Geomorphology 278 (2017) 280–286

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

ACME, a GIS tool for Automated Cirque Metric Extraction

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ARTICLE INFO

Article history:
Received 16 September 2016
Received in revised form 15 November 2016
Accepted 15 November 2016
Available online 24 November 2016

Keywords:
Glacial geomorphology
Glacial cirque
Morphometry
GIS
Hypsometry
Metrics

ABSTRACT

Regional scale studies of glacial cirque metrics provide key insights on the (palaeo) environment related to the formation of these erosional landforms. The growing availability of high resolution terrain models means that more glacial cirques can be identified and mapped in the future. However, the extraction of their metrics still largely relies on time consuming manual techniques or the combination of, more or less obsolete, GIS tools. In this paper, a newly coded toolbox is provided for the automated, and comparatively quick, extraction of 16 key glacial cirque metrics; including length, width, circularity, planar and 3D area, elevation, slope, aspect, plan closure and hypsometry. The set of tools, named ACME (Automated Cirque Metric Extraction), is coded in Python, runs in one of the most commonly used GIS packages (ArcGIS) and has a user friendly interface. A polygon layer of mapped cirques is required for all metrics, while a Digital Terrain Model and a point layer of cirque threshold midpoints are needed to run some of the tools. Results from ACME are comparable to those from other techniques and can be obtained rapidly, allowing large cirque datasets to be analysed and potentially important regional trends highlighted.

1. Introduction

Glacial cirques are armchair-shaped hollows, open down-valley and bounded up-valley by a steep slope (Evans and Cox, 1974) (Fig. 1). Cirques are carved by relatively small glaciers, usually confined to the uppermost elevations of a landscape and are typical of alpine landscapes (Gastaldi, 1873). Cirque sizes and shapes have been proved to reveal important clues regarding the palaeoenvironment these landforms developed in, and they can shed light on the dynamics of glacier-bed interaction in alpine settings (Barr and Spagnolo, 2015 and references therein). For example, cirque aspect provides information about the extent and magnitude of past glaciations as well as past variations in solar radiation and prevailing wind directions (Derbyshire and Evans, 1976; Nelson and Jackson, 2003; Evans, 2006). However, the study of individual landform metrics is not particularly insightful and only the analysis of large populations reveals meaningful patterns (e.g. Evans, 1977; Mindrescu et al., 2010; Mitchell and Humphries, 2015), but these are hampered by the limited availability of time-efficient tools able to cope with large databases.

The history of publications on cirque metrics, a term used here to describe both shape and size, is many decades long (e.g. Evans, 1977) and the literature is vast (see Table 4 in Barr and Spagnolo, 2015). From the days when scientists used rulers and protractors on topographic maps (e.g. Temple, 1965), and likely spent hours measuring the size and shape of a single glacial cirque, spatial analysis technology has advanced considerably. Many recent papers, in particular, have started to take full advantage of high resolution Digital Terrain Models (DTM) and Geographical Information Systems (GIS), allowing for rapid and improved analyses of cirque size and shape from large datasets (e.g. Anders et al., 2010; Principato and Lee, 2014). However, each metric analysed often requires a separate tool, or a combination of tools, that are not necessarily easy to find, implement, and combine for non-GIS experts. Most importantly, a number of metrics recommended for, and traditionally used in, the study of glacial cirques cannot be calculated in a GIS environment because, until now, a GIS tool specific for the task had not been developed.

In this paper, we consider the most fundamental cirque metrics and present GIS tools designed for their automatic calculation, provided a minimum number of inputs are available. The tools are all packaged within a single toolbox, ACME (Automated Cirque Metric Extraction). The use of ACME improves the speed and quality of studies on cirque metrics, allowing very large populations of mapped cirques to be analysed and important regional-, and perhaps continental-scale, patterns to be discovered.

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http://dx.doi.org/10.1016/j.geomorph.2016.11.018
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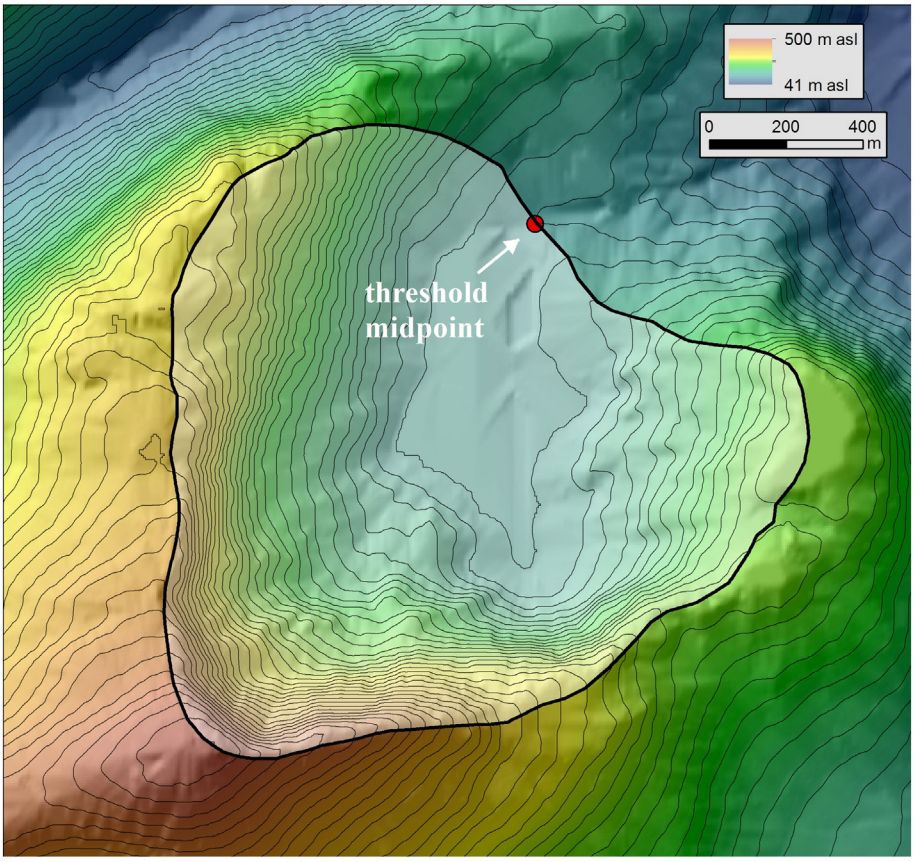

Fig. 1. An example of a cirque in Ireland showing the inputs required for ACME to work. All tools need cirques to be mapped as polygons (in this example the cirque polygon is delimited by the thick black line). The length and width tool requires cirque threshold midpoints (the red dot in this example), while a terrain model is needed in the 3D statistics and hypsometry tools. In this figure, contours are every 10 m of elevation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Application of cirque metrics analyses

All output metrics derived from ACME, which will be described in detail in Section 3, can be, and have been, used to understand the temporal evolution of cirques and the glaciers that formed them. Importantly, these metrics and their spatial/geographical variability can help identify the dominant processes that have contributed to the formation of these landforms and decipher (palaeo) environmental, including climatic, factors that have affected the glacial history of specific regions.

For example, cirque length, width, height, perimeter, area and circularity are used to measure different stages of cirque development (Bathrellos et al., 2014) or whether cirques have been mostly occupied by cirque glaciers rather than valley glaciers (Damiani and Pannuzi, 1987). The geographical variations of these metrics in relation to aspect have also been used to infer different styles of glacial activity (Barr and Spagnolo, 2013) as well as the influence of periglacial processes on cirque development (Delmas et al., 2015). Aspect in itself can be analysed to understand past patterns in solar radiation and, specifically, differential cloudiness between morning and afternoon (Evans, 1977, 2006). It is also an important metric to understand the impact of prevailing wind directions (Křížek and Mida, 2013) and the extent of former glaciations (Nelson and Jackson, 2003). Plan closure can be used to evaluate cirque development, with the assumption that a less enclosed cirque (i.e. smaller plan closure) might indicate an early stage of development (Mîndrescu and Evans, 2014). Studies on the spatial variability in cirque elevation metrics can reveal a number of palaeoenvironmental aspects, including past precipitation gradients (Peterson and Robinson, 1969). Spatial trends in any of the ACME output metrics in relation to lithology, structure and tectonics can also be used to understand geological controls on cirque development and post-glacial modifications (Principato and Lee, 2014). Finally, the study of hypsometric variables, when compared to former equilibrium line altitudes, has been used to test feedbacks between glacial erosion and uplift in mountainous regions worldwide (Foster et al., 2008; Egholm et al., 2009; Barr and Spagnolo, 2014). An in-depth review of previous studies on cirque metrics and a full list of pertinent references can be found in Barr and Spagnolo (2015).

3. Description of the tools

ACME is subdivided into four tools: (1) length and width; (2) perimeter, area and circularity; (3) 3D statistics; and (4) hypsometry (Fig. 2). This subdivision allows users to derive specific metrics separately, as the more metrics that are analysed together the longer a single tool will take to run. The tools require different inputs and extensions and operate with scripts of various levels of complexity. Tools (1) and (2) can be used to study any cirque, while tools (3) and (4), for which ArcGIS Spatial Analyst and 3D Analyst extensions are required, are best suited for unglaciated cirques or those where the subglacial topography is known. Once downloaded, ACME can be added as a new Toolbox to the ArcToolbox list within an ArcGIS session (ArcMap). All tools are coded in Python and their use is described in detail below, after a short introduction of the required inputs. The tools are made available as supplementary material accompanying this article.

3.1. Input requirements

Users might apply different techniques and map cirques from varying sources (e.g. a DTM or a satellite image) using different GIS software. For ACME to work, all cirques, for which the metrics are sought, need to

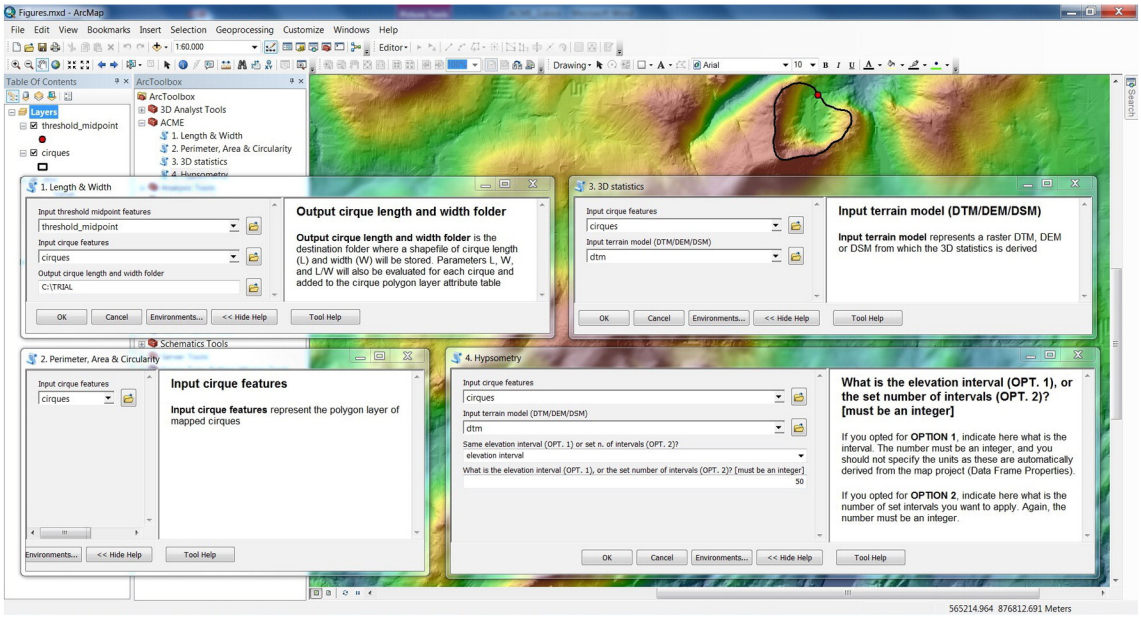

Fig. 2. The interface of ACME. When launched, each tool generates a new pop-up window (1 to 4). All tools require a polygon (shapefile or geodatabase feature class) of mapped cirques (input cirque features). The Length & Width tool also requires a point layer of cirque threshold midpoints (Input threshold midpoint features) which must be located within the boundary of the cirque polygon. Output cirque length and width folder is the destination folder where a shapefile of cirque length and width will be stored. The 3D statistics and Hypsometry tools require a terrain model (Input terrain model), which can be a DTM, DEM or DSM, as an input. Two options are provided for determining elevation intervals within which to calculate the hypsometry metrics. OPT 1 uses the same elevation interval for all cirques, which must be specified in the bottom box. OPT 2 uses the same number of intervals per cirque, also specified in the bottom box. Results from all tools are stored in the attribute table of the cirque polygon layer.

be mapped as polygons and saved as an ESRI polygon feature class (either shapefile or geodatabase polygon feature class) (Fig. 1). Cirques are typically characterised by an overdeepened floor and a steep headwall. The perimeter of the cirque polygon will pass through: (i) the break of slope that delimits a cirque's downvalley extent, i.e. the cirque threshold; (ii) the spurs that delimit a cirque laterally and which are often curving inward downvalley; and (iii) the break of slope that could be present on the upper portion of the cirque headwall, upvalley. As (iii) is often difficult to identify, an easier approach, and one that can guarantee more consistency in a large cirque mapping exercise, is to delimit the cirque upvalley along the crestline above the headwall (Fig. 1). The four ACME tools will generate and populate the following fields in the attribute table of the cirque polygon feature class: 'L', 'W' and 'L/W' from tool (1); 'Perimeter', 'Area_2D' and 'Circular' from tool (2), 'Z_min', 'Z_max', 'Z_range', 'Z_mean', 'Area_3D', 'Slope_mean', 'Aspect_mean' and 'Plan_closure' from tool (3); 'hypso_max' and 'HI' from tool (4). These metrics are described in detail in Sections 3.2 to 3.5. If the attribute table of the cirque polygon feature class is open when the tools run, the values are not updated on the screen. The tools either needs to run with the attribute table closed, or the table needs to be closed and re-opened after the tool has finished working. When these metrics have a unit, this is always the same as that of the ArcMap project and can be checked in the Data Frame Properties. The only exceptions are slope, aspect and plan closure metrics which are in degrees.

In order to obtain cirque length and width, an ESRI point feature class (either shapefile or geodatabase point feature class) of cirque threshold midpoints must also be provided. A glacial cirque threshold usually corresponds to the cirque frontal moraine or the rock lip or edge (i.e. break of slope) that separates the cirque overdeepening upvalley from the glacial valley below. The threshold midpoint of a cirque can be identified manually by roughly estimating its location half way along the frontal moraine or bedrock sill that typically delimits the cirque down-valley (Figs. 1 and 3a). It can also be automatically extracted using a GIS tool, such as the ArcGIS Feature to Point (imposing 'inside' as an option), if the moraine or bedrock sill has been previously mapped as a line. A terrain model in raster format, such as a DTM, DEM or DSM, is required in order to run the 3D metrics statistics and hypsometry tools. All three inputs need to be in the same, projected, coordinate system.

3.2. Length & Width tool

This tool calculates the length of cirques, 'L', as the length of the line within the cirque polygon that intersects the cirque threshold midpoint and splits the polygon into two equal halves (Fig. 3b). It also calculates the width of cirques, 'W', as the length of the line perpendicular to the length line and intersecting the length line midpoint (half way through the length line) (Fig. 3b). The elongation, 'L/W', is derived from 'L' and 'W'. Both length and width lines are stored as separate shapefiles ('cirque_length' and 'cirque_width') in a user-defined destination folder. Users are required to specify a polygon and a point feature class that corresponds to the mapped cirques and the threshold midpoint respectively (Fig. 2). Users must also specify the folder where the resulting length and width line shapefiles should be saved (Fig. 2).

In principle, a threshold midpoint should intersect the cirque boundary. Given the possibility that some digitising errors may occur, the tool will work when a threshold midpoint is within the cirque polygon, whether or not at (i.e. snapped to) the exact cirque boundary. However, it will not work when the point is outside the cirque. Should the tool not find a corresponding threshold midpoint within a mapped cirque, or more than one threshold midpoint (for example in the case of a compound cirque), it will return a warning message "cirque X does not have a threshold or has two or more thresholds (e.g. is part of two or more nested cirques)", X being the cirque's ID number. A value of 0 will be added in the L, W and L/W fields for that specific cirque. Users are recommended to run the tool separately for compound cirques, once for the outer cirques, and a second time for the inner cirques.

The tool is designed to work with features that agree with the classic definition of cirques, i.e., features with a sub-circular or semi-circular

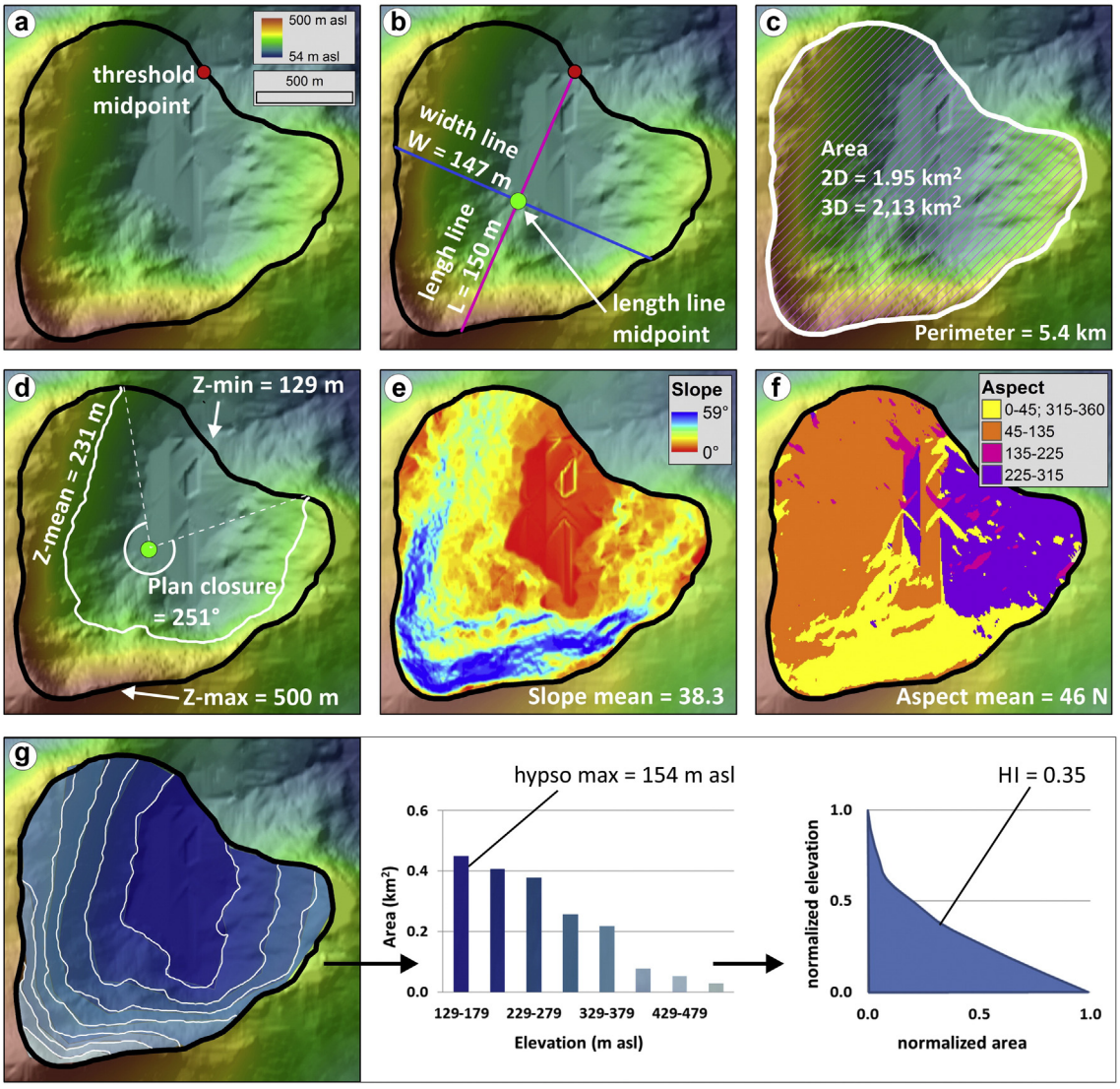

Fig. 3. A summary of key measured metrics. (a) Illustrates a cirque mapped as a polygon, with a black outline and a threshold midpoint (red dot). Panel (b) shows the length line, derived as the line passing through the threshold midpoint and splitting the cirque into two equal-area halves; the width line is perpendicular to the length line and passes through its midpoint (half way through the length line). Panel (c) shows the perimeter (white line) and area (the hatched area enclosed by the white line). Panel (d) indicates the minimum, mean and maximum cirque elevations. It shows the mean elevation contour (white), the end points of which, along with the cirque centroid (green dot), are used to derive the plan closure angle. In (e) the slope of each pixel (for this specific DTM the pixel size is 25 m^2) comprised by the cirque surface has been extracted and the mean slope calculated. Similarly, in (f) the aspect (in degrees, from 0 to 360 N) of each pixel has been extracted, converted to radians and the mean aspect calculated and returned as degrees north. Panel (g) illustrates how the hypsometric parameters are derived. In this case, areas were calculated every 50 m (white contours); the hypsometric maximum is the elevation bin for which the land surface area is highest, while the hypsometric integral is the area below the curve of the normalised, cumulative plot of area vs. elevation. All parameters shown in this figure are added to the cirque's feature class attribute table and populated once the tools are run. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

plan shape, that encompasses an arcuate headwall and an open down-valley extent (Evans and Cox, 1974). The tool will work with more complex shapes, but should not be relied upon for curving, elongated features, though given the definition above, such features are unlikely to be cirques.

3.3. Perimeter, Area & Circularity tool

This tool calculates the perimeter ('Perimeter'), area ('Area_2D') and circularity ('Circular') of the mapped cirques (Fig. 3c). Circularity is defined as the ratio between the cirque perimeter and the perimeter of a circle of the same area (Aniya and Welch, 1981). Large values indicate low circularity while values closer to 1 indicate high circularity. Perimeter, area and circularity are stored in the attribute table of the cirque polygon layer. Perimeter and area are returned in the same units (squared for the area) as the ArcMap project (Data Frame Properties). The only required input for this tool is the polygon layer (shapefile or geodatabase feature class) of the mapped cirques.

3.4. 3D statistics tool

The 3D statistics tool produces a number of outputs and requires both the mapped cirque boundaries and a terrain model, e.g. a DTM, as inputs. For each cirque, the following metrics will be calculated:

- Z_min, Z_max, Z_range and Z_mean, corresponding to the minimum and maximum elevation (altitude), the range of elevations (max-min) and the mean elevation (Fig. 3d). Units are the same as the ArcMap project (Data Frame properties).

- Area_3D, corresponding to the 3D (non-planar) surface area of the cirque (Fig. 3c). Units are the same as the ArcMap project (Data Frame properties). The tool is based on an ArcGIS functionality (called 'Surface Volume') that will calculate the area only for pixels that are at least 50% within the boundary of the cirque polygon. Thus, a number of boundary pixels might not be included in the calculation, meaning that the tool would underestimate the real Area_3D. This is an issue of some relevance when the resolution of the DTM is coarse (e.g. 30 m) and cirques are very small (e.g. <100.000 m^2), because the relative number and size of boundary pixels that might be disregarded is large. In exceptional circumstances, the underestimated Area_3D could (erroneously) be lower than Area_2D, the calculation of which is exact and not affected by this boundary pixels issue. When high resolution DTMs are not available, ACME users could consider resampling the coarse-resolution DTM to a higher resolution (e.g. 5 m).
- Slope_mean, providing the mean value of slopes, in degrees (Fig. 3e). Each cirque comprises a certain number of terrain model pixels, for which slope can be measured. Slope_mean calculates the average of all pixels' slope.
- Aspect_mean, corresponding to the mean value of aspects, in degrees north (within the 0–360° interval) (Fig. 3f). The tool returns the mean of all pixel aspects by converting these into radians, extracting the mean sine and cosine of these values, calculating the arctangent of the ratio between mean sine and mean cosine, then finally converting this back into degrees. Mean aspect is calculated by averaging all values across the entire surface of a cirque. This is a much preferred metric to the cirque length line's azimuth when it comes to evaluate the total effect of solar radiation and wind direction on cirque distribution.
- Plan_clos, corresponding to the plan closure of the cirque and which provides a quantitative evaluation of the planar shape of cirques (Gordon, 1977). Values are also in degrees (within the 0–360° interval). It is calculated as 360° minus the angle between the cirque midpoint (so called "centre of gravity" or "centroid") and start and end points along the mid-elevation (half Z_range) contour (Fig. 3d).

3.5. Hypsometry tool

The Hypsometry tool calculates the hypsometric maximum ('hypso_max') and integral ('HI') of each cirque (Fig. 3g). These metrics can be used to evaluate the interplay between glacial erosion, topography and climate (Barr and Spagnolo, 2014). Hypsometric analyses are based on the calculation of the area within a specified elevation interval. The Hypsometry tool works by specifying either a same interval (OPTION 1) or a set number of intervals (OPTION 2) for all cirques. For example, if OPTION 1 is selected and a value of 50 (m) is specified, the hypsometry statistics will be based on areas calculated every 50 m of elevation, regardless of the cirque elevation range. This means that the hypsometric statistics on 'shallow' cirques will be based on few area calculations (i.e. few bins/class intervals), while results on 'deep' cirques will be based on many calculations. Users should also keep in mind that when selecting an elevation interval, this should be below the minimum elevation (altitudinal) range of the cirques. If this is not the case, a warning message "The selected elevation interval is higher than the elevation range of cirque X, hypso_max and HI will be returned as −9999", X being the ID number of the cirque, will be shown in the result window. If OPTION 2 is selected and a value of 12 is specified, the hypsometry statistics will be based on areas calculated for 12 elevation intervals distributed evenly along the elevation range of all cirques under investigation, therefore the elevation interval will vary depending on the cirque elevation (altitude) range. For instance, a cirque that spans 1200 m, will be sampled every 100 m, while one that spans 600 m, will be sampled every 50 m. Regardless of the chosen option, and the elevation interval adopted, the returned hypsometric maximum value corresponds to the mid elevation of the elevation interval where the area is highest. For example, if the elevation interval is 50 m, and the area is highest in the 2350–2400 m elevation interval bin, then a value of 2375 is populated in the hypso_max field.

4. Tools test

To demonstrate its utility, ACME is here used to analyse the morphometry of 3520 cirques on the Kamchatka Peninsula (Eastern Russia), mapped from ASTER GDEM by Barr and Spagnolo (2013). Cirque metrics for this dataset, calculated using ACME, are provided in Table 1 along with those presented in the original paper. The latter were calculated using a combination of GIS techniques (e.g. Pérez-Peña et al., 2009), some of which use an interface in Italian (Federici and Spagnolo, 2004) and are no longer compatible with recent versions of ArcGIS. Table 1 demonstrates that ACME values are very similar to those published before and the differences between the two are not statistically significant, with the exception of cirque width. However, the comparison on this latter parameter is undermined by the fact that Barr and Spagnolo (2013) calculated cirque width using a slightly different method (i.e. as the longest line within the cirque polygon perpendicular to the cirque length line). This means that their width measurements are consistently greater than those calculated using ACME

Table 1
Summary metrics for cirques on the Kamchatka Peninsula. In each case, values reflect the mean of the entire cirque population (n = 3520). Results from a two-tail z-test (without equal variances) are shown in the last column.

Metric	ACME	Barr and Spagnolo (2013)	z-test results
L (m)	866	868	Not stat. sig. (p = 0.638)
W (m)	964	992	Stat. sig. (p < 0.001)
Perimeter (m)	3082	Not calculated	n/a
Area_2D (km2)	0.73	0.73	Not stat. sig. (p = 0.994)
Circularity	1.05	1.05	Not stat. sig. (p = 0.951)
Z_min (m)	988	988	Not stat. sig. (p = 0.929)
Z_max (m)	1410	1408	Not stat. sig. (p = 0.843)
Z_range (m)	422	421	Not stat. sig. (p = 0.759)
Z_mean (m)	1180	1177	Not stat. sig. (p = 0.657)
Area_3D (km2)	0.84	Not calculated	n/a
Slope_mean (°)	27	28	Not stat. sig. (p = 0.236)
Aspect mean (°)	006	006	Not stat. sig. (p = 0.300)
Plan_clos (°)	151	Not calculated	n/a
Hypso_max (1 m elevation interval) (m)	1159	Not calculated	n/a
Hypso_max (50 intervals) (m)	1160	Not calculated	n/a
HI (1 m elevation interval) (m)	0.46	Not calculated	n/a
HI (50 intervals) (m)	0.47	Not calculated	n/a

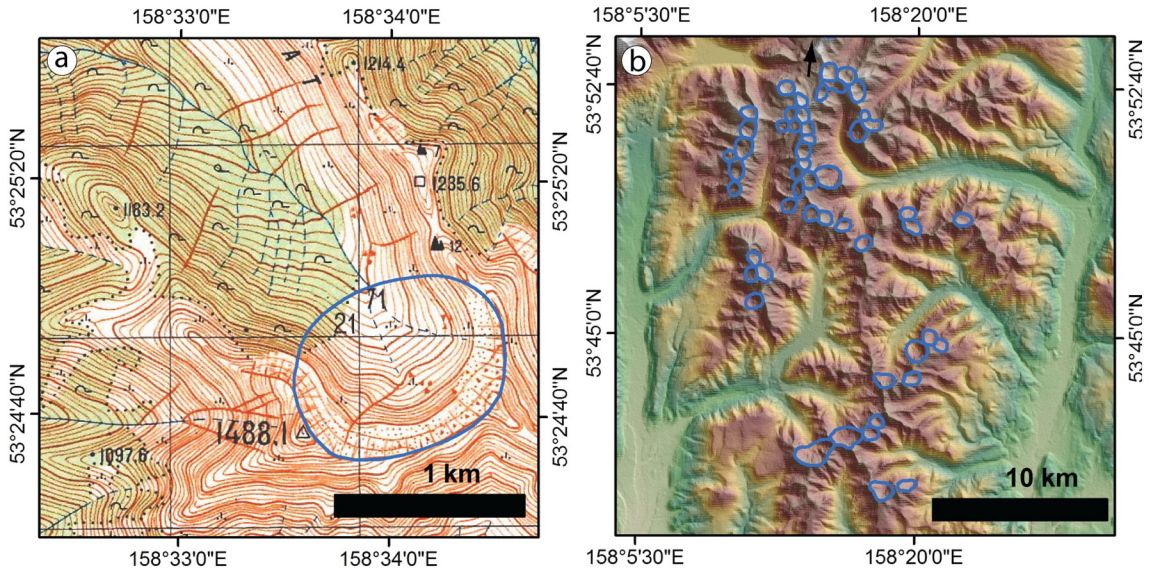

Fig. 4. Example cirques (blue polygons) on the Kamchatka peninsula, shown against (a) a (1:50,000) topographic map and (b) SRTM DEM. Altitudinal data for these cirques are shown in Table 2. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(based on the line perpendicular to the length line and intersecting the length line midpoint). There is currently no consensus on how best to measure cirque width (Barr and Spagnolo, 2015), but given that differences between estimates are typically in the order of 10s of meters (when cirques are 100s of meters wide), this has little impact on interpretations made from the cirque record. Overall, ACME returns metrics comparable to those obtained in the past, with the advantage that ACME (i) contains all relevant tools within a same toolbox, (ii) works on the most recent software version of one of the most commonly used GIS packages, (iii) is in English and (iv) includes new GIS implementations of techniques that were originally developed for a topographic, manual approach and were not available to GIS users (e.g. plan closure).

To further test ACME, the minimum and maximum elevations, along with the elevation range, of 51 cirques are compared to those derived from a (much more time consuming) topographic approach, where minimum and maximum elevations were measured on orthrectified topographic maps (with the cirques shapefile used as an overlay) (Fig. 4) (Table 2). Differences between results from the two approaches are minimal and not statistically significant, but ACME is much faster and calculates a number of other metrics that a topographic approach would be unable to return (e.g. average aspect) or would require many hours of work per cirque (hypsometric integral).

In ACME, the only circumstance where the user has discretion over the choice of measurement method is when analysing cirque hypsometry. Specifically, the user can opt to analyse hypsometry using fixed elevation intervals or using the same number of intervals for each cirque and is prompted to select a method. The impact that this choice has on resulting hypsometric data from the Kamchatkan cirque database is highlighted in Figure 5. This reveals that as the elevation interval increases or the set number of intervals decreases, both hypsometric maximum and hypsometric integral increase. With a low elevation interval or high number of intervals, the data will be more precise but the computational time could be considerably longer. Therefore, users must balance their required precision versus processing time.

5. Conclusions

Morphometric studies on glacial cirques have revealed how their metrics can provide important insights about past and present environmental conditions (Barr and Spagnolo, 2015 and references therein). These studies are often limited to relatively small sample sizes or numbers of parameters analysed, because the extraction of the metrics is very time consuming. With the growing availability of high resolution terrain models, new regions can be studied and more cirques can be identified and mapped than ever before. To facilitate the analyses of their size and shape characteristics, ACME, a new GIS toolbox, has been developed. ACME automatically extracts 16 glacial cirques metrics. Some of these metrics require only a polygon layer of mapped cirques as an input; others also need a DTM and/or a point layer of mapped cirque threshold midpoints. The 16 metrics are the length, width, elongation, perimeter, planar area, circularity, minimum, mean and maximum elevations, elevation range, 3D area, mean slope, mean aspect, plan closure, hypsometric maximum and hypsometric integral. The interpretation of these metrics can reveal important insights into the environmental conditions under which cirques are formed, including climate. Some of these metrics (e.g. minimum elevation) are routinely discussed in glacial cirque morphometry studies; others (e.g. plan closure) have been seldom used because their calculation, until now, could only be done via a time consuming topographic approach (Barr and Spagnolo, 2015). ACME is now able to quickly and efficiently extract all these parameters automatically. Importantly, ACME results are comparable to those from previous studies based on a combination of other, more or less obsolete, GIS applications and to those manually extracted via a topographic approach.

Table 2
Altitudinal data for a group of 51 cirques (shown in Fig. 4) on the Kamchatka Peninsula. Values are calculated using the GIS tool presented here (ACME) and from topographic maps (Topographic (manual) approach).

Cirque number	ACME	Topographic (manual) approach	z-test results
Mean_Z_min (m)	1220	1214	Not stat. sig. ($p = 0.855$)
Mean_Z_max (m)	1632	1628	Not stat. sig. ($p = 0.876$)
Mean_Z_range (m)	412	414	Not stat. sig. ($p = 0.927$)

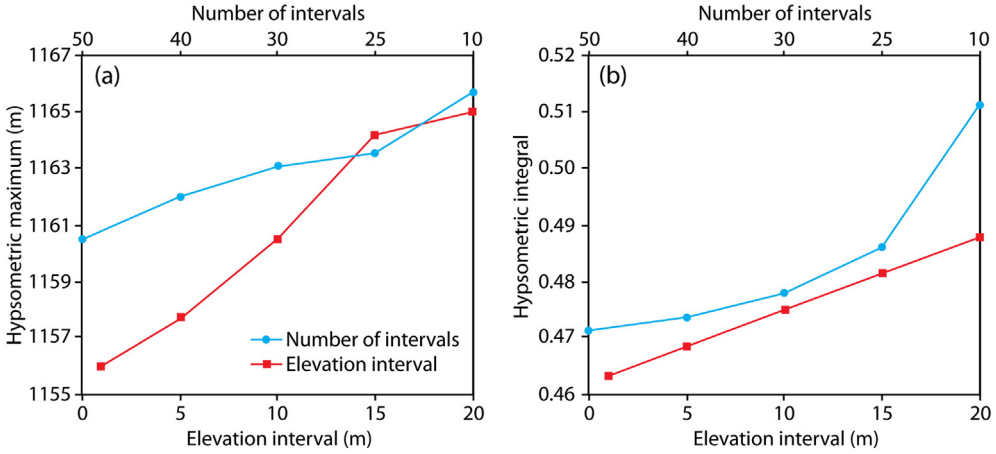

Fig. 5. Mean (a) Hypsometric maximum (Hypso_max) and (b) hypsometric integral (HI) for cirques (n = 3520) on the Kamchatka Peninsula, calculated using different numbers of intervals and different elevation intervals. Both the hypsometric maximum (in a) and the hypsometric integral (in b) increase with the elevation intervals and decrease with the number of intervals.

Weblink

ACME can be accessed through the supplementary material accompanynig this paper.

Acknowledgement

This paper is dedicated to Ian Evans. His passion for the analyses of glacial cirque metrics, along with his productivity and generosity, has not only allowed these landforms to be now recognised as key indicators of palaeoenvironmental conditions, but has also been an inspiration to many young researchers. We are also thankful to Clare Boston and 3 anonymous reviewers who greatly improved the original text; and to Richard Marston for his editorial assistance.

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