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Sink detection on tilted terrain for automated identification of glacial cirques

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Glacial cirques are morphologically distinct but complex landforms and represent a vital part of high mountain topography. Their distribution, elevation and relief are expected to hold information on (1) the extent of glacial occupation, (2) the mechanism of glacial cirque erosion, and (3) how glacial in concert with periglacial processes can limit peak altitude and mountain range height. While easily detectably for the expert's eye both in nature and on various representations of topography, their complicated nature makes them a nemesis for computer algorithms. Consequently, manual mapping of glacial cirques is commonplace in many mountain landscapes worldwide, but consistent datasets of cirque distribution and objectively mapped cirques and their morphometrical attributes are lacking.

Among the biggest problems for algorithm development are the complexity in shape and the great variability of cirque size. For example, glacial cirques can be rather circular or longitudinal in extent, exist as individual and composite landforms, show prominent topographic depressions or can entirely be filled with water or sediment. For these reasons, attributes like circularity, size, drainage area and topology of landform elements (e.g. a flat floor surrounded by steep walls) have only a limited potential for automated cirque detection.

Here we present a novel, geomorphometric method for automated identification of glacial cirques on digital elevation models that exploits their genetic bowl-like shape. First, we differentiate between glacial and fluvial terrain employing an algorithm based on a moving window approach and multi-scale curvature, which is also capable of fitting the analysis window to valley width. We then fit a plane to the valley stretch clipped by the analysis window and rotate the terrain around the center cell until the plane is level. Doing so, we produce sinks of considerable size if the clipped terrain represents a cirque, while no or only very small sinks develop on other valley stretches. We normalize sink area by window size for sink classification, apply this method to the Sawtooth Mountains, Idaho, and to Fiordland, New Zealand, and compare the results to manually mapped reference cirques. Results indicate that false negatives are produced only in very rugged terrain and false positives occur in rare cases, when valleys are strongly curved in longitudinal direction.