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Answers to the seemingly straightforward questions "what is a mountain?" and "where are the mountains of the world?" are in fact quite complex, and there have been few attempts to map the mountains of the earth in a consistent and rigorous fashion. However, knowing exactly where mountain ecosystems are distributed on the planet is a precursor to conserving them, as called for in Sustainable Development Goals 6 and 15 of the United Nations 2030 Agenda for Sustainable Development. In this article we first compare 3 characterizations of global mountain distributions, including a new, high-resolution (250 m) map of global mountains derived from terrain characteristics. We show how differences in conceptual definition, methodology, and spatial resolution of source data can result in differences in the extent and location of lands classed as mountains. For example, the new 250-m resource documents a larger global mountain extent than previous characterizations, although it excludes plateaus, hilly forelands, and other landforms that are often considered part of mountain areas. We then introduce the Global Mountain Explorer, a new web-based application specifically developed for exploration, visualization, and comparison of these maps. This new open-access tool is an intuitive and versatile resource suitable for a broad range of users and applications.

Keywords: *Global mountains; mountain ecosystems; digital elevation model; terrain analysis; landforms.*

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Introduction

Mountains are universally recognized for their economic, ecological, and social value. As the water towers of the world (Bandyopadhyay et al 1997), mountains provide much of the global water supply so critical for human survival and the persistence of all life on the planet. In addition to water, mountains provide timber and nontimber forest products, mineral resources, and many other food, fiber, and fuel products. Mountains modify macroclimates and produce associated mesoclimate and microclimate regions (Bailey 2009). Mountains are areas of high ecosystem, species, and genetic diversity (Körner 2004; Chape et al 2008). They are evolutionarily important both in establishing geographic barriers (isolation) to gene flow that can contribute to speciation and in influencing patterns of colonization and shifts in species distributions (Knowles and Massatti 2017). Furthermore, cultural values associated with mountain environments range from aesthetic to recreational to spiritual, and mountains are often accorded a high intrinsic existence value by individuals who do not live in or visit them but nonetheless believe they benefit from their presence. Human dependence on mountains is considerable, with some 400 million (Körner et al 2017) to 900 million (FAO 2015) people living on or deriving part or all of their livelihoods from mountains.

Managing mountain regions for the sustained delivery of critical goods and services requires an increasingly detailed understanding of mountain locations and extents. Deciding on how best to delineate and represent the mountain space requires particular attention to and understanding of key underpinning assumptions and a critical assessment of the

TABLE 1 Criteria for defining the 6 mountain classes of the K1 characterization, and each class's area and percent of global land surface (Kapos et al 2000). For classes 5 and 6, a circular neighborhood analysis window (NAW) with a radius of 7 km was used to determine relative relief as the absolute value of the difference between maximum and minimum elevations in the NAW.

Class	Elevation	Slope	Relative relief	Area	Area as percent of global land surface
1	>4500 m	Not used	Not used	1.8 million km^2	1.2%
2	3500–4499 m	Not used	Not used	2.7 million km^2	1.8%
3	2500–3499 m	Not used	Not used	6.9 million km^2	4.7%
4	1500–2499 m	>3.5%	Not used	5.3 million km^2	3.6%
5	1000–1499 m	>8.75% **OR** >300 m		6.2 million km^2	4.2%
6	300–999 m	Not used	>300 m	13.0 million km^2	8.8%
Totals				35.9 million km^2	24.3%

consequences that these delineation choices have for the results that are generated. This is especially important given new global policy mandates such as the Sustainable Development Goals (SDGs) (United Nations 2015), which call for the sustainable management and effective conservation of mountain ecosystems. SDG 15 (Life on Land) states "By 2030, ensure the conservation of mountain ecosystems," and SDG 6 (Clean Water and Sanitation) similarly mandates "By 2020, protect and restore water-related ecosystems, including mountains." Mountain conservation has been a recognized policy priority at the global level since its inclusion in Chapter 13 (Managing Fragile Ecosystems: Sustainable Mountain Development) of Agenda 21 at the Rio Conference in 1992 (Ives et al 1997). Conserving mountain ecosystems requires an understanding of their location and condition.

Globally comprehensive and detailed maps of mountain systems are a valuable resource for researchers, managers, and policymakers. Körner et al (2017) reviewed 2 major attempts to classify and map global mountain systems from terrain data using a GIS (geographic information system), as described in Kapos et al (2000) and Körner et al (2011), hereinafter referred to as K1 and K2, respectively. In this article, we introduce a new high-resolution global mountains data layer, which we call K3 and which was developed as an input to the classification and mapping of global ecological land units (Sayre et al 2014). We then compare these 3 layers and introduce the Global Mountain Explorer (GME), an online open-access tool for visualizing these mountain area extents. This work specifically addresses Task 1.0 in the work plan of the Group on Earth Observations initiative Global Network for Observations and Information in Mountain Environments (GEO 2017). The objective of Task 1.0 is to bring together existing datasets focused on the delineation of mountain regions and to enable comparisons across mountain regions of key biophysical phenomena and socioeconomic processes.

The K1 mountain characterization

In the K1 characterization, mountain locations and extent were mapped as part of a global delineation of mountain forests. The mountains of the world were mapped based on terrain characteristics, and the global area of forests on those mountains was determined. The K1 characterization used the GTOPO30 (Global 30 Arc-Second Elevation) (https://lta.cr.usgs.gov/GTOPO30), an authoritative global digital elevation model (DEM) with a resolution of approximately 1 km at the equator. The K1 authors developed 6 classes of mountains based on a combination of elevation and relative relief, a measure of elevational range within a specified area. Slope was calculated in a raster-based, 3×3 pixel moving neighborhood analysis window (NAW), while relative relief was calculated in a 5 pixel ($\sim$80 km^2) radius as the difference between maximum and minimum elevation in the circular NAW. Mountain classes above 2500 m were assigned using only elevation ranges, whereas mountain classes below 2500 m were assigned using both elevation range and relative relief when the latter exceeded 300 m. The K1 criteria are listed in Table 1. The authors reported the total area for each mountain class as the sum of the areas of all pixels assigned to each class. They then intersected the resulting global mountains layer with an existing global forests layer to produce a global mountain forests layer, which they then discussed from both geographic and biodiversity perspectives. This work was produced by the World Conservation Monitoring Center and was the first global, objectively produced characterization of mountain extents. It identified 26.4% of the land area of the earth as mountainous.

The K2 mountain characterization

In the K2 characterization, the focus was on developing a standardized definition and map of mountains for global mountain biodiversity research and the subsequent subdivision of life zones along elevation gradients. The K2 authors first mapped the mountains of the world based on

terrain characteristics, and then identified different mountain climate settings by allocating mountain areas into bioclimatic belts. Körner et al (2011) produced a map of global mountains based on ruggedness. Rather than emphasizing absolute elevation, relative relief, which the authors termed "ruggedness," was used as a "simple and pragmatic proxy for steepness" of slope (Körner et al 2011, page 74). Coastal terrain that is relatively low in elevation but has steep slopes and pronounced changes in elevation over small areas is typically recognized as mountainous. The K2 focus on ruggedness acknowledges that steepness of slope is related to the structuring of habitats and their microclimates and disturbance regimes, which represent the environmental potential to which organisms respond. Ruggedness is also a key factor in determining the potential for mechanized agriculture.

The K2 characterization used a 1-km DEM and classified pixels as rugged if relative relief in a 3×3 pixel NAW exceeded 200 m. Relative relief was defined as the difference between the highest and lowest elevations in the approximately 9 km^2 NAW. The ruggedness of the surface was then generalized to a grid with a resolution of 2′30″ ($\sim$4.6 km spacing at the equator, or pixels with an approximate area of 22 km^2), and any rugged cell at this resolution was defined as a mountain. The delineated mountains were stratified into 7 bioclimatic zones by first dividing mountain terrain into areas above (alpine) and below (montane) a calculated potential climatic treeline (Paulsen and Körner 2014), and then further stratifying montane areas into bioclimatic belts ranging from upper montane to frost-free rugged lowland terrain.

The K2 characterization produced a robust global mountains data layer that has been adopted as the conceptual and data standard for the Global Mountain Biodiversity Assessment (GMBA) network for mountain biodiversity and biogeography research. A polygon-based inventory of named mountain systems associated with the K2 characterization (Körner et al 2017) is used as the base layer in the GMBA Mountain Portal (http://www.mountainbiodiversity.org) and in the mountain region module of the Map of Life (https://mol.org/regions/?regiontype=mountains). The K2 characterization identified 12.4% of the terrestrial surface as mountainous, less than half of the mountain area reported in K1. Körner et al (2017) attributed the larger area identified as mountainous in K1 to inclusion of high plateaus, intermontane valleys, and hilly forelands.

The new K3 mountain characterization

As an input to the modeling of global ecological land units, Sayre et al (2014) produced a map of global landforms with a number of different types of plains, hills, and mountain features. They used the US Geological Survey's 250-m GMTED2010 (Global Multi-resolution Terrain Elevation Data 2010) DEM (Danielson and Gesch

2011) for the analysis, which is finer in spatial resolution than the 1 km^2 DEM used for K1 by a factor of 16, and finer than the generalized K2 resolution of $\sim$22 km^2 by a factor of 350. This global landform product was based on the classification logic of Hammond (1954) but only used 2 of Hammond's 3 parameters, namely slope and relative relief (the absolute value of the difference between the maximum and minimum elevations in a NAW). The third Hammond landforms parameter is the profile parameter, a measure of the amount of gently sloping land in upland areas. Its inclusion in landform modeling allows for the identification of tablelands and scattered mountains. A modification of the original Hammond approach, which facilitates processing by removing the computationally intensive profile parameter, was developed by True (2002) and has subsequently come to be known as the MoRAP (Missouri Resources Assessment Partnership) approach. Sayre et al (2014) used the MoRAP approach, and the global landforms product from that work did not therefore contain tablelands.

Having produced a global landforms product that lacked tablelands and scattered mountains classes, the team that produced the Sayre et al (2014) characterization decided to redo their global landforms product to include these classes. Karagulle et al (2017) therefore produced a new global Hammond landforms characterization which used the profile parameter and included tablelands and scattered mountains. The Karagulle et al (2017) global landforms layer was the source dataset from which the new K3 mountain layer was extracted. While the K3 resource was originally developed as an input to terrestrial ecosystem mapping, it was recognized that it also represented a mapping of global mountain distributions with higher spatial resolution than existing resources, and that a comparison of K3 with K1 and K2 was warranted.

The K3 characterization (Karagulle et al 2017) includes 4 classes of mountains: high, scattered high, low, and scattered low. All other terrain on the planet is classified into different types of hills, plains, and plateaus. The nonmountain classes are not included in this assessment, with the exception of high plateaus with >900 m relative relief, which are often perceived as mountains.

A map of the global distribution of the 4 K3 mountain classes is presented in Figure 1; criteria for differentiating these 4 classes are presented in Table 2. Table 2 also includes the total area of each K3 mountain class and its percent of the land surface of the earth, excluding Antarctica. The sum of the areas of all mountain classes was calculated using a Mollweide equal-area projection and a total land surface area (excluding Antarctica) of 134,087,846 km^2. The sum was also calculated on the unprojected (geographic) data using a geodesic areas processing algorithm. Calculations using the projected data yielded a total mountain area of 40,957,238 km^2 (30.55% of global land area); the geodesic calculation yielded 40,869,376 km^2

FIGURE 1 A map of global mountain areas in 4 classes (high, scattered high, low, scattered low) from the new K3 high-resolution spatial characterization of global mountain distributions.
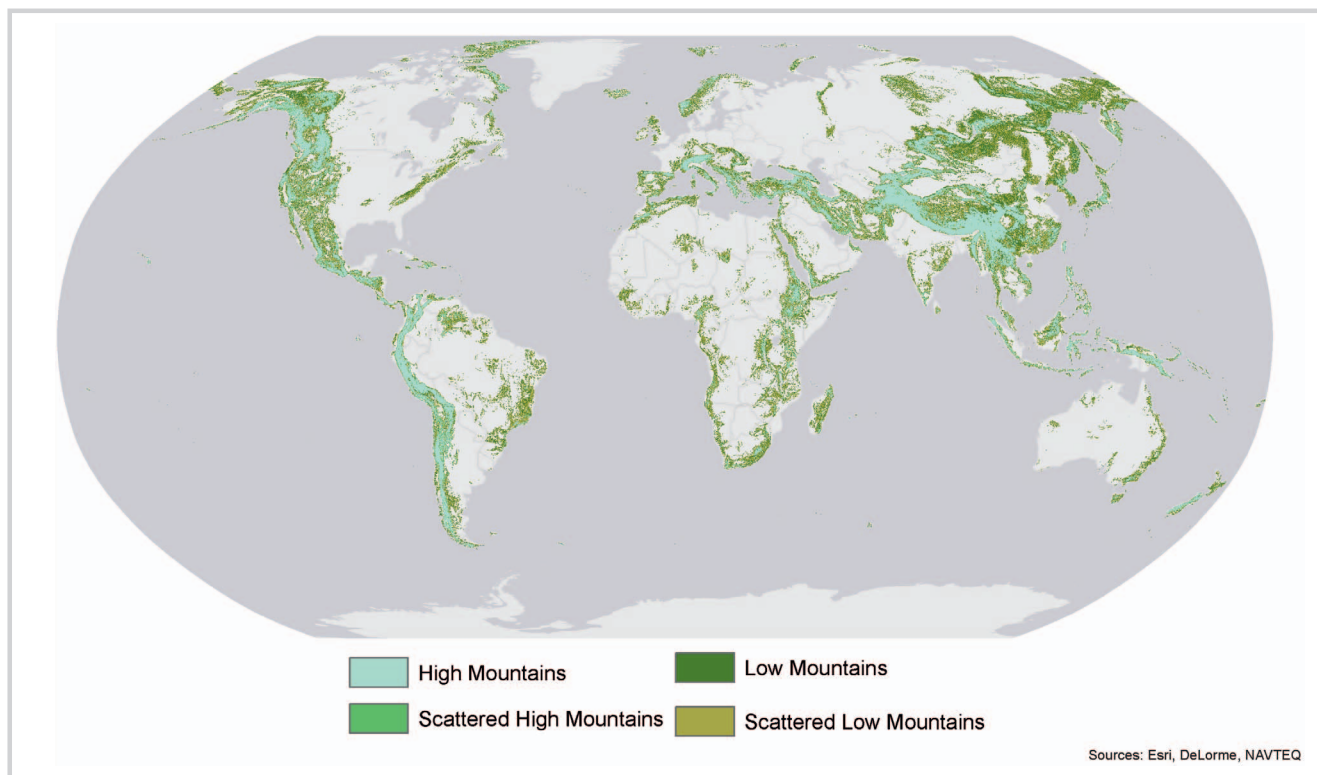
(30.48% of global land area). We also calculated the geodesic area of high-relief tablelands, as humans commonly perceive these areas as mountains. High-relief (relative relief >900 m) tablelands have a relatively small global extent at 61,122 km^2 (0.05% of land area).

Comparisons among K1, K2, and K3

While the 3 characterizations were developed for different purposes and used different criteria, comparison of the aggregated, 2-class (mountains versus

TABLE 2 Criteria for defining the 4 mountain classes of the K3 characterization, and each class's area and percent of global land surface (Karagulle et al 2017). Slope was averaged from the 250-m pixels in a 3-km neighborhood analysis window (NAW). Slope class refers to the percent of area of high slope (≥8%) in the NAW. Relative relief is the absolute value of the difference between the maximum and minimum elevations in a 6 km NAW. Profile refers to the amount (% area) of high slope (≥8%) in a 6 km NAW in upland (higher than the midpoint of the elevation range in the NAW) or lowland (lower than the midpoint of the elevation range in the NAW) pixels. Areas were derived from a geodesic calculation based on a total land area (excluding Antarctica) of 134,087,846 km^2.

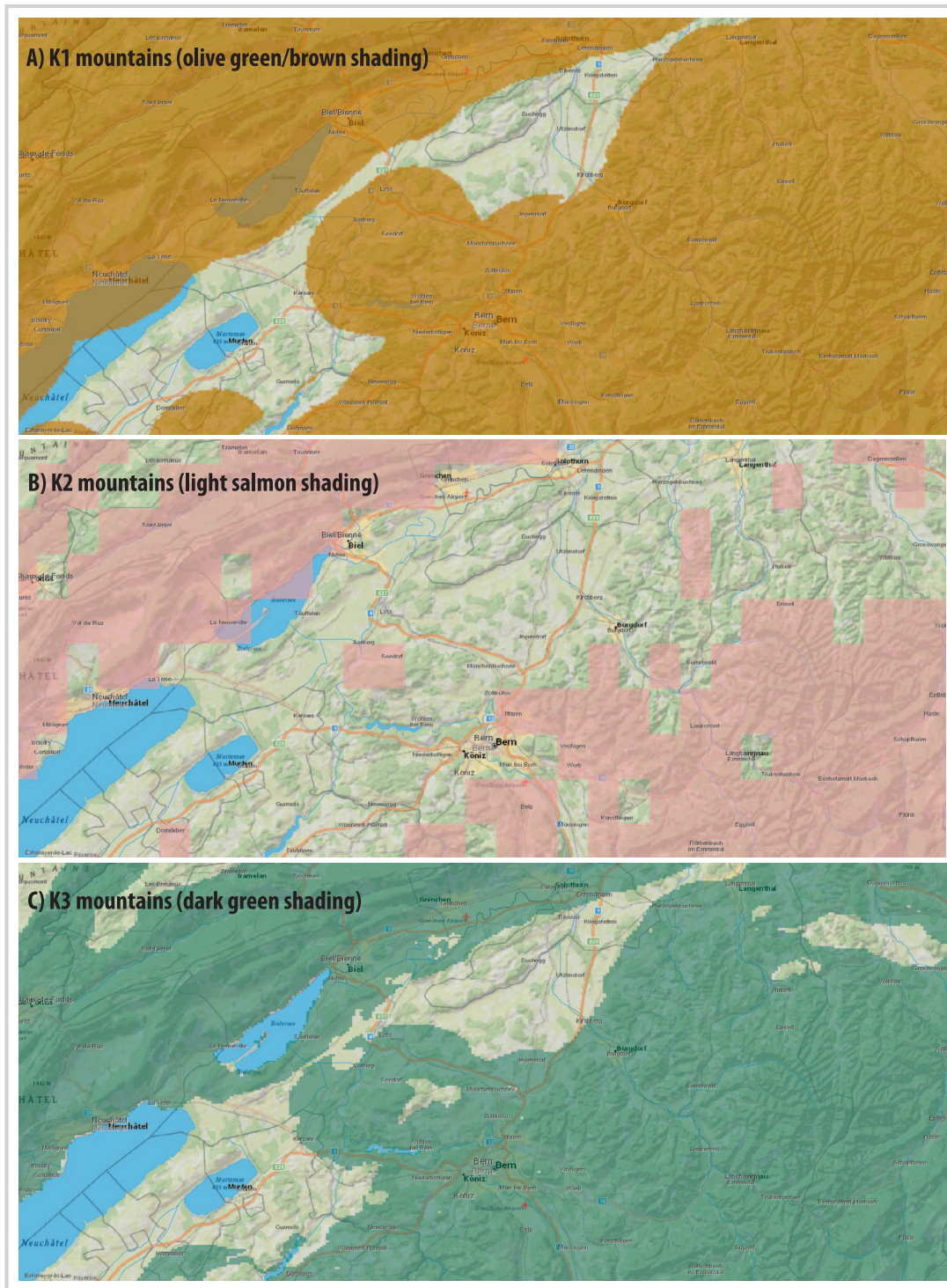| Class	Slope class	Relative relief	Profile	Area	Area as percent of global land surface
High mountains	81–100%	>900 m	Not used	12,579,032 km^2	9.4%
	51–80%	>900 m	>50% of all cells in the NAW are high (≥8%) slope		
Scattered high mountains	51–80%	>900 m	≤50% of lowland cells in the NAW are high (≥8%) slope	2,563,661 km^2	1.9%
Low mountains	81–100%	301–900 m	Not used	12,519,699 km^2	9.3%
	51–80%	301–900 m	>50% of all cells in the NAW are high (≥8%) slope		
Scattered low mountains	51–80%	301–900 m	≤50% of lowland cells in the NAW are high (≥8%) slope	13,208,399 km^2	9.8%
Totals				40,869,376 km^2	30.5%

FIGURE 2 Regional scale comparison of the 3 characterizations of mountain versus non-mountain areas across much of Europe.
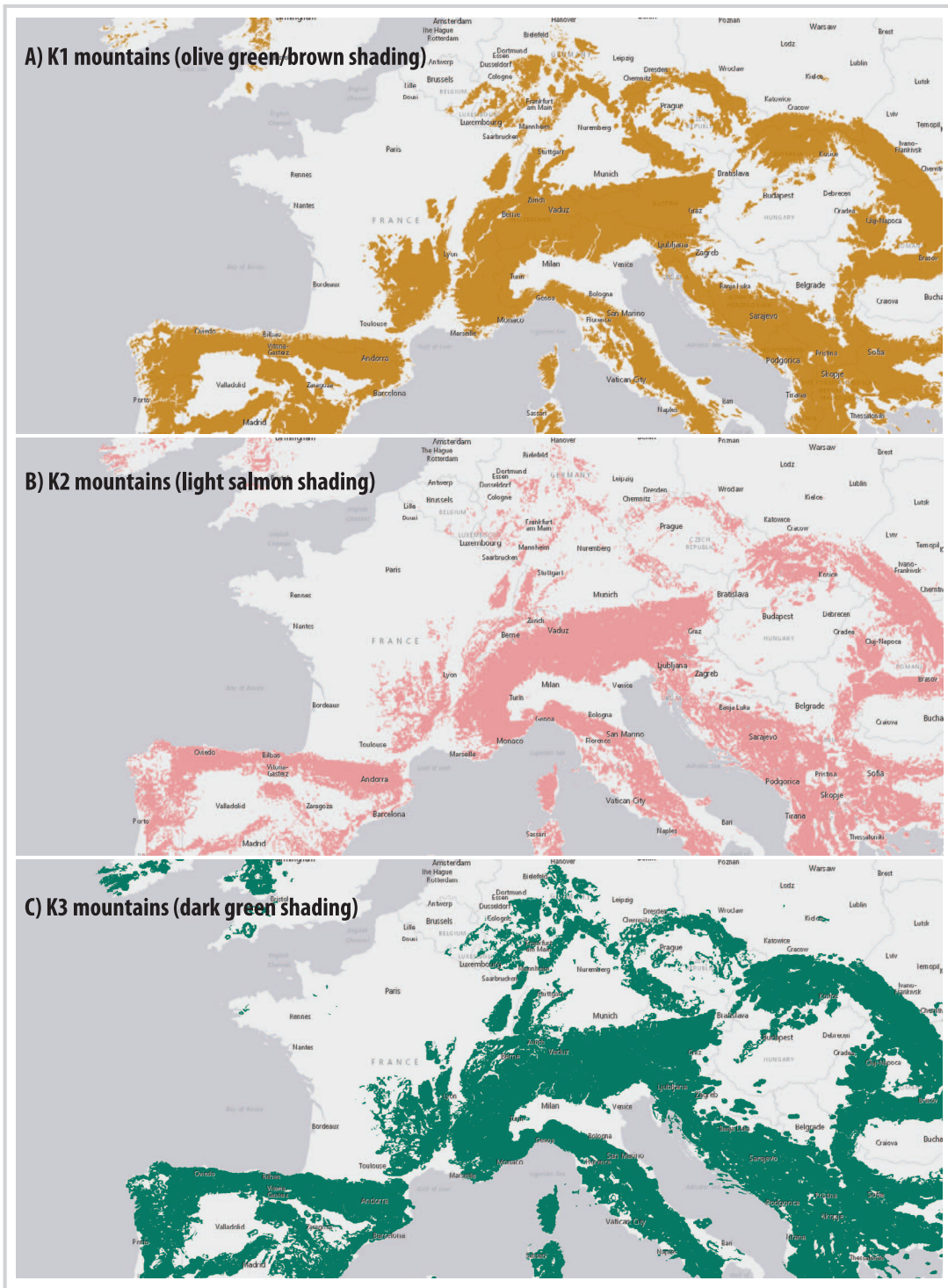
nonmountains), terrain-derived outputs of each is appropriate and informative, and essential for informing resource allocation decisions, management planning, and decision-making in general. Accordingly, we present a set of visual comparisons of K1, K2, and K3 mountain distributions at regional (Figure 2) and local (Figure 3) scales. Table 3 compares key characteristics of the 3 resources.

FIGURE 3   Local scale comparison of the 3 characterizations of mountain versus non-mountain areas in an area near Biel, Switzerland. Note the difference in the extent to which the different characterizations were able to delineate the shoreline of Lake Biel (Bielersee).

A) K1 mountains (olive green/brown shading)

B) K2 mountains (light salmon shading)

C) K3 mountains (dark green shading)

To facilitate spatial comparison and visualization, the K1 and K2 datasets were first reconciled to the same base resolution (250 m) as K3. For K1, the classes were recomputed using the finer resolution (250 m) GMTED2010 DEM instead of the coarser resolution (1 km) GTOPO30 DEM, but keeping the same criteria and NAW sizes used in the original K1 implementation. The K2 data were not similarly recalculated using the 250-m DEM but

TABLE 3 General characteristics of the K1, K2, and K3 global mountain area characterizations.

Characteristic	K1	K2	K3
Geospatial data format	Raster	Raster and vector polygon	Raster
Year source DEM was produced	1996	2005	2010
Approximate spatial resolution of source DEM at equator	1000 m	1000 m	250 m
Global pixel resolution for attribution as mountain terrain	1000 × 1000 m	4600 × 4600 m	250 × 250 m
Classifier(s)	Elevation Slope Relative relief	Relative relief	Slope class Relative relief Profile
Number and types of mountain classes	6 classes: • >4500 m • 3500–4499 m • 2500–3499 m • 1500–2499 m • 1000–1499 m • 300–999 m	1 class: mountain terrain	4 classes: • High mountains • Scattered high mountains • Low mountains • Scattered low mountains
Distinguishing features	• Original, mature, DEM-derived resource • Includes forest attributes	• Conceptually simple • Includes name attribution and considerable value-added attribution related to climate and biodiversity	• High spatial resolution • Complex characterization of terrain features including profile (gently sloping areas in upland regions)
Source	Kapos et al 2000	Körner et al 2011	Karagulle et al 2017

DEM indicates digital elevation model.

were downscaled to the same 250-m raster framework by simple subdivision of the parent (∼4.6 × 4.6 km) cells into smaller (250 × 250 m) cells, each of which retained the same attribution as the parent cell. This piecewise-constant re-meshing is the raster equivalent of assuming that the attributes of a polygon are uniform throughout its area.

Interactive visual comparison—the Global Mountain Explorer

Despite the availability of well-developed and accessible documentation describing K1, K2, and K3, challenges remain in understanding how and where they differ. To facilitate access to and exploration of the 3 characterizations, we developed a web-based tool called the Global Mountain Explorer or GME (Figure 4), accessible at https://rmgsc.cr.usgs.gov/gme/.

The GME allows for visualization and query of K1, K2, and K3 either separately or in pairwise comparisons. The K1, K2, and K3 characterizations are accessible in both binary (mountain versus nonmountain) and all-classes formats. Pan, zoom, and query functionalities are included, and a query anywhere on the map returns the

binary values for K1, K2, and K3 in a pop-up box. The GME allows for visualization of the global mountains data layers over a variety of base maps, including satellite imagery, topographic maps, light and dark canvas land and water maps, and road maps. It also has a text-based exploration tool, allowing the user to explore areas of interest by typing in the names of mountains (eg Mt Kilimanjaro), regions (eg Tibet), and other places. The data are being served as image services (raster format), and the GIS data files are available for download at https://rmgsc.cr.usgs.gov/ecosystems/datadownload.shtml.

Comparison of global mountain distributions

A great deal of visual similarity is evident between K1 and K3 when inspecting the layers in a GIS overlay environment. The same regions are classed as mountains, and the same areas have similar mountain-type designations (eg class 1 in K1 (>4500 m) matches the high mountains class in K3, and class 6 in K1 (300 to 1000 m and relative relief >300 m) matches the scattered low mountains class in K3. As would be expected based on its much finer spatial resolution, the K3 characterization hugs lake shorelines much better than K1 and K2, which

FIGURE 4 User interface for the Global Mountain Explorer, a freely accessible online tool that allows query, visualization, and comparison of the K1, K2, and K3 global mountain characterizations. Advanced functionality includes a slider bar (the vertical line separating the display of K3 mountains to the left and K2 mountains to the right) for pairwise visual comparisons, availability of several base maps for backdrop, and a text-based "find address or place" locator.
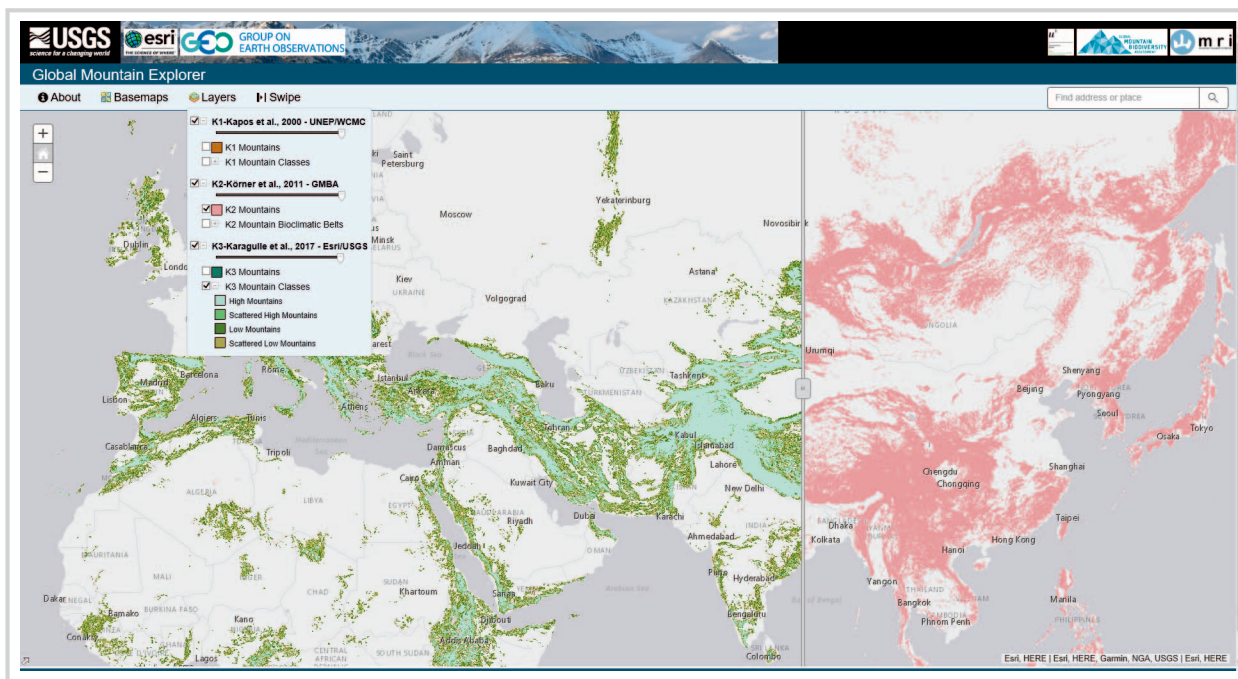
both frequently classify parts of or entire lakes as mountains (Figure 3). In a visual and human-perspective sense, the highly spatially resolved K3 features appear to best characterize the general lay of the land. The increased spatial resolution and smaller NAW size of K3 had the effect of including more transitional area (eg at the foot of a mountain) in a mountain class than K1 and K2.

The total area classed as mountains in K1, K2, and K3, and its percentage of global land surface (excluding Antarctica), are summarized in Table 4. The differences are striking, ranging from about 12% of the global land surface in K2 to about 26% in K1 and about 30% in K3. Körner et al (2017, page 5) attributed the difference between K1 and K2 to K1's inclusion of "intramountain and forelands terrain, as well as hill country." However, the K3 percentage is even higher, and it specifically excludes tablelands, hills, and plains. Moreover, K3 high tablelands with considerable relief make up <0.1% of the

global land surface, so their contribution to mountains' share of global land surface is insignificant. Differences among K1, K2, and K3 areas mapped as mountains, whether as global totals or in any smaller geography of interest, are evident. Further exploration of the actual magnitude and causes of these differences is merited, but always with the recognition that the 3 approaches differed in terms of definitions, methods, and spatial resolutions. Boundaries of mountain regions are definition-dependent, which can have consequences for policy and decision-making.

Mountain regions versus mountain features

Contributing to the difficulty in producing a universally recognized and authoritative characterization of mountains is confusion between mountain regions and mountains as discrete landforms. A lone mountain rising from a plain is universally considered a mountain. Two

TABLE 4 Global land surface (excluding Antarctica), mountain area, and mountains as a percentage of global land surface under the 3 characterizations. The K1 and K2 total land surface areas and mountain areas and percentages are as reported in Körner et al (2017).

Characterization	Total global land surface excluding Antarctica	Total mountain area	Mountain area as percent of global land surface	Source
K1	133,724,000 km²	35,238,000 km²	26.4%	(Körner et al 2011)
K2	133,724,000 km²	16,434,000 km²	12.3%	(Körner et al 2011)
K3	134,088,000 km²	40,869,000 km²	30.5%	(Karagulle et al 2017)

separated mountains in proximity rising from a plain will also universally be regarded as 2 mountains—but the total area occupied by the mountains and the land between them, depending on the separation, may or may not be regarded as a mountain region. Well-connected mountains forming ranges are often considered both as mountains, in a landscape features sense, and as mountain regions.

The distinction is further complicated by the use of an NAW in raster processing of DEMs. Feature identification is partially a function of NAW size, where a relatively small NAW will produce a more fragmented map of discrete landform features and a relatively large NAW will produce a more smoothed map of blended features in regions. In addition to NAW size, postexecution filtering and other refinement of raster outputs can also emphasize the regional nature of mountain feature distributions. NAW size is an important consideration, and Karagulle et al (2017) demonstrated the importance of tailoring NAW size to landform parameter (slope, relative relief, and profile [the amount of gently sloping land in upland regions]), rather than using a fixed NAW for every parameter. They also used a geostatistical averaging tool (focal statistics majority rule) to refine the distribution of the plains class, which was initially overrepresented in Sayre et al (2014). This operation reduced isolated mountain and hill fragments in a largely plains matrix, the inclusion of fragmented plains in mountain regions, and the occurrence of artifacts (eg artificial skirts around bases of mountains).

The city of Bern, Switzerland (center right in Figure 2), with an elevation of ~540 m, is an interesting example of the features versus regions consideration. By the K1 criteria, Bern is identified as a mountain as it falls in the class of 300–999 m elevation, with relative relief of >300 m. The NAW size for the K1 calculation of relative relief was ~80 km^2. While residents of Bern may not consider the city itself as a discrete mountain, they would likely agree that an 80 km^2 circular area centered on Bern would be a mountainous region. The K2 analysis does not identify Bern as a mountain feature. The K3 analysis, using a 250-m source DEM, places Bern in the scattered low mountains class, using the criteria of slope 50–80%, relative relief 300–900 m, and >50% of the NAW in gently (<8%) sloping land. The K3 NAW sizes were 0.78 km^2 for the slope and relative relief parameters as well as 1.56 km^2 for the profile parameter—much smaller NAW sizes than those used for K1 and K2—and identified discrete landform features at a high spatial resolution.

The K1, K2, and K3 characterizations each delineate mountains as GIS-derived spatial entities, with corresponding fixed class names for the types of mountains resulting from the modeling. As such, these efforts lack a semantic, ontological development through the inclusion of named features. Couclelis (1996) discussed the difficulty in attempting to bound

indeterminate (from a human perspective) objects, which is one of the difficulties in standardizing characterizations of mountains. Along these lines, Buckley and Frye (2006) advocated a stronger cartographic treatment when producing GIS maps. They recommended including place names for mapped features and suggested sets of standardized terms for physiographical and marine features.

A limitation of the new, high-resolution K3 resource is the current lack of mountain place names as data attributes, and future development of these attributes is recommended. The GME does, however, include a generalized name query function against an external geonames database. The user can type in any place name (eg Sweetwater Mountains, California), and the displayed area will change to that location. Having a separate georeferenced place names layer associated with the data in the GME helps to overcome the limitation of a lack of mountain names as attributes in the data themselves. Importantly, the K2 resource has evolved in this direction, thus enhancing its utility.

A polygon version of K2, derived from the original raster K2 data and a number of other mountain and place name references, is now available (http://www.gmba.unibe. ch/services/tools/mountain__inventory). The new K2 global mountains inventory (http://www. mountainbiodiversity.org/explore) contains 1003 named polygons representing mountains and mountain ranges, and these geographies contain area calculations and bioclimatic and demographic attributes (Körner et al 2017).

Conclusion

We present a comparison of 2 previously described (K1, K2) and 1 new (K3) high-resolution maps of the extent of global mountains derived from an index of slope inclination, an index of variation in vertical relief, and an index of the profile character. The comparisons are facilitated by a new online visualization and query application, the GME, which enables visual comparisons of mountain locations and extents among the 3 characterizations. The GME allows for comparison of the 3 different characterizations at any scale (eg global, regional, and local), and facilitates an understanding of how different definitions of mountain areas result in different mapped distributions. The new K3 data and the GME tool are intended to advance understanding of the distribution of global mountains and assist in the decision-making processes so important for maintaining biodiversity and providing the ecosystem services upon which many humans depend.

We suggest that the improvement in spatial resolution gained by using a 250-m DEM results in greater accuracy of terrain-based mountain feature boundaries. While the increase in spatial resolution offered by the new K3

characterization is welcome, it also makes a more rigorous comparison of the 3 mountain data layers difficult. In the most general comparison of the global mountain extents among K1, K2, and K3, we find a more than twofold difference between K2 and the other layers. K2 used only 1 parameter, ruggedness, to define mountains, but it also generalized the initial 1 km^2 ruggedness results to a coarser sampling resolution. A more detailed comparison between K1, K2, and K3 with each data layer derived from the same source DEM (eg 250 m) would facilitate the explanation of differences in output based on differences in methods and criteria. The separation of differences caused by criteria from differences caused by spatial resolution is warranted and merits future investigation.

We show how both the choice of criteria with which to define mountains and the spatial resolution of the output and display influence the amount of area mapped as mountains. Each of the 3 characterizations was designed for a different purpose, and that intended purpose remains its most appropriate use. K1 is most appropriate for calculations of forest areas in mountain regions and similar applications. K2 is most appropriate for use in analyses of climate and species–habitat relationships in mountain environments and for assessments of mountain biodiversity quantity and condition. K3 is most appropriate for understanding geomorphological variation and terrain-type distributions in mountain environments. K1 and especially K3 are high-spatial-resolution resources and emphasize mountainous terrain types more as embedded physiographical features of the larger landscape rather than as mountain regions. K2 places more emphasis on defining generalized areas as mountain ranges and regions and less emphasis on geographical variation of fine-scale terrain characteristics. The GME is intended to facilitate choosing which global mountain characterization is best suited to a particular application because it allows for easy visualization of the 3 options.

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