suffix.
As they mention boulders on top of the glacier-like forms I encourage the authors to make a short reference to terrestrial rock glaciers.	We agree that reference should be made to rock glaciers and debris glaciers as terrestrial analogues in this context (also see Short Comment C1422). Therefore, the following statement has been added to Section 1.1.2. "*….Debate surrounding the amount of water ice involved in VFF composition (including GLFs) has led to varying interpretations being made, including as ice assisted talus flow (~20 – 30% ice; Squyres 1978, 1979), rock-glaciers (~30 –*

	80% ice; Colaprete and Jakosky, 1998; Mangold, 2003), and debris-covered glaciers (>80% ice; Head et al., 2005; Li et al., 2005). Since the distinctions between these forms – and between them and 'standard' glaciers - is not sharply defined even on Earth, we are not yet in a position to definitively attribute martian equivalents to any or all of them. We therefore follow the convention of much of the published literature and refer to these forms as 'glacier-like', accepting that they may eventually, when more information becomes available, be more accurately reclassified as some related form such as rock glaciers or mass flows. That said, the latter is unlikely to hold universally on Mars since many GLFs do not show distinctive source areas for their mass, many have lost substantial mass since their formation (Section 2.2 below), and many appear from radar data to be composed largely of water ice (this section)."
I would like to see more arguments for the statement on p2962, line 6, and again in the summary 2977/14 "…current GLFs are the remnants of a once far larger ice mass…".	As well as the existing references to three papers that present information to support this expanded former extent we now include the following statement of the nature of this evidence on p. 2962 line 9 (in the original manuscript): "*Such an expanded former extent has been inferred from detailed regional geomorphological reconstructions, for example identifying former ice limits from variations in surface texture and the existence of distal moraine-like ridges. Allied to local topography such reconstructions have allowed the reconstruction of both former ice extent and local ice-flow directions (e.g., Dickson et al., 2010)."*
2964/10 Use upper case for names.	Altered as suggested.
2977/11 Mars'	Altered as suggested.
Fig 7c mark the bedrock protuberances in the figure.	We do not believe bedrock is visible in Fig. 7c; we believe the entire scene is the tongue of a deformed GLF.
Fig. 2 add color code.	Altered as suggested.
Fig. 6 the colors of MLRs and compressional ridges are difficult to distinguish.	We will look closely at this at the proof stage and amend one of the classes if the colours are indeed too close to be easily distinguished. We prefer to wait for final colour rendering because we are already using blue and green elsewhere in the figure.
Fig. 9 boulder instead of bounder.	Altered as suggested.
Fig. 10 distance scales are not readable.	We have amended the scale and text on this Figure (see also response to Referee Comment C1120)
It is obvious the authors of this paper (AOTPs) use many acronyms – this may be inconvenient to readers who are not so familiar	We agree that this may be inconvenient to the reader – but on the whole acronyms are probably preferable to repeating long names. To mitigate this issue we have inserted a table (Table 1) providing a summary of all acronyms used. Table 1 is introduced in the Introduction (p. 2959 line 4) with the following new text:

with these terms.	*"Since this contribution is primarily intended for readers who are primarily interested in the terrestrial cryosphere, and who may not therefore be familiar with the literature relating to the martian cryosphere, a list of the acronyms used herein is given in Table 1."*

Please do not hesitate to request any further information you might need. I look forward to hearing from you.

Kind regards,

Bryn Hubbard (corresponding author)