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3D structure of Khumbu Glacier, Nepal, from borehole experiments

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Predicting the response of Earth's high-elevation debris-covered glaciers (HEDCGs) to anticipated climate change represents an important current research challenge. While 2D and 3D computer models of glacier motion and geometrical change are now highly sophisticated, their application to HEDCGs is hampered by a dearth of empirical information for model calibration and validation. This knowledge gap principally reflects logistical difficulties associated with carrying out research at such glaciers, particularly in terms of obtaining information relating to subsurface conditions and processes. Thus, key information that could be used to guide models such as englacial temperature fields, the occurrence and nature of glacier drainage, sediment incorporation and transfer, and 3D dynamic characteristics remain largely unknown.

Here, we report on 27 boreholes drilled and instrumented at five sites across the debris-covered tongue of Khumbu Glacier, Nepal, for the EverDrill research project. We report on our drilling experiences, including challenges that were anticipated and encountered and the adaptations made to overcome them, and on the results of experiments undertaken in the boreholes. The latter includes measurements of ice temperature, ice deformation, and the glacier's englacial debris load. Temperatures were measured to be approaching melting point. Ice deformation was found to be low but variable. While the englacial ice contained surprisingly little distributed debris – allowing two boreholes to be drilled to greater than $\sim$150 m - discrete shallow layers of impenetrable debris, interpreted to originate from valley-side avalanches, were encountered during drilling.