Englacial debris content of a Himalayan debris-covered glacier revealed by an optical televiwer

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1. Motivation

- Glaciers across High Mountain Asia provide water resources to huge populations.
- Debris-covered glacier melt rate controlled by **spatially variable supraglacial debris layer**.
- Supraglacial debris thickness controlled partly by **englacial debris melt-out**.
- Englacial debris contents are **unknown** and simplified even in most sophisticated models.

*Figure 1 – Labelled schematic of a debris-covered glacier (Khumbu Glacier, Nepal); Miles et al. (in review)*
2. Method

- Four boreholes
  - Drilled by hot, pressurised water
  - Logged by optical televiewer (OPTV; a borehole-based camera)
- Four OPTV image logs
  - 360° high-resolution images
  - Total 345.5 m of glacier’s interior
- Analysed for englacial debris
3. OPTV image sections & results

Englacial debris contents, from OPTV images, are:

i) **Higher** than at other glaciers around the world

ii) **Lower** than assumed in few models that can consider englacial debris

<table>
<thead>
<tr>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 4</th>
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<tbody>
<tr>
<td>Depth beneath surface (m)</td>
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<td>Mean borehole englacial debris concentrations (% by volume)</td>
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<tr>
<td>6.5%</td>
<td>0.1%</td>
<td>0.7%</td>
<td>0.3%</td>
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4. Influence on future melt rates

• Simple model projections, using OPTV-derived englacial debris concentrations:
  
  • To predict englacial debris melt-out and surface melt rates in the currently clean-ice upper ablation area (Fig. 3)
  
  • Show importance of vertical distribution of higher concentration englacial debris layers for future melt-out, predicting ~20 years of enhanced melt before supraglacial debris layer is thick enough to insulate the ice surface (black dotted line; Fig. 3A)

• The variable debris content with depth (Fig. 3A) acts both to:
  
  • i) delay peak melt rate and time to insulation compared to a uniform mean debris content (Fig. 3B)
  
  • ii) speed up time to insulation compared to a low englacial debris content (not reached at all in Fig. 3C)

Figure 3 – Results from simple model projections; Miles et al. (submitted)