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The Cryosphere Discussions

Interactive comment on "Review article: The hydrology of debris-covered glaciers – state of the science and future research directions" *by* Katie E. Miles et al.

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We thank both reviewers and, given the broad nature and overlap of the suggestions and limitations raised, we address both together.

Summary of Reviews

Specific comments aside (all of which we are willing and able to address), both reviewers express concerns with the structure and content of the manuscript in its present form and ask directly or indirectly for the following.

1. Greater clarity in terms of how the hydrology of debris covered glaciers may be

expected to differ from that of 'clean ice' glaciers, to include greater representation of the latter.

2. The review to extend beyond a literature summary, and for it to provide added value to the reader.

3. The final section on research priorities to follow more directly from the review (and to include an indication of the methods that might be most appropriate for addressing these unresolved issues [Rev #1]).

Authors' Response

We believe strongly that there is substantial merit in a review of the hydrology of high-elevation debris covered glaciers (DCGs). First, we are convinced that the hydrology of high-elevation DCGs is sufficiently distinctive (expanded upon below) to warrant a dedicated review. It is notable that none of the existing widely recognised reviews of glacier hydrology explicitly addresses the hydrology of DCGs. Second, with some notable exceptions, the community of researchers working on high-elevation DCGs tends not to overlap with that researching clean-ice glacier hydrology. We believe a review of DCG hydrology – hitherto not provided – would be of use to both communities and hopefully lead to greater research integration. Part of the problem in providing such a review is that relatively little is known about the hydrology of high-elevation DCGs: certain hydrological processes operating at clean-ice glaciers presumably hold at DCGs (such as englacial water ingress via crevasses and micro-scale inter-crystalline permeability), but others are unknown (such as the details of water flow beneath a thick surface debris layer, the formation and effectiveness of moulins, the role of surface ponds in terms of delivering meltwater to the glacier base, and even whether the glacier base is temperate and therefore hosts an effective drainage system at all). Therefore, the nature of the problem is such that a review of high-elevation DCG hydrology will largely be pointing to what is currently unknown or poorly-known relative to our understanding of lower-elevation clean-ice glacier hydrology. However, we accept that, despite this

requirement for a review of the hydrology of DCGs, our initial manuscript could have provided this better. We agree with the reviewers in this regard and propose below several substantial revisions to the manuscript that we believe will result in it providing a valuable review.

1. The revised manuscript will focus explicitly on Himalayan debris-covered glaciers (changing the title accordingly), allowing (i) clearer separation between the hydrology of the DCGs reviewed and that of contrasting clean-ice glaciers, and (ii) the special hydrological influence of the monsoon as well as that of the low- or reversed-angle glacier tongue (and its consequences) to be considered explicitly. The revised manuscript will refer to debris covered glaciers outside the Himalayas only where directly relevant.

2. The Introduction will now include a section dedicated to how debris-covered glaciers differ fundamentally from clean ice glaciers. A number of key influences will be identified, including: ice being sourced from extremely high elevations (and therefore assumed to be cold); a steep surface gradient, usually including an ice-fall, in the upper ablation area; a very low or reversed gradient debris-covered tongue in the lower ablation area; an inverted mass balance regime across the ablation area as a whole; the presence of linked supraglacial lakes in the lower ablation area; the frequent presence of a proglacial lake; the common presence of a substantial thickness of subglacial morainic deposits; and the hydrological role of the monsoon. All of these will be expected to influence hydrology in some way, but most remain to be evaluated.

3. The subsequent four main sections - addressing supraglacial, englacial, subglacial, and proglacial hydrology - will each be restructured into three sub-sections: (i) a brief summary of what is known on the basis of research at clean-ice glaciers, followed by (ii) a thorough summary of what is known at Himalayan DCGs, and finally (iii) an evaluation of what is not known (but needs to be) at Himalayan DCGs, identified with respect to the distinctive characteristics of DCG hydrology noted in the Introduction. This restructuring into formal sub-sections will add clarity to the review and lead more logically into the subsequent discussion of avenues for future research. Thus, for example, all

features identified as priorities on Figure 10 will now have been considered explicitly earlier in the manuscript.

4. The revised manuscript will include brief suggestions relating to how each of the avenues identified for future research might be carried out.

5. We will replace some of the more specific photographic figures with schematic illustrations.

We believe that, taken together, these revisions will provide a clear and valuable review that also provides substantially more added value than a straightforward summary of the literature - as requested by the reviewers.

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