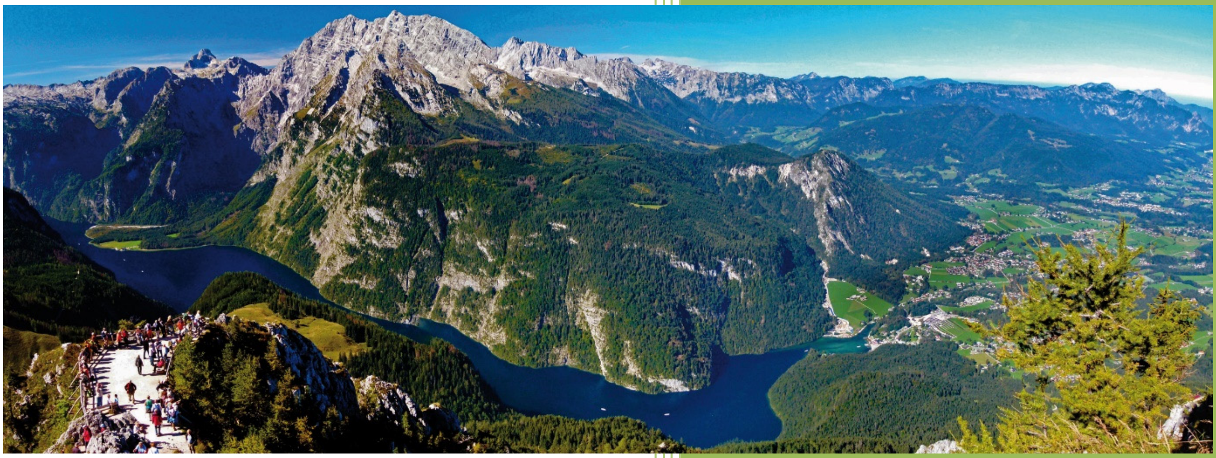
26 - 30 April 2016
Berchtesgaden, Germany

UNBOUNDED MAPPING OF MOUNTAINS

Proceedings of the 10th ICA Mountain Cartography Workshop



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UNBOUNDED MAPPING OF MOUNTAINS

Proceedings of the 10th ICA Mountain Cartography Workshop
26 – 30 April 2016, Berchtesgaden, Germany

Workshop Organisation

Technische Universität Dresden
Institute of Cartography
Dresden, Germany

Organising Committee

Benjamin Schröter, Manfred Buchroithner, Uta Heidig
Technische Universität Dresden Institute of
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View from Jenner (1,874 m) above Lake Königssee (603 m) towards Watzmann (2,713 m)
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FOREWORD

In 2016, the ICA Commission on Mountain Cartography celebrated the 10th "Jubilee" Workshop from April 26 to 30, at Carl-von-Stahl-Haus, a rustic mountain hotel on the Austria-German border, 1,733 m above sea level and adjacent to Berchtesgaden National Park. The overall theme of this workshop, "Unbounded Mapping of Mountains", brought together 48 participants from 18 countries, including all six permanently populated continents.

This publication is the outcome of presentations on various mountain cartography topics, from cutting-edge research to overview reports, and includes both theoretical and practical aspects of the discipline. Contributions cover broad aspects of mountain cartography: relief, mountain and hiking, ecology, glaciers, snow and skiing, and history. I strongly believe that many of published and presented topics can inspire readers in further research and professional activities in the field of mountain cartography.

As commission chair, I wish to thank the participants and contributors who have made this publication possible. I also have sad news to report. Our colleague, Jacek Drachal, a long-time commission member and participant at many workshops, passed away recently. His last article is posthumously published here. Finally, speaking for myself and all workshop participants, I would like to thank to Benjamin Schröter and Manfred Buchroithner from the Institute for Cartography, Technical University Dresden, Germany, for hosting such a well-organized event and preparing this valuable publication.

Dušan Petrovič
Chair, ICA Commission on Mountain Cartography
Ljubljana, May 2017

WELCOME

Some fifteen years after my first organisation of a Workshop of the ICA Commission on Mountain Cartography I was asked by the chairman of this commission if I would be willing to organise the 10th "Jubilee" Workshop. As initiator of the ICA "MC" Commission in the 1990s, after short consideration I agreed. Thus, after the meeting at the Rudolfshütte in the Hohe Tauern Range of the Austrian Alps in the year 2000 I thought that for me as Austrian Citizen and German Cartography Professor it might be a good idea to perform the 2016 Workshop in the Carl-von-Stahl-Haus, located exactly at the Austro-German border, at the rim of the Berchtesgaden National Park, near the City of Salzburg. Like in 1999 with Heinz Slupetzky, this time I found immediately an appropriate cooperator in the person of Benjamin Schröter. His devoted work cannot be thanked enough. As passionate mountaineer and fieldworker and as multiple participant in ICA CMC workshops Ben made an excellent job in both organising the meeting and compiling these workshop proceedings. Nevertheless we could not have completed this volume in time without the relentless support of Uta Heidig from our Institute for Cartography of TU Dresden. My thanks go also to her.

Participants listening to Michael Fishers inspiring talk in the rustic lecturing room.

When Benjamin suggested to address the border location of the Carl-von-Stahl-Haus in the workshop slogan I immediately agreed and we chose "Unbounded Mapping of Mountains" as topic for the 10th ICA Mountain Cartography Workshop. After we had sent out the first workshop announcement Geoff Aitken replied: "Unbounded is a superbly open and self-fulfilling concept! Unbounded by: national borders, history, conventions, commercial constraints, sheet lines, colour, technology etc. – such freedoms. Being unbounded let us get on with what really matters." There is nothing else to add.

The setting around the Carl-von-Stahl-Haus, just a "stone's throw" away from the highest rock face in the Eastern Alps, the mighty 1,800 m high East Face of Watzmann (2,713 m), and the alpine spring snow cover were inspiring for both scientific discussions and practical field-use of high-mountain maps. In this context the German Alpine Club and the Berchtesgaden National Park Administration has to be thanked for map provision. Both the well-suited lecturing facilities and the excellent gastronomy contributed to the success of this ICA Workshop. Within three and a half days, ten sessions covered topics including relief aspects, mountain and hiking cartography, ecology-related aspects, glacier-related aspects, snow- and ski-related aspects as well as historical aspects, apart from miscellanea. The presentation of Michael Vogel, Director of Berchtesgaden National Park, was a very informing introduction the surroundings of the workshop venue and complemented the scientific programme. Out of the 32 presentations held at the workshop 21 full papers and 9 abtracts are published in this volume.

Carl-von-Stahl-Haus during the pretty winterly first workshop days.

The Commission Business Meeting was also held during the workshop and the minutes are available from the Commission Website (www.mountaincartography.org). Furthermore, the (now) already published Commission Poster on the U.N. global goals for sustainable development was intensively discussed during the workshop. Tom Patterson's Trivia Challenge represented an evening highlight and revealed several "blank spots" on some workshop participant's mental map.

Due to a late but intense onset of winter the recreation day needed to be shifted in order to guarantee safe conditions for the participants. In perfect weather conditions several people summited the Schneibstein (2,275 m), others took a stroll to Jenner (1,874 m) and explored the still snow-covered alpine meadows in its vicinity, a few participants went all the way to Königssee and several people just enjoyed the spring-like temperatures and relaxed at the terrace of the Carl-von-Stahl-Haus.

A three-day post-workshop excursion brought part of the participants to the studio of the internationally leading geosculptor Wolfgang Pusch in Berchtesgaden, to the biggest ice cave on earth, the Eisriesenwelt near Werfen/Austria, to Ramsau am Dachstein, to Schladming with the world's largest lenticular true-3D geodisplay depicting the 3.5 km wide Dachstein South Face, produced by TU Dresden cartographers, to Admont with its world-famous monasterial library with invaluable ancient maps and finally to the Gesäuse National Park with its overflight simulation facility, also generated by the TU Dresden cartographers.

Wolfgang Pusch explaining his newest landscape model – Eiger, Mönch, Jungfrau and the Aletsch Glacier.

I look forward to the 11th ICA Mountain Cartography Workshop, which will take place on the island of Hvar, Croatia, between 21st and 25th May 2018. I hope to meet many interested mountain cartographers there again!

Manfred Buchroithner
Local Organising Committee
Dresden, May 2017

GROUP PHOTOGRAPH

Participants of the 10th ICA Mountain Cartography Workshop held at the Carl-von-Stahl-Haus, Berchtesgaden, Germany (Photography by Karel Kriz).

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RELIEF ASPECTS

PRODUCING MANUAL SMALL-SCALE SHADED RELIEF

Tom Patterson
US National Park Service, Leesburg, NY, USA

ABSTRACT

This paper introduces two hand-drawn shaded relief images, one of the World and the other the contiguous United States, which are available on the Natural Earth Data website. The motivation for this project: at small map scales, manual methods yield relief shadings with a generalized appearance not possible via automated methods. Discussion focuses on manual drawing procedures using Adobe Photoshop and a Wacom tablet. Production considerations also receive attention, including projections, lighting, generalization, drawing style, and map scale.

Keywords: shaded relief, small-scale, generalization, manual, Photoshop, Natural Earth

1 INTRODUCTION

Out of necessity, to fill a mapping void not adequately met by existing data and software, I produced two small-scale shaded relief pieces by hand. The first relief, created in 2015, depicts the entire world. It is available for free on NaturalEarthData.com (Kelso and Patterson 2009) as a grayscale GeoTIFF (10,800 x 5,400 pixels) in the Geographic projection. The shaded relief art registers with 1:50-million scale Natural Earth vector data (Figure 1).

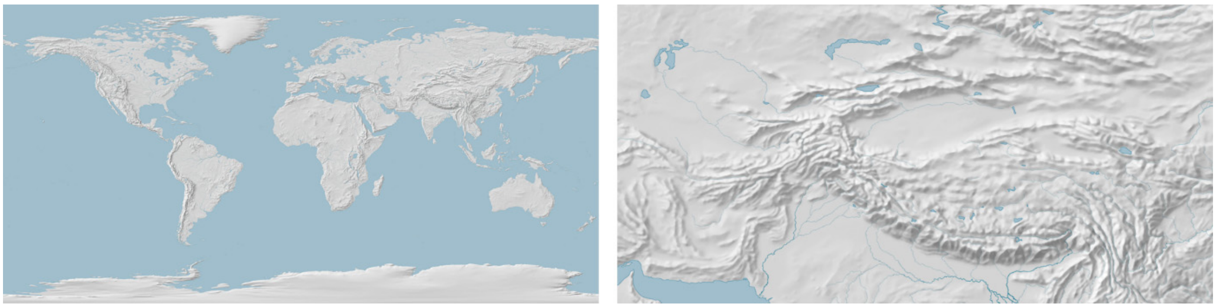

Figure 1: Manual shaded relief of the world. (left) Full coverage with blue water bodies added for reference. (right) Detailed excerpt of Central Asia, Tibet, and the Himalayas.

In 2016, I drew a second and more detailed shaded relief of the contiguous United States, which includes adjacent areas in southern Canada, Latin America, and the Caribbean. Also available on the Natural Earth website, it is offered as a grayscale GeoTIFF (12,578 x 9,494 pixels) in the Web Mercator projection. The contiguous United States relief registers with 1:10-million scale Natural Earth vector data (Figure 2).

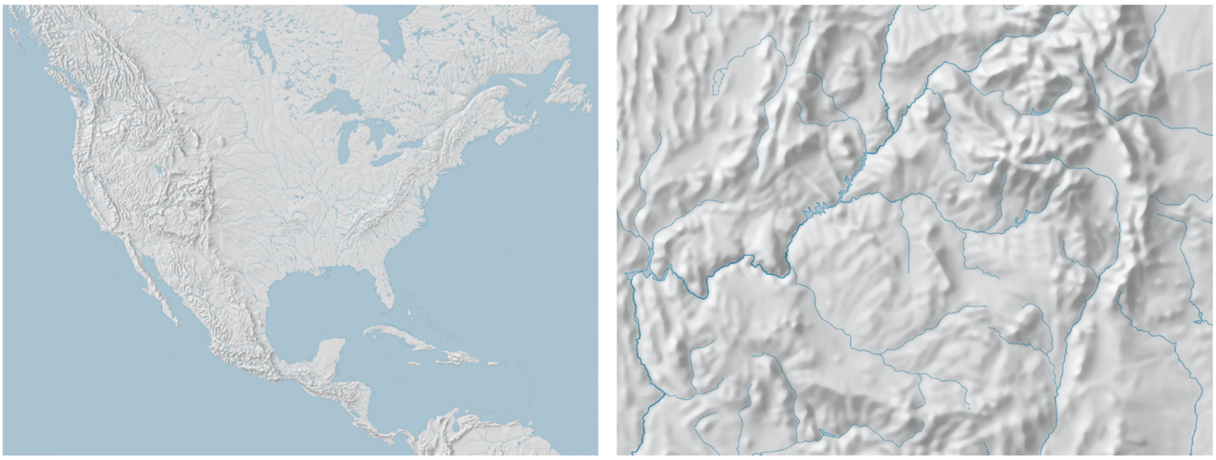

Figure 2: Manual shaded relief of the contiguous US. (left) Full coverage with blue water bodies added for reference. (right) Detailed excerpt of the Colorado Plateau and southern Rocky Mountains.

The following sections examine how small-scale shaded relief differs from large-scale shaded relief and my rationale for undertaking this project. I discuss how to draw manual shaded relief for use by mapmakers in a wide range of projects. The paper finishes with a review of the planning and production considerations for drawing shaded relief.

2 RATIONALE FOR MANUAL SHADED RELIEF

Digital relief production is now at a mature stage after several decades of development. At large and medium scales, automated techniques routinely yield shaded relief depictions that rival and sometimes surpass the visual quality of the very best hand-drawn artwork of the past (Figure 3). Digital shaded relief renders are certainly more accurate than their manual counterparts - no potentially fallible human interpretation of terrain is involved. In addition, digital reliefs take just a few minutes to produce compared to tens of hours required to produce a manual reliefs. Given these advantages, why then did I turn to anachronistic manual production methods?

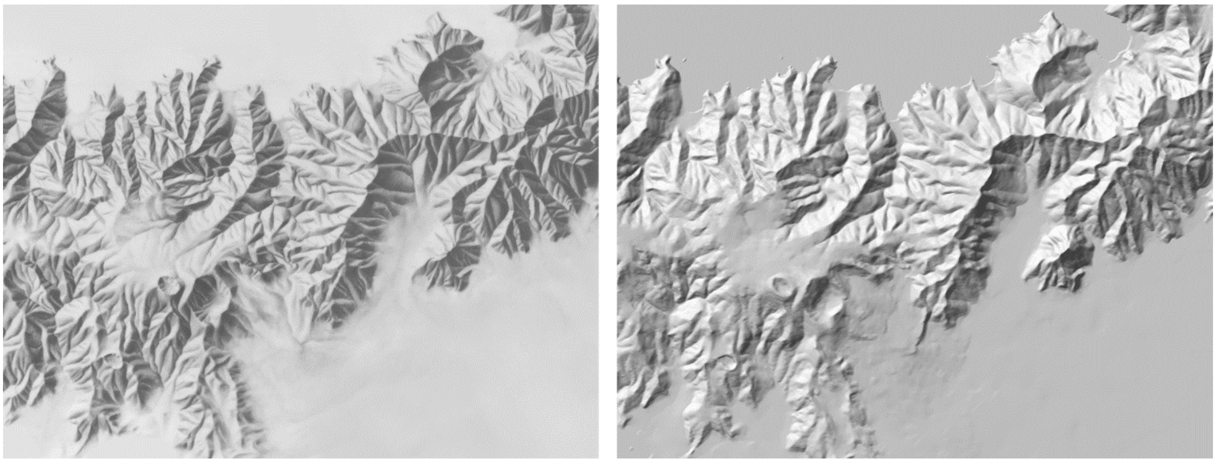

Figure 3: Tutuila, American Samoa, at 1:24,000-scale. (left) A 1980 manual relief by Michael Wood. (right) A 2016 digital relief created with default settings in Natural Scene Designer Pro 7.0.

The answer has everything to with appearance. At very small map scales automated relief shading methods fall short due to poor generalization. High-resolution elevation data when rendered with standard cartography and GIS software yield shaded relief with excessive detail - mountain ranges often look like gritty "sandpaper" textures (Figure 4A). In extreme cases, the tightly packed mountain shadows coalesce as a uniform dark tone when rendered.

The problem lies with the heterogeneous nature of small-scale elevation data. The height values on these data have great variability over short distances, such as when a tall peak and deep canyon are close to one another. When rendered digitally, these data produce shaded relief with similarly heterogeneous pixels - the brightest and darkest pixels are immediately adjacent, creating a noisy pattern across the shaded relief. Ideally, in order for your eye to discern illuminated and shadowed slopes on either side of a ridge, these slopes must have at least several pixels of width, and preferably even more.

Downsampling elevation data (Figure 4B) and then smoothing it (Figure 4C) is the common method of reducing noisy terrain detail at small scales, which when rendered produces blurry, indistinct shaded relief resembling melted plastic. The resolution bumping technique (Patterson 2001), which involves merging detailed and smoothed elevation data prior to rendering a shaded relief, yields similar results (Figure 4D). And Terrain Sculptor software (Leonowicz et. al. 2010), which produces nicely generalized shaded relief artwork at large and medium-scales, is ineffective at very small scales (Figure 4E).

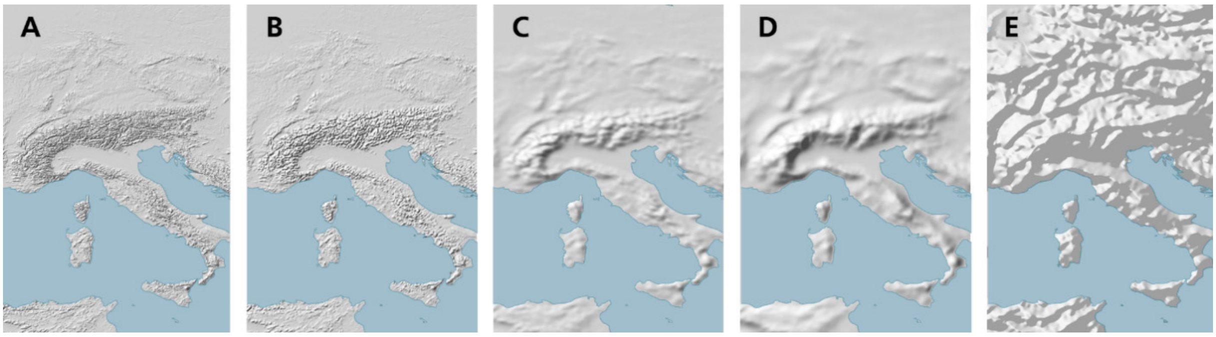

Figure 4: Small-scale shaded relief created digitally. The choice is between highly detailed relief (A and B) and too much generalization (C, D, and E).

To develop appropriately generalized small-scale shaded relief, I turned to the manual relief shading techniques that I learned in the 1980s. (For manual relief examples, visit ShadedReliefArchive.com). This approach allowed me to represent complex mountain ranges as gray and white tones that captured their key characteristics, including orientation, ruggedness, relative elevation, and large secondary features. Given the small scale and limited space in which to draw, the resulting shaded relief is similar to a caricature. But instead of exaggerating a person's facial features - noses, chins, eyes, etc., I emphasized mountains, plateaus, canyons, and escarpments at the expense of lower and flatter terrain, while simultaneously being mindful of map accuracy. I also wanted the shaded relief to have a soft, clean style that could combine unobtrusively with other information on reference and thematic maps. Going back to my manual roots was the only way to create what I needed. The project, however, had a modern dimension (Tóth 2010): I drew the reliefs using digital production tools (Figure 5).

Figure 5: Drawing shaded relief in Adobe Photoshop with a Wacom tablet and stylus.

3 DRAWING TECHNIQUE

To draw shaded relief images that exhibited both manual style and digital accuracy involved multiple layers in Adobe Photoshop. The base layer was a digital shaded relief created with the resolution bumping technique described previously. I generated the base relief in Natural Scene Designer Pro with 1,800 percent vertical exaggeration (Figure 6A). This generic gray base provided a way to gauge the relative height and generalized structure of terrain features. The next Photoshop layer above this was an empty layer that received my drawing strokes made with the Wacom tablet, which would eventually become the final shaded relief when merged with the base relief below (Figure 6B). As a reference while drawing, I would temporarily turn on a layer containing Natural Earth vector coastlines, drainages, and spot elevations (Figure 6C). Having this information as a guide allowed me to fit the final relief precisely to the rivers. The topmost layer was another reference layer containing highly detailed shaded relief generated from SRTM elevation data. I would briefly turn this layer on while drawing to see subtle terrain features (Figure 6D).

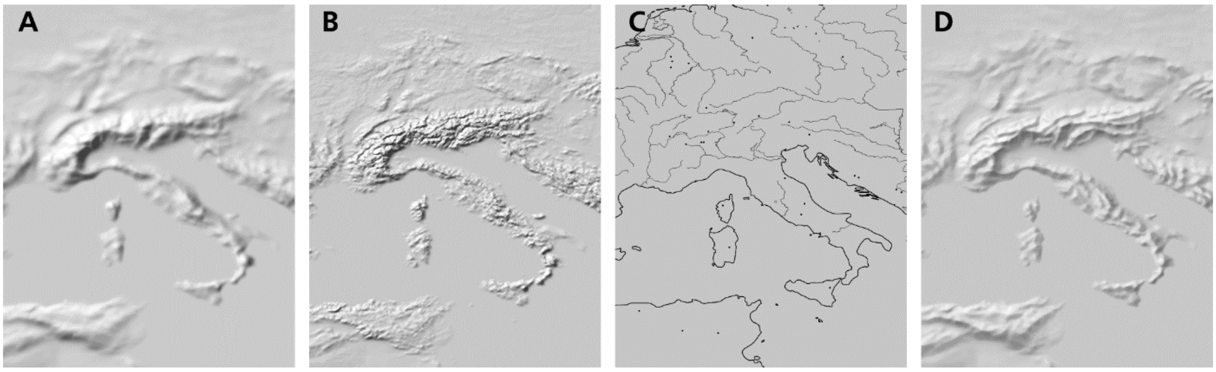

Figure 6: Photoshop layers. (A) Digital shaded relief base. (B) Drawing layer. (C) Natural Earth vectors used for reference. (D) Detailed reference shaded relief.

The manual reliefs that I drew were not entirely manual. For example, the world shaded relief in the Geographic projection had extreme east-west polar stretching, which presented drawing challenges. For example, a small mountain range in a polar region could stretch out to nearly the entire width of the map, creating an inadequate base for manual relief drawing. Consequently, Antarctica and high arctic islands contain mostly digital shaded relief supplemented with minimal manual touchups. Some large, flat areas elsewhere, such as the Amazon basin, Canadian Shield, and West Siberian Plain, also received only minor manual work. The digital shaded relief that appears very lightly in these areas looked acceptable as is.

The focus of my drawing correlated with terrain prominence - bigger, higher features received the most attention. I drew with a soft brush in Photoshop that I could quickly change in size using keyboard commands (the Wacom tablet also has programmable buttons for accomplishing this). Drawing in grayscale, I alternated between light and dark tones by toggling the foreground/background colors using another keyboard command. I applied tones lightly using multiple brush strokes with the brush opacity ranging from 10 to 50 percent. Using the pressure sensitive Wacom tablet and stylus allowed for the application of very subtle tones.

Some areas were harder to draw than others, such as mountain ranges that trend parallel to the assumed northwest light source, such as the Caucasus. In these local situations, I shifted the illumination direction slightly to the north or west to draw the range more clearly. Even trickier to depict were arcing mountain ranges that required switching the shadowed slopes from one side to the other, usually at natural breaks in the terrain. The mountains along the Pacific coast of North America from Alaska through British Columbia and on to Washington exemplify this problem. I also took into account light and shadows on adjacent terrain when locally varying the light source to maintain consistency. Another difficulty was depicting complex but relatively low terrain, such as the mountains of southeast China, in an understandable manner. I had to carefully study this area to identify topographic trends and patterns.

Drawing shaded relief efficiently requires a relaxed, but attentive state of mind. Taking frequent breaks helps. Over thinking how to depict the terrain would slow down progress and result in poor renderings. Fortunately, working in Photoshop gave me a second or even a third chance to get it right. I redrew the Canadian Rockies three times.

Besides the mechanics of drawing, the final shaded relief is a reflection of my geographic and aesthetic preferences. Some prominent landforms that were hard to discern on small-scale digital relief, such as the southern Andes, received greater emphasis. I broadened and darkened the short but steep slopes that characterize these mountains. I deemphasized other areas. For example, to diminish visual noise, not all of the many mountain ranges found in the Great Basin of the US appear on the relief map. Relatively low features with straight, regular sides rising above flat lowlands, such as the Ural Mountains of Russia and several mesas on the prairies of northwestern Canada, appear with too much contrast on digital relief. They received slight flattening adjustments.

As a final tweak to the relief art, I lightly applied Photoshop's Dry Brush and Median filters to the entire map - a grayscale DEM inserted into Photoshop layer mask limited this filtering to mountain summits and other high elevation areas. This yielded crisp ridgelines that accentuated the three dimensional appearance of landforms.

4 PRODUCTION CONSIDERATIONS

Creating a manual shaded relief involves careful planning. I considered the following variables before and while engaged in drawing.

4.1 MAP PROJECTION

Choosing the right map projection for a shaded relief released online, downloaded by unknown persons, and used for making a variety of different maps is a challenge. The main problem: whichever projection you select will probably differ from what the user will want to use - there are dozens of common small-scale map projections to choose from. Transforming the shaded relief from one projection to another at the very least degrades image quality and often introduces undesirable distortion, such as stretching or compression, especially on the map periphery. Lighting is another concern. For example, northwest illumination on shaded relief in a cylindrical projection becomes multidirectional when transformed to a polar projection (Figure 7). To minimize these potential problems, one must select a map projection that will accommodate the most likely projection choices by end users.

I selected the Geographic (Plate Carrée) projection for the shaded relief of the world (Figure 7, left). This generic cylindrical projection is the default choice for delivering world raster data by online providers. Although few final maps employ the Geographic projection, it is nevertheless a malleable choice that transforms with acceptable levels of distortion to more preferred world map projections, such as the Eckert IV, Robinson, and Winkel Tripel (Šavrič et. al. 2015). However, transforming the relief to the now popular Web Mercator projection is not advisable because of the extreme stretching at high latitudes. In fact, no available relief product, digital or manual, works adequately with the Web Mercator projection near the poles.

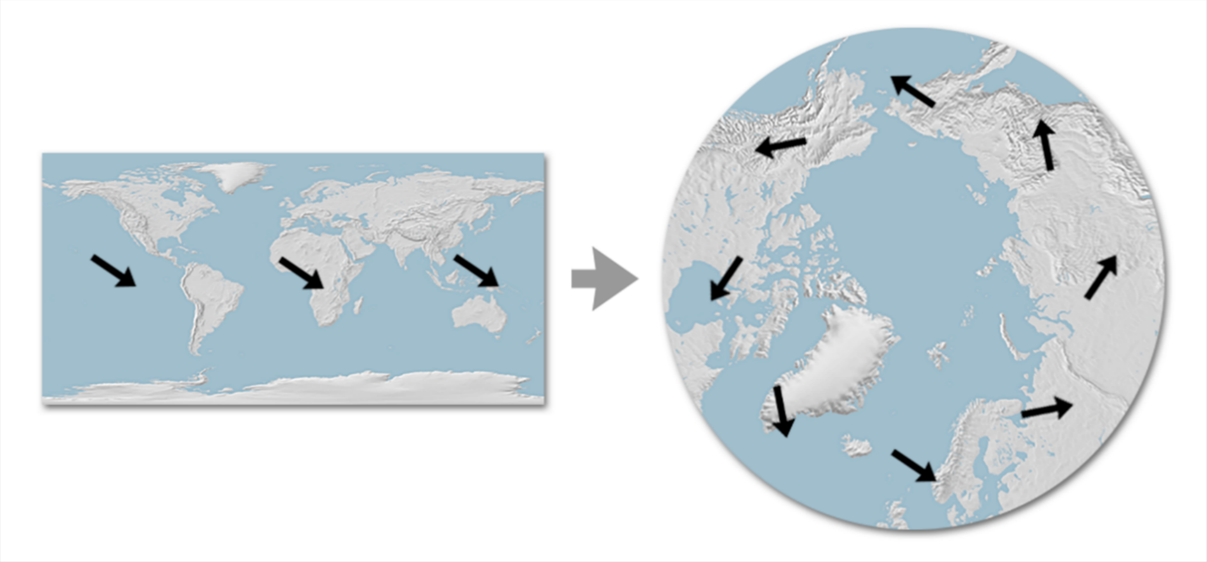

Figure 7: (left) World shaded relief with black arrows indicating standard northwest illumination. (right) Transforming the world relief from the Geographic projection to a polar projection results in inconsistent illumination.

I selected an entirely different projection for the shaded relief of the contiguous US. Because the map coverage focuses on mid and low latitudes, I drew the relief in the Web Mercator projection. This choice is obviously ideal for Web mapping and it also works well when transforming the relief to more traditional equal-area projections, such as the Albers Conic and Lambert Azimuthal. To compensate for some image compression that occurs in northern areas during reprojection, I drew these areas with slightly less relief detail (Figure 8, right).

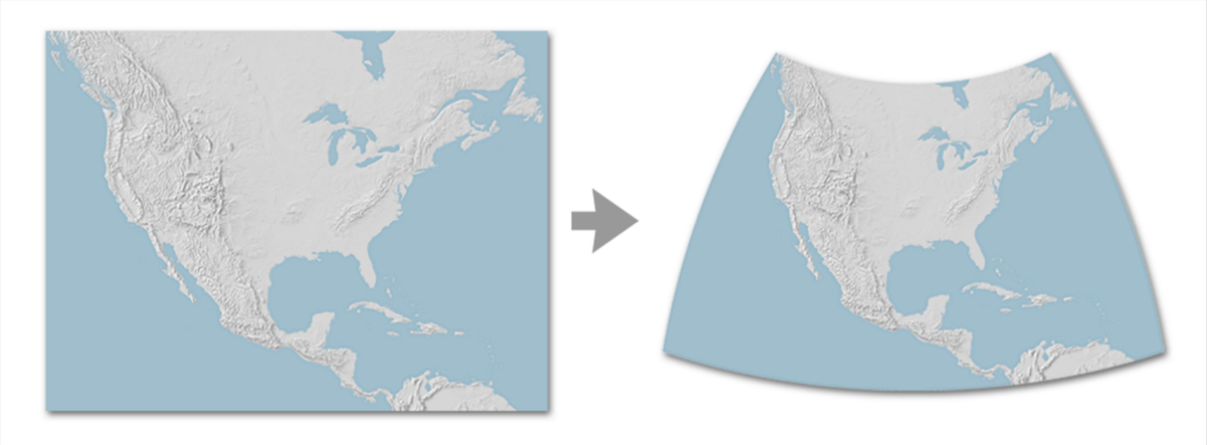

Figure 8: Transforming shaded relief of the contiguous US from the Web Mercator projection (left) to the Lambert Azimuthal Equal-Area projection (right).

4.2 LIGHT DIRECTION

As was discussed previously, illumination originating from the northwest (315 degrees azimuth) is standard for shaded relief depiction, but it does not work well when ridges and valleys trend in the same direction as the light. The lack of shadows causes even high mountains to become inconspicuous when they blend in with the flat gray background tones. Locally adjusting the light direction slightly (up to 30 degrees in either direction from northwest) counters this problem (Imhof 1982).

I varied the light direction using two methods. Generating the base relief in a beta version Natural Scene Designer Pro 7.0 allowed the use of auxiliary light sources (with the light coming from different directions) for local areas, in addition to standard northwest lighting elsewhere on the relief (Figure 9). The program interpolates the light direction in intervening areas between the auxiliary lights that the user sets. These adjustments allowed me to better define major mountain ranges on the base relief. Additionally, when drawing the final relief in Photoshop, I applied light direction adjustments to subordinate terrain features. My goal was to depict all terrain features, from the smallest ridge to the largest range, as clearly as possible. Many of these adjustments occurred with little conscious thought; I relied on decades of experience to instinctively make on-the-fly light adjustments as I drew.

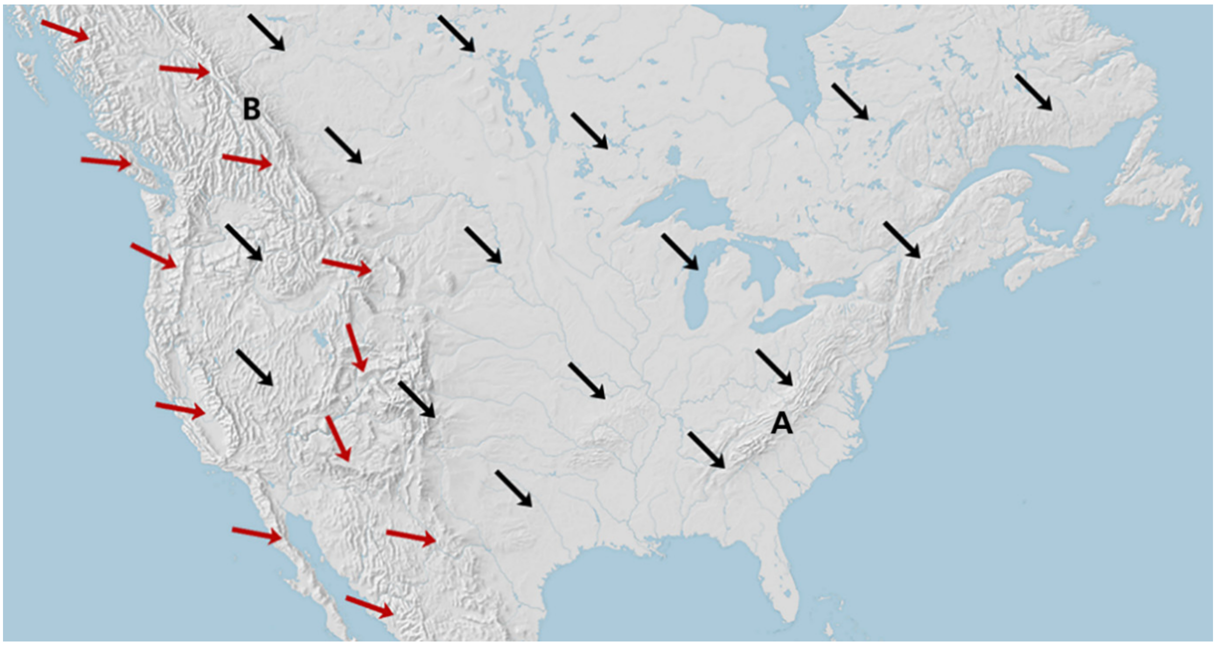

Figure 9: Black arrows indicate shaded relief depicted with standard northwest illumination, such as the perpendicularly aligned Appalachian Mountains (A). Red arrows show changes to the illumination direction to better depict uncooperative terrain, such as the northwest trending spine of the Canadian Rockies (B).

4.3 GENERALIZATION

The amount of detail found on a small-scale shaded relief in large part depends on the production method. Digital shaded relief tends toward greater detail because the data from which it derives are already detailed, and applying generalization involves additional work often using inadequate methods that yield poor results (Figure 4). Manual shaded relief, on the other hand, is often highly generalized because drawing proceeds very slowly and including more detail beyond the bare minimum requires an even greater investment of time.

The manual reliefs that I drew attempt to fill the middle ground between these generalization extremes. Drawing on top of a base relief derived from digital data helped make the work go quicker - and produced more accurate results. When drawing, I tried not to vary the magnification level in order to keep the amount of terrain detail consistent from one region to the next. I would look at the detailed digital terrain (on the reference layer in Photoshop) with a slightly unfocused gaze to allow the primary and secondary terrain features to emerge (Figure 10, left). My final relief drawing depicted what I saw minus the tertiary terrain features (Figure 10, right).

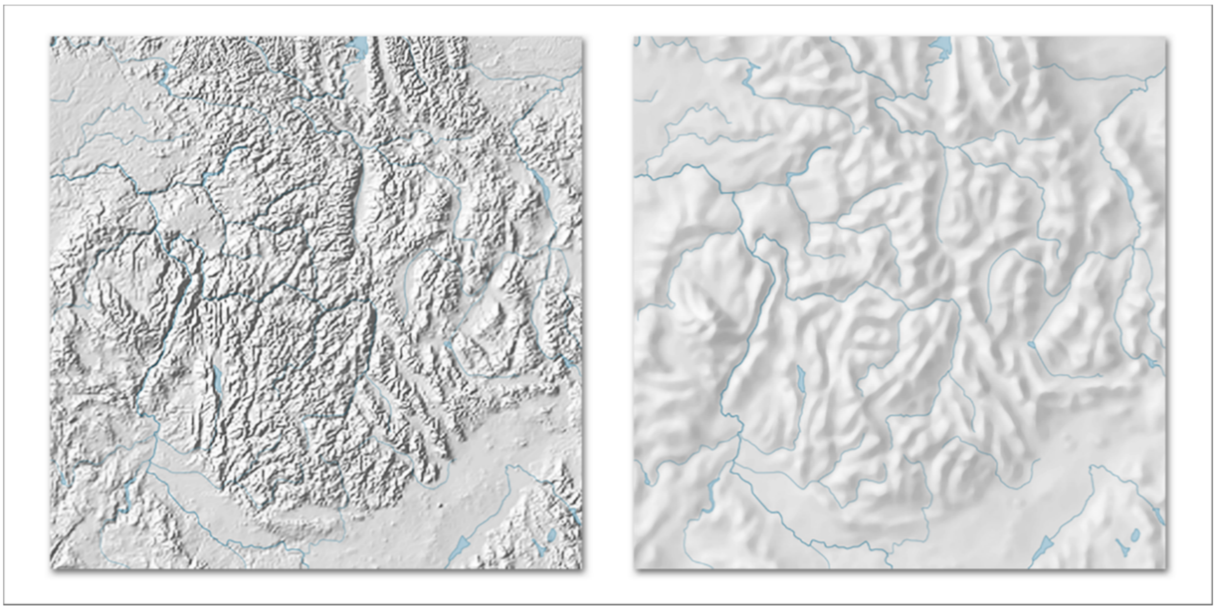

Figure 10: (left) Digital shaded relief derived from SRTM data used for reference when drawing. (right) The final generalized manual shaded relief.

I also adjusted relative terrain height while drawing. The base relief had 1,800 percent vertical exaggeration. After my initial drawing was complete, I compared the prominence of mountains, plateaus, etc. and made necessary adjustments based on their surveyed elevations. Adding slightly more contrast to a mountain crest made it appear higher; removing tone and contrast would lower it.

4.4 DRAWING STYLE

A distinguishing characteristic of manual shaded relief is the great variety in drawing styles between artists (Figure 11). My stylistic preference is for soft, clean relief that can serve as a neutral backdrop on thematic maps. To keep the overall relief light, I paint the illuminated northwest slopes with white. This technique gives landforms a three-dimensional appearance without having to paint excessively dark shadows on the southeast slopes. In addition, flat lowland areas contain only a modest amount of gray in the interest of overall lightness. How I draw small-scale shaded relief artwork takes a stylistic cue from the appearance of digital relief rendered at large scales (Figure 3, right).

4.5 MAP SCALE

Shaded relief and map scale have an elastic relationship. To determine which map scales most benefit from manual shaded relief depiction, I inspected digital shaded relief prepared for a National Park Service web-mapping project (Patterson 2013). Focusing on the rugged western United States, I judged that at scales less than Zoom Level 6 (about 1:10 million) the digital shaded relief was too detailed and would benefit from manual generalization (Figure 12). At scales greater than Zoom Level 9 (about 1:1 million) the digital relief generally looked acceptable as is. And between Zoom Levels 6 and 9 lies a gray area where manual enhancements could help depending on the nature of the terrain - higher, more rugged terrain being the most in need of manual touchups. It is important to note that these recommendations are highly subjective, based on my personal preferences and the terrain characteristics of the United States. Landscapes elsewhere in the world may differ.

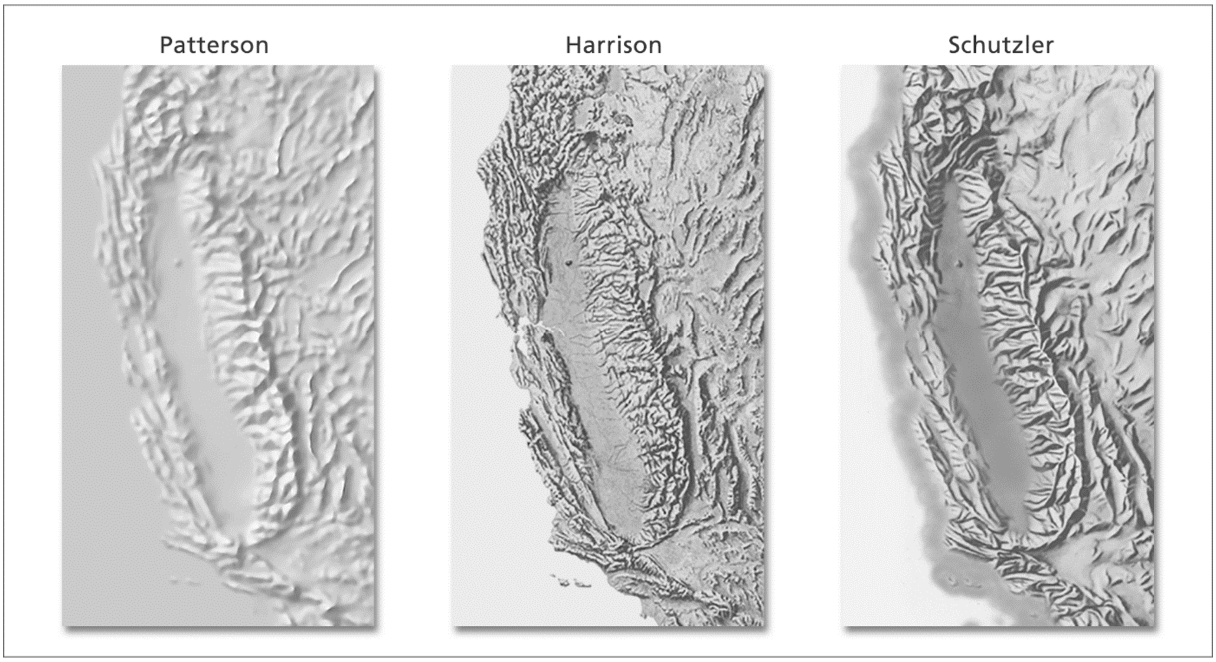

Figure 11: Manual relief artists have different drawing styles. The author (Patterson), influenced by digital relief production, favors brighter illumination and lighter shadows compared to Harrison (1969) and Schutzler (1965).

The two shaded relief pieces that I drew are useable on maps at a range of scales. For instance, although the world shaded relief fits 1:50 million-scale Natural Earth vectors, map scales between 1:40 and 1:100 million looked acceptable in test printings. Just how large the scale is depends on your tolerance for generalized relief and the purpose of your map. The final relief art contains more pixels than needed relative to the terrain detail, so image resolution is not an issue at modestly larger scales. Large wall maps viewed from a distance are amenable to the most relief enlargement. At smaller scales approaching 1:200 million, the relief starts to look like a busy texture rather than a terrain depiction. The relief of the contiguous US, prepared for use with 1:10 million-scale Natural Earth, is also usable at a range of map scales.

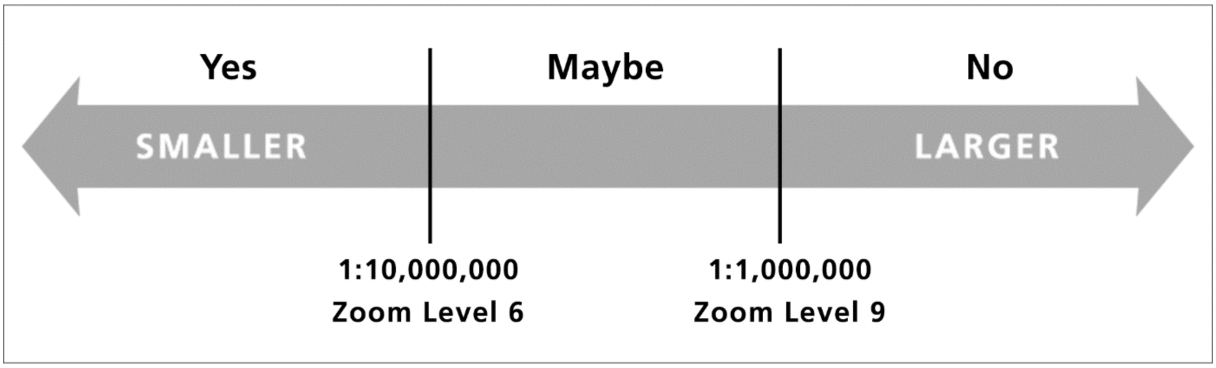

Figure 12: Manual shaded relief enhancements work best at map scales of 1:10 million and smaller.

5 CONCLUSION

Because relief shading by hand takes considerable time and requires skills that a dwindling number of people today have, my work could be among the last of its kind. I do not plan to draw more small-scale shaded relief artwork.

On the other hand, the manual shaded relief pieces discussed here have proven popular online. Users have downloaded the manual shaded relief of the world over 5,600 times since its release two years ago. The manual shaded relief of the US has had nearly 3,000 downloads in one year. Considering that the reliefs are reusable on multiple maps once someone has obtained them, the raw downloaded numbers may underestimate actual use.

Considering the supply versus demand impasse, a need exists for producing automated small-scale shaded relief with appropriate generalization and a pleasing style. With the many triumphs that automation has brought to relief presentation in the last 25 years, small-scale relief presentation remains one of the last major problems in need of solving. I pose this challenge to those of you with a technological bent.

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RELIEF ASPECTS

COMPARING TLS AND ALS CREATED DTM OF KUZLOVEC TORRENT

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ABSTRACT

A rugged torrent of Kuzlovec in Polhov Gradec hills was chosen for TLS (Terrestrial Laser Scanning, also Terrestrial Lidar) surveying in order to obtain a DTM (Digital Terrain Model), to model tree trunks, and to create a reference for hydraulic modelling of the torrent flow. Sequential events, such as sleet and landslides, created the need for a second TLS survey of the same area for comparison of the DTMs. The third TLS survey is compared to the previous TLS survey as well as to ALS (Airborne Laser Scanning, also Airborne Lidar) survey which was performed in the same area. Some aspects of TLS and ALS for terrain modelling are presented.

Keywords: TLS, ALS, Lidar, DTM

1 INTRODUCTION

Kuzlovec torrent is situated in the Polhov Gradec Hills northeast of Slovenia's capital city Ljubljana. The torrent lies in a forested area, formed by steep slopes, rocks and cascades. The gorge of the torrent can be seen in Figure 1.

Figure 1: Orthophoto image of Kuzlovec gorge.

Many changes to the gorge shape have occurred in the past years. Some have occurred due to variable flow of the torrent, some due to other phenomena. A massive sleet happened in February 2014, causing numerous additional fallen tree trunks in the creek bed. Later that year it rained heavily for some days resulting in floods in the area. The gorge turned out to be, although difficult to access (as can be seen in Figure 2), very suitable for research on TLS surveying and modelling and comparing height models of fast changing terrain.

Figure 2: The creek bed of Kuzlovec.

Three TLS surveys in successive years (2013, 2014 and 2015) and an ALS survey (2015) were performed in the most rugged area of the valley floor. Surveys and comparison of the results are described in the following sections.

2 GEODETIC SURVEY AND TLS

2. 1 GEODETIC SURVEY

Coordinates of ground control points (GCPs) have to be obtained to geo-reference the point cloud, generated from TLS. The easiest way to obtain GCP coordinates is by using GNSS technology. We used 3 Leica Viva geodetic GNSS receivers. Because there was no GSM signal in the work area, we had to perform static GNSS measurements. Base points in the forest were surveyed for at least 90 minutes. The results of the survey were very bad, point accuracy was worse than ± 0.5 m. The accuracy obtained is not sufficient to be used for GCPs.

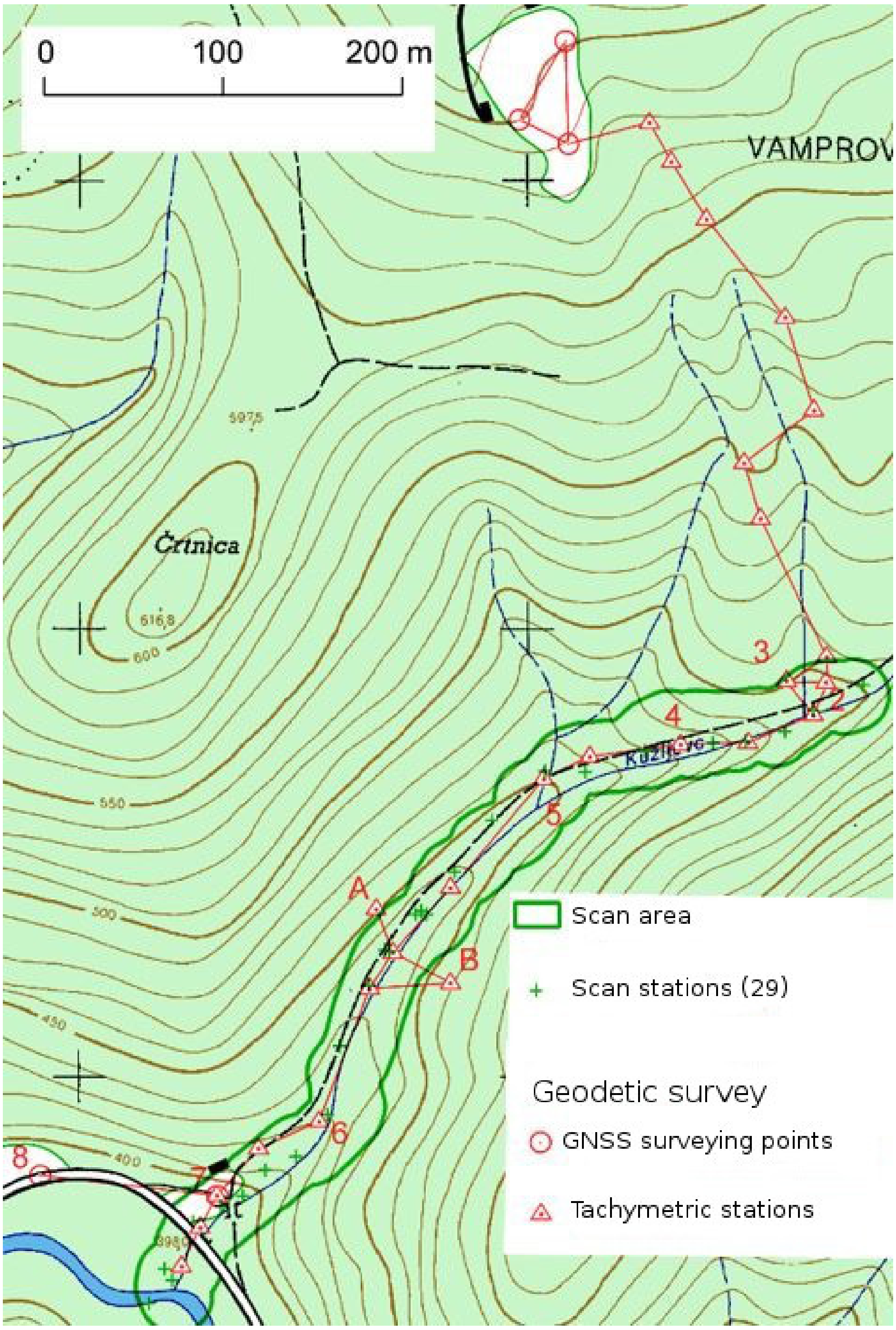

Figure 3: Topographic maps showing the area with geodetic points and scan stations.

A combined GNSS and classical terrestrial geodetic survey was then performed in order to obtain GCPs. GNSS survey was carried out in the clearing north of the gorge, see Figure 3, and at the roadside near the mouth of the torrent. A geodetic traverse using precise geodetic total station was then executed between both GNSS arrays. Horizontal accuracy of ± 3 cm was achieved applying the least square adjustment. Tachymetric stations are marked as triangles in Figure 3. Some lines of sight are very short due to dense vegetation in some parts of the traverse.

Tachymetric stations were temporarily marked, along with some other significant points. All these points were used as GCPs for TLS.

2.1 TLS SURVEYS

Riegl VZ-400 (see Figure 4) with Nikon D700 camera was used for TLS in the initial survey in 2013. Scans were made at 29 stations. Density of the scans was 4 cm per 50 m for riverbed and 8 cm per 50 m for slopes. Standard deviation of points in the point cloud from registration was ±1.5 cm, while absolute accuracy from geo-referencing was ±3.5 cm.

Figure 4: Riegl VZ-400 TLS.

Results of the processed Lidar data were the following:

- DTM (resolution 5 cm),
- Models of tree trunks (not presented in the paper) and
- Model for hydraulic modelling of the torrent flow.

As noted in the introduction, extensive changes occurred in the year 2014. Sleet caused many more fallen tree trunks, there were some minor landslides and high waters remodelled the shape of the riverbed. An example of the changes can be seen in Figure 5. Left image is from 2013, right image of the same area is from 2014.

Figure 5: Change of terrain in one year.

To assess the differences after those events the second TLS survey was executed in August of 2014. We used our scanner which is the same model at the one used before, but our scanner did not have the camera at the time. Density of the scans was 1 cm per 20 m. Accuracy from registration was ±0.6 cm, after geo-referencing it was ±1.2 cm. Scanned area was smaller than in 2013. The lower part of the gorge was altered by man so this part was omitted.

The third survey was performed in April 2015. Not many drastic changes occurred from the previous survey. An ALS was performed at a similar time because we wanted to compare the results of ALS to TLS. Density of the scans was again 1 cm per 20 m. Accuracy from registration was ±1.5 cm, while after geo-referencing it was ±1.2 cm. The scanned area was similar to the previous survey. Some basic information of all TLS surveys is presented in Table 1.

Table 1: Comparison of TLS surveys.

Year	Scan stations	Points surveyed
2013	29	443 mil.
2014	13	259 mil.
2015	12	225 mil.

3 CREATION OF DTM FROM TLS

A basic product of any laser scanning is a point cloud. A DTM can be created from a geo-referenced point cloud using classification to determine the ground points. Afterwards, interpolation with desired resolution is used on the ground points to obtain terrain models. The DTM of 2013 is shown perspectively in Figure 6. Blue colour denotes the approximate position of the stream.

Figure 6: DTM from 2013 TLS.

3.1 COMPARISON OF DTMS

As the same area was scanned in 2013, 2014 and 2015, DTMs of each year can be compared in the mutual area. As it can be seen from Figures 7 and 8, there were two separate streams in a part of the gorge in 2013, while in 2014 there was only single stream in the same part. Note the hill shading is reversed on Figures 7 and 8.

Figure 7: DTM of the mutual area from 2013.

Figure 8: DTM of the mutual area from 2014.

The differences of model heights from 2013 to 2014 and from 2014 to 2015 can be seen in Figures 9 and 10, respectively. Red colour denotes loss, while green indicates accumulation of the material. The differences go even beyond 2 meters.

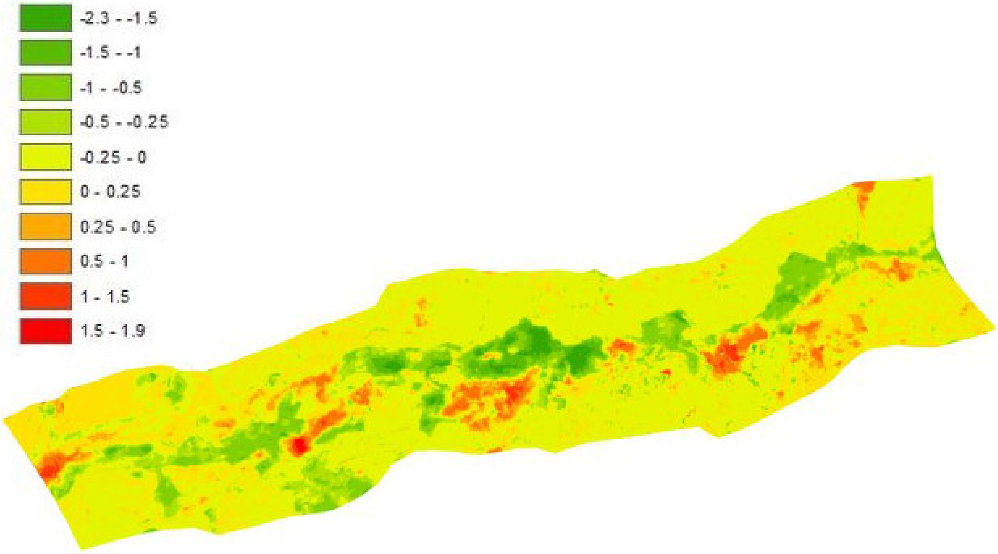

Figure 9: Differences of DTMs 2013 – 2014 (in meters).

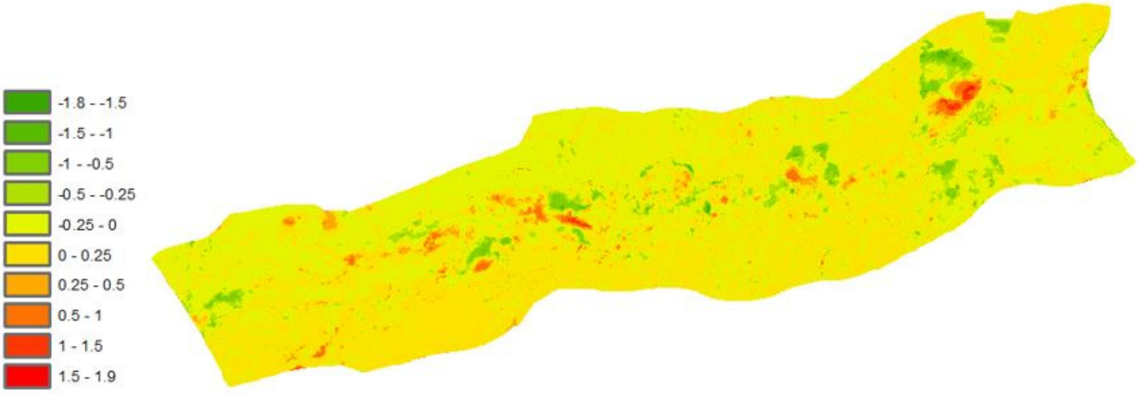

Figure 10: Differences of DTMs 2014 – 2015 (in meters).

4 ALS OF THE AREA

In March of 2015 an ALS survey was performed in the area of Kuzlovec torrent. The helicopter-based survey was done by the Slovenian company Flycom. Density of the scan was 50 points/m^2. A DTM of 25 cm resolution was derived from classified ground points. A perspective view of the ALS-derived DTM is shown in Figure 11.

Figure 11: DTM from ALS.

4.1 COMPARING TLS AND ALS

The differences of terrain heights from ALS and TLS, presented in Figure 12, which range from – 2 to + 1.5 meters, are not results of actual terrain change. There could be some minor changes, but not of this magnitude. Both surveys were performed close in time.

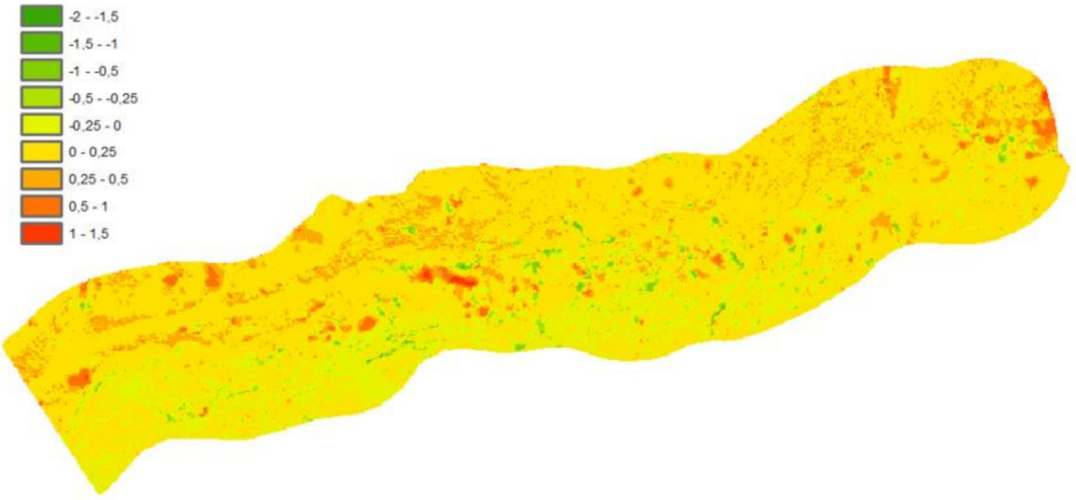

Figure 12: Differences of DTMs from TLS and ALS (in meters).

Such discrepancies might be the result of different processing tools. The ALS data was processed with professional, therefore more robust software, and there were some nonremovable anomalies present in TLS results.

When comparing ALS and TLS in general, there are some obvious specifics:

- Price: TLS is cheaper for smaller areas, ALS for larger areas.
- Equipment: ALS is much more expensive (scanner + INS + GNSS, calibration).
- Ground control points: Not necessary for ALS, can be used for quality improvement; necessary for TLS.
- Once started, ALS is much quicker and covers larger areas.
- TLS can reach hidden spots, which are not visible from the top.
- Limited use of ALS in forested areas (penetration of laser beam through vegetation).

5 CONCLUSION

Lidar data from ALS is very suitable for terrain modelling. It can provide very accurate DTMs with high resolution. It's very efficient time-wise and effort-wise. As can be seen from previous sections, even TLS can be used for DTM creation, but some limitations have to be considered.

When creating a DTM from a point cloud, the operator should be careful in classifying ground points. Another fact remains; the equipment is very expensive.

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RELIEF ASPECTS

THE CREATION OF RELIEF MODELS OVER TIME - DEVELOPMENT, USAGE, PERSPECTIVES AND TRENDS

A COMPARISON BETWEEN ANALOGOUS AND DIGITAL RELIEF MODELS IN ALPINE AREAS

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ABSTRACT

The focus of this paper is to examine various methods of relief model creation. Over time different analogous as well as digital approaches have been utilized that document the broad variety of techniques. Relief models of Alpine areas can be dated back all the way to the 16th century (Gygax 1937). As time passed, not only the materials used for generating such models have changed but also the production techniques. In the past centuries the only way to create relief models was by hand. Nowadays digital terrain models utilizing computer-based techniques are in use. However the results are not only tactile models but include also a wide range of other virtual products.

Toni Mair (1940-2015) once said: "…even in the last phase of creating relief models, man is superior to the machine" (Mair 2009). But is this still true today? Can computer-generated 3D printer models already compete with the high quality handmade models created e.g. by Charles François Exchaquet (1746-1792), Joachim Eugen Müller (1752-1833), Charles-Eugène Perron (1837-1909), Albert Heim (1849-1937), Xaver Imfeld (1853-1909), Simon Simon (1857-1925), Carl Meili (1871-1919), Karl Wenschow (1884-1947), Joseph Reichlin (1872-1927) and Eduard Imhof (1895-1986)?

This contribution, by example of selected famous and impressive relief models of the past centuries, will try to find out whether state of the art techniques can bear comparison at all with past techniques. The overall aim is to analyze the historical, current as well as evolving manufacturing methods in order to find out the optimal method for creating relief models today.

Keywords: relief models, terrain models, analogous techniques, digital techniques, 3D printing

1 INTRODUCTION

Ever since the 16th century mountainous areas have been depicted in form of terrain models. The relief replica of the Innerschweiz (also known as Urschweiz) created by Franz Ludwig Pfyffer von Wyher (1716-1802) between 1762 and 1786 is regarded to be as one of the oldest and best known still preserved terrain models of Switzerland. From a surveyor's perspective, Pfyffer's work is highly accurate, bearing in mind that this model was manufactured almost 100 years before the first modern map of Switzerland was created by Guillaume-Henri Dufour (Niederöst 2002). The relief model was based on first-hand observations and measurements that served later as a source for the construction of maps. Approximately in the middle of the 19th century this production process however changed. Relief models were then made by the help of maps and geodetic data. Based on map contour lines terraced models were constructed and modelled with plaster. Over time not only different materials were used for modelling, but also the manufacturing methods changed. At the beginning, terrain models were exclusively made by hand. Meanwhile they can be created completely without any manual input - among other nowadays by means of 3D printers.

However, Toni Mair (1940-2015) described these computer-generated models as "… amateurishly simplified, strongly exaggerated, unnaturally painted maps …" Furthermore, he stated: "If the relief maker speaks about the weaknesses of computer-generated models, he receives the same answer again and again - the system is being refined and the representation constantly optimized. Well, one has heard this already for 40 years. However, no noticeable improvement has occurred till now… Even in the final phase of creating relief models, man is superior to the machine" (Mair 2009). Therefore the question arises, what is the situation almost 10 years later? Can computer-generated models from a 3D printer compete with the high quality handmade models created for example by Xaver Imfeld (1853-1909) produced in 19th century?

Before analyzing relief models in general it is important to focus on common terms from a cartographic perspective. Existing and former construction techniques can therefore be characterized and subdivided into analogous and digital methods that will briefly be characterized in this contribution. In conclusion selected relief models will be analyzed and compared.

2 MAP-RELATED REPRESENTATIONS

Since the beginning of relief model creation attempts have been undertaken to represent the earth’s surface by means of cartographic representations in a realistic and natural fashion. Starting with two dimensional illustrations, such as topographic maps, that depict the earth's surface in a very abstract way, a wide range of so-called map-related representation techniques were developed to communicate 3D reality in a comprehensible way. These techniques can be subdivided into planar (two-dimensional) and elevated (three-dimensional) depiction methods (Hake et al. 2002).

Maps, aerial and satellite images, panoramas, block diagrams, axonometric perspectives, profiles as well as cartographic anamorphosis are amongst other methods assigned to planar (two-dimensional) map-related representations. However, these representations depict the earth's surface only in a two-dimensional fashion. Information, such as streets, paths, settlement areas, rivers, glaciers etc. can be easily extracted and interpreted however terrain extraction is often very tedious. Furthermore not every user has the ability to obtain and interpret the third dimension correctly. Therefore in order to assist the user, the systematical reproduction of terrain is in many cases mandatory. This can be accomplished by the use of relief shading, anaglyph images, stereo images, holography, animations or even virtual reality scenes. The mentioned methods however only resemble a two dimensional representation that communicates a 3D impression. Even stereo images that give the user an appealing virtual 3D feeling can lead to deceptions or misinterpretations due to unforeseen visual effects. The accurate interpretation of stereo images depends therefore highly on key factors such as the observation standpoint as well as light direction and intensity. Beside these facts, not everybody is able to perceive stereo images as a 3D depiction.

Figure 1: Detail of ÖK50 (Austrian topographic map 1:50,000 – not to scale) © BEV: www.austrianmap.at

So-called elevated map-related representations can be regarded as true 3D. These forms of expression are superior to planar 2D depictions. They primarily include globes as well as relief and terrain models. They can be viewed from all directions and do not restrict the observer.

In addition, globes are completely free of distortion. However they unfortunately only embrace small scales. On the other side, relief and terrain models can also encompass larger scales (Arnberger 1966, Imhof 1972).

Relief and terrain models represent a three-dimensional, generalized reproduction of a defined portion of the earth's surface. They can be viewed from more or less all directions and are independent of changing illumination. One of the key advantages is however that the point of observation can be changed much faster and easier than in reality. Therefore, these models can be regarded as one of the most coherent cartographic forms of representation for three dimensional phenomena. When comparing a 2D map with a true 3D relief model it can be clearly observed that the third dimension with all its peculiarities needs no abstraction and that a very natural bird’s-eye view of the earth’s surface is proclaimed (Figure 1 and Figure 2).

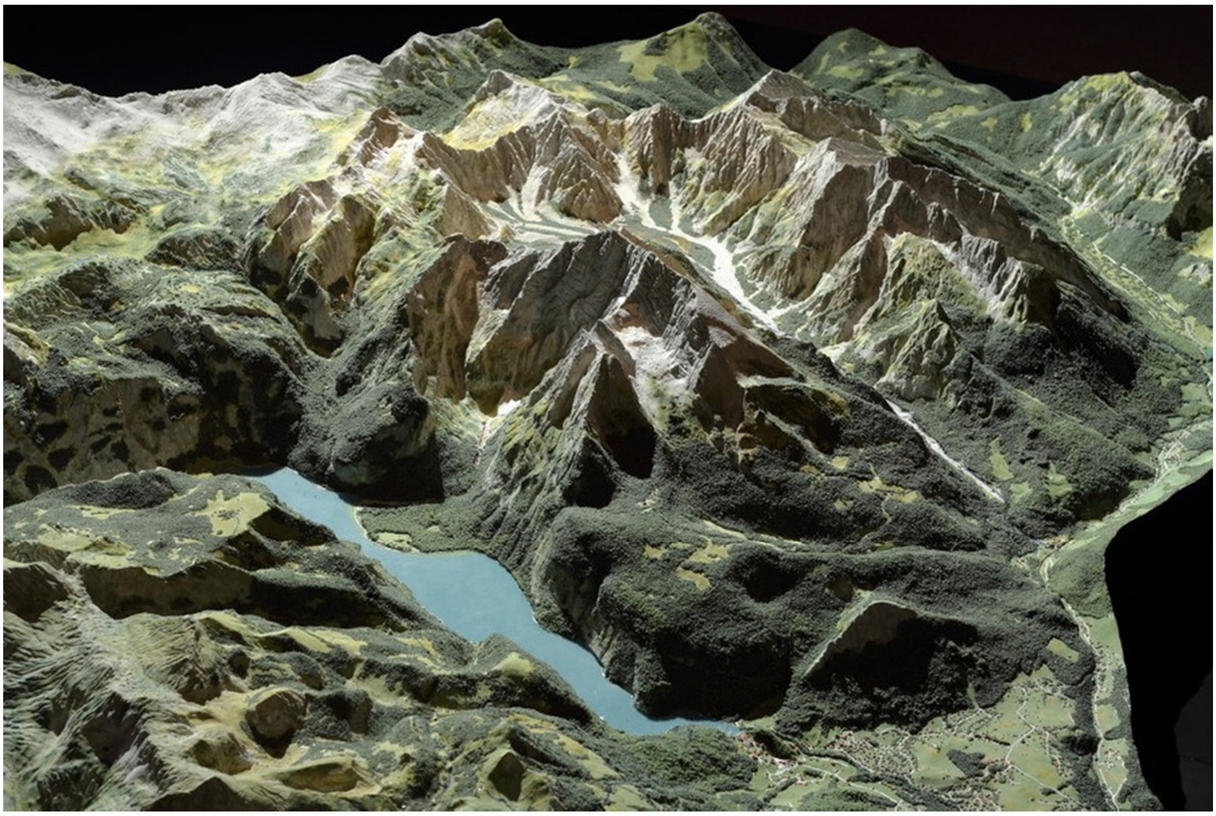

Figure 2: Pusch Wolfgang, Berchtesgadener Alps, scale: 1:10,000, dimension: 300 x 290cm, viewing direction: South-West © www.bergmodelle.de

The term relief originates from the French language and means “sculptured elaborated picture”. In a geographical sense it embraces all the continental and marine forms as well as all differences in elevation and slope between higher and lower parts of a surface.

In literature the terms “terrain relief“, “landscape relief“, “terrain model“, “landscape model“, “relief model“ or “landscape relief model” are frequently assigned equivalently. Mair uses the term landscape relief model and defines it as a “…concrete three-dimensional realistic representation of a landscape, which conforms in scale, in form of the morphology and in geographical contents to reality, or which illustrates the geology” (Mair 2012).

In former time reliefs served initially as a basis for map construction, military purposes or boundary surveys. Today they are used in schools and universities or are displayed in public space as eye catchers in exhibitions, museums, tourist facilities or national park visitor centers.

However, due to physical inconveniences such as weight, dimension and especially the time consuming construction they are rarely suitable for long transportation as well as mass production. Therefore they primarily serve as art objects and showpieces (Mair et al. 2006).

3 MANUFACTURING METHODS

Since the 16th century various construction methods are being pursued. Many of them have been slightly adjusted by the relief builder over time. Not only to improve the operational procedure but also to emphasize the individuality of the creator. Therefore a vast variety of different techniques are currently known. These manufacturing procedures similar to the above described map-related representations are subdivided into analogous and digital methods. In addition the analogous manufacturing methods can be further distinguished in manual and mechanical techniques, which get by without any digital workflow. Relief models made by means of digital methods, are based on digital data and/or computer-assisted construction methods. The following table gives an overview of the predominant techniques since the 16th century (Table 1).

Table 1: Manufacturing methods since the 16th century adapted from Caldwell (2001), Imhof (1972) and Mair (2006).

MANUFACTURING METHODS		
analogous	manual	wood carving
		formed with different materials
		metal pins and nails
	combination	contour lines
	mechanical	vertical lines/profile lines
		pantograph
		Wenschow method
digital	additive technologies	selective curing
		selective sintering
		aimed deposition
		bond-first pattern lamination
	subtractive technologies	computerized numerical control milling machine
	formative technologies	vacuum

3.1 ANALOGOUS TECHNIQUES

One of the first methods to create a terrain model was to carve the landscape out of a piece of wood by hand. The oldest still preserved relief model of an Alpine area was produced this way. It was presumably commissioned by emperor Maximilian I (1459-1519) due to boundary disputes and created by Paul Dax (1506-1561) in the year 1540 (Bühler 1941) according to Zemann 21 years after Maximilian's death (Zemann 1986). Dax's fieldwork that took place between 1544 and 1554 was located in the Bavarian-Tyrolean border area. Thus, his authorship seems assumed but not proven. The mentioned relief is a model of the "Wettersteingebirge" (Figure 3). Dax's first-hand measurements and field campaign served as basis. The model was carved out of wood and then linen was glued on the model. Afterwards the canvas was painted scenically and single trees out of wire were included (Gygax 1937). In addition, paper strips with settlement and mountain names were stuck on the model (Figure 4). According to Gygax (Gygax 1937) the valleys and main mountain ranges, which are represented by rounded embankment-like structures, show astonishingly exact terrain features. The relief model covers the area from the "Zugspitze" to the "Ferchensee" and has a dimension of 170x70 cm (in the broadest place). The scale is approximately 1:10,000 (Alpenverein 2017).

Based on Franz Ludwig Pfyffer von Wyhers field work, observations, measurements, plans and sketches, he modelled the relief replica of the Urschweiz between 1762 and 1786. He used all kinds of material for the modelling process. For the shape of the landscape he used among other things wood, charcoal, brick fragments, cardboard pieces, loam, plaster and wax. The surface was modelled from sand and plaster on which he poured wax. This allowed him to work in greater detail. He used natural rock fragments for the peaks. To be able to transfer the form of the landscape to the model he used a square grid which was drawn on the basic board. With vertical round timber sticks he marked the course of the mountain ranges (Niederöst 2005:157, Gygax 1937).

Figure 3: Wetterstein, scale: 1:10,000, relief model, wooden foundation covered with a strengthened canvas, painted, dated: ca. 15th/16th century (probably the oldest relief of the Alps), dimension: 170x70 cm © Alpenverein-Museum, ÖAV Art/2823.

Figure 4: Detail of Wetterstein model: trees, field and mountain names on paper stripes © Alpenverein-Museum, ÖAV Art/2823.

The method of the round timber sticks was then adapted over time by nails and metal pins. The length of the used nails was adjusted to the height of the elevation. The gaps between the nails and pins were then filled out with all sorts of material and the surface of the relief model was then formed manually (Terrain Models 2017).

The oldest official map series of Switzerland, the "Dufourkarte" was published between 1845 and 1865. At that time, the terrain was depicted by means of hachures. As of 1870 for the first time contour lines were used in the "Siegfried-Atlas". The precision of the terrain models resulting from such maps increased. With the help of such contour lines, terraced models were built. So-called step/layer models were made. These were then filled with plaster to produce a mold that served as a reusable cast for the construction of terrain models. One of the most well-known representatives of this time was Xaver Imfeld. Since then, contour lines are not only used in the manual/analogous relief production, but also machine or computer-assisted methods make use of them as well (Mair et al. 2006).

Apart from contour lines also vertical lines, such as profile lines, were introduced in the relief building process. According to Imhof (Imhof 1972), the raw form of the model can be produced through parallel, densely stacked equidistant profile plates - similar to terraced models based on contour lines. The manual construction process was however very time consuming therefore mechanical manufacturing procedures became more important (Arnberger 1966, Imhof 1972).

One of these methods was conceived by Karl Wenschow in Munich after the First World War. He constructed a relief carving machine (similar to a pantograph), with which the contour lines were traced. A connected milling device then cut a terraced model out of a block of plaster. Prior to this process the contour lines were etched into a zinc plate to generate a guidance groove that secured higher accuracy. The milling head was arbitrarily adjustable in the z-axis and started removing material from the highest altitude downwards. Finally, the manual morphologic revision of the terraced model was carried out by means of engraving knives (Arnberger 1966, Imhof 1962, 1972).

However, one of the most common methods today is still to create a terraced model manually. Copies of the contour line are glued on a plywood plate. The size and thickness of the plates depends on the scale of the final model. The plywood sheets are then cut along the contour lines either with a manual jigsaw or an electrically operated saw (Mair et al. 2006). The individual elements are then arranged to a layer model. Subsequently, a negative mold is produced out of silicone rubber that serves as a basis for the creation of a positive plaster model. The morphologic forms are then carved into the plaster cast. Aerial images, maps and photographs serve as templates. Finally, the finished model is painted (Mair et al. 2006). Toni Mair brought this technique to perfection and describes in „Das Landschaftsrelief (2006)" in detail the construction of such relief models (Mair et al. 2006).

3.2 DIGITAL TECHNIQUES

In order to obtain high-quality results with the above described manual manufacturing methods experience paired with expenditure of time as well as substantial financial investment is required. Therefore new efficient automated procedures are being pursued that try to ease and simplify the workflow. Caldwell (Caldwell 2001) gives an overview of these automated procedures, which can be subdivided in additive (filling), subtractive (removing) and formative (modifying) technologies. These techniques can be summarized as rapid prototyping (also called 3D printing), a method to quickly produce a scaled model utilizing 3D computer aided design (CAD) data.

While the additive technology adds material to create a model, the subtractive technique carves material away from a solid block and the formative technology works with counter pressure. Nowadays, subtractive and additive methods are mainly in use, however higher accuracy is gained with the additive technology opposed to the subtractive approach (Caldwell 2001). The greatest difference compared with the methods used by Imfeld, Wenschow or Mair (besides the fact that they are analogous approaches) is the usage of the input data. While the former methods are based on analogous maps, the computer generated models utilize digital terrain models (DTM) (Caldwell 2001).

Computer numerically controlled (CNC) milling belongs to the subtractive technology and cuts away material from a solid block that consists mainly of synthetic foam. Depending on the drill head other material such as wood, metal or composite materials can be processed (Caldwell 2001).

According to Caldwell (Caldwell 2001) additive technologies can be classified in selective curing, selective sintering, aimed deposition as well as bond-first pattern lamination. A liquid synthetic resin is used for the selective curing technology, which hardens under laser light. Stereolithography, a special type of selective curing, was one of the first additive methods. In the following chapter a relief model based on this technology will be analyzed. On the other hand, the selective sintering method uses pulverized material instead of liquid synthetic material. The powder consisting of synthetic material, metal or ceramic, melts through heat exposure and then solidifies. During the so-called aimed deposition procedure, an inkjet printer creates the model. Thereby a nozzle sprays thermoplastic material drop by drop. The bond-first pattern lamination method builds up the model in layers. A laser cuts the shape of the model out of a sheet of paper or a plate made of ceramic or synthetic material. Another layer which is cut to size by a laser is then attached. Each and every layer is cut along the assigned contour line. The edges of the individual layers are then burned by the laser and change their tint to a brownish color. Thus, the observer sees steep areas darker opposed to the lighter flat ones (Caldwell 2001).

In the following chapter two selected relief models, which were created with different manufacturing methods (analogous and digital), will be analyzed and compared. The first relief to be examined was manufactured manually by Xaver Imfeld according to Imhof (Imhof 1981) in the golden age of relief making (1870-1914). A terraced model based on contour lines served as foundation. This method is still in use today and represents the most accurate manual manufacturing method. The second terrain model described, was generated by a 3D printer approximately 100 years later. Thereby the procedure of stereolithography was consulted. This example that was produced in 1998 was constructed using primarily computer-based technology. The only manual workflow was the colorization process. Today this method of stereolithography is still in use.

4 ANALYSIS

Xaver Imfeld was one of the most talented topographers of Switzerland. He not only created impressive terrain models, but also painted beautiful panoramas and collaborated on the Siegfried-Atlas of Switzerland. This map series was the first that contained height information in form of contour lines. Imfeld finished his model of the Matterhorn in 1896. Map sheets of the Siegfried-Atlas together with several 100 geodetic points, which were determined trigonometrically and photogrammetrically, served as data basis (Gygax 1937). At first he cut layers out of cardboard along the contour lines of the map and piled them up to generate a terraced model. The geodetic points were then marked with metal pins. After that he modelled the shape of the terrain with cement and the fine structures with plastilina clay. In order to achieve the appropriate results he used photographs and landscape drawings as templates. Subsequently he created a plaster cast of the model and gave it a finishing touch by carving the finest structures in the plaster.

From this original model he created several plaster casts and colorized them (Gygax 1937). One of these casts was compiled in 1903 and is in possession of the Austrian Alpine Club museum in Innsbruck (Figure 5). The model was built at a scale of 1:5,000 and measures 96 cm by 140 cm. Imfeld created the model initially to promote the Matterhorn mountain railway. In addition to that, he also sold paperweights of his model (Mair et al. 2006). Imfelds teacher, Albert Heim, described this model as “a landmark in the history of topography” (Mair et al. 2006).

The model is covered with many details and maintains a high level of precision. According to Gygax it is amongst the most accurate and most impressive models that were ever constructed in those days (Gygax 1937). Examining the relief model more closely, it can be observed that the forests and trees are built out of small plaster grains and colored dark green. Other terrain features such as meadows are colored in a lighter green with a tinge of brown and yellow (Figure 6). Besides the trees, also a hut was reconstructed with plaster and colored in brown (Figure 7). Waterbodies are colored blue. A small pond was painted onto the plaster model and streams were carved into the plaster and also colored blue. The glacier has a white tint with a touch of blue and grey that looks as if it is flowing down towards the valley. Figure 8 shows some ice falls and crevasses, which were carved in the plaster. The edges were contoured in blue for a more natural and realistic look. The rocks are depicted slender and colored brownish with a tinge of violet in some sections.

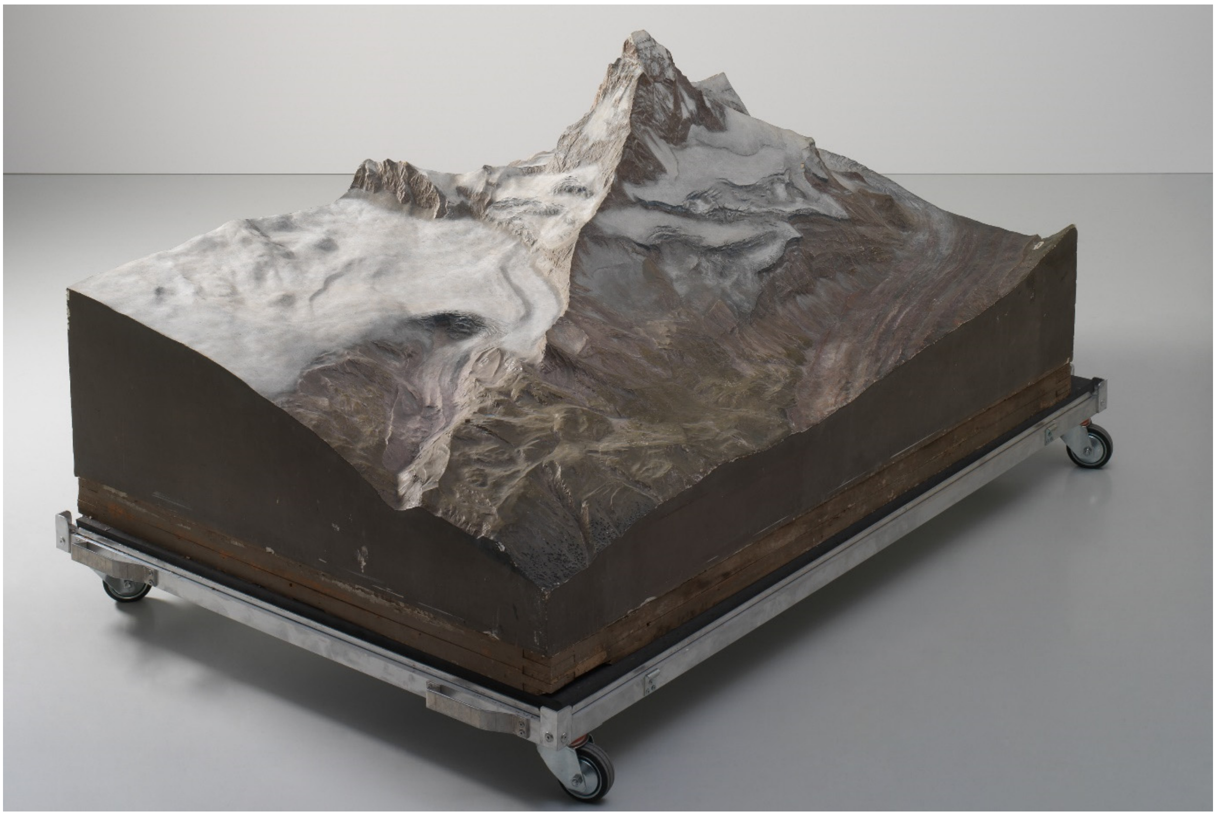

Figure 5: Imfeld Xaver, Matterhorn, scale: 1:5,000, Relief, technique: plaster, painted, 1903, dimension: 96x140.5 cm © Alpenverein-Museum, Österreichischer Alpenverein/2757.

Figure 6: Detailed view of trees out of plaster © Katharina Biedermann 2016.

Figure 7: Detailed view huts and glacier © Katharina Biedermann 2016.

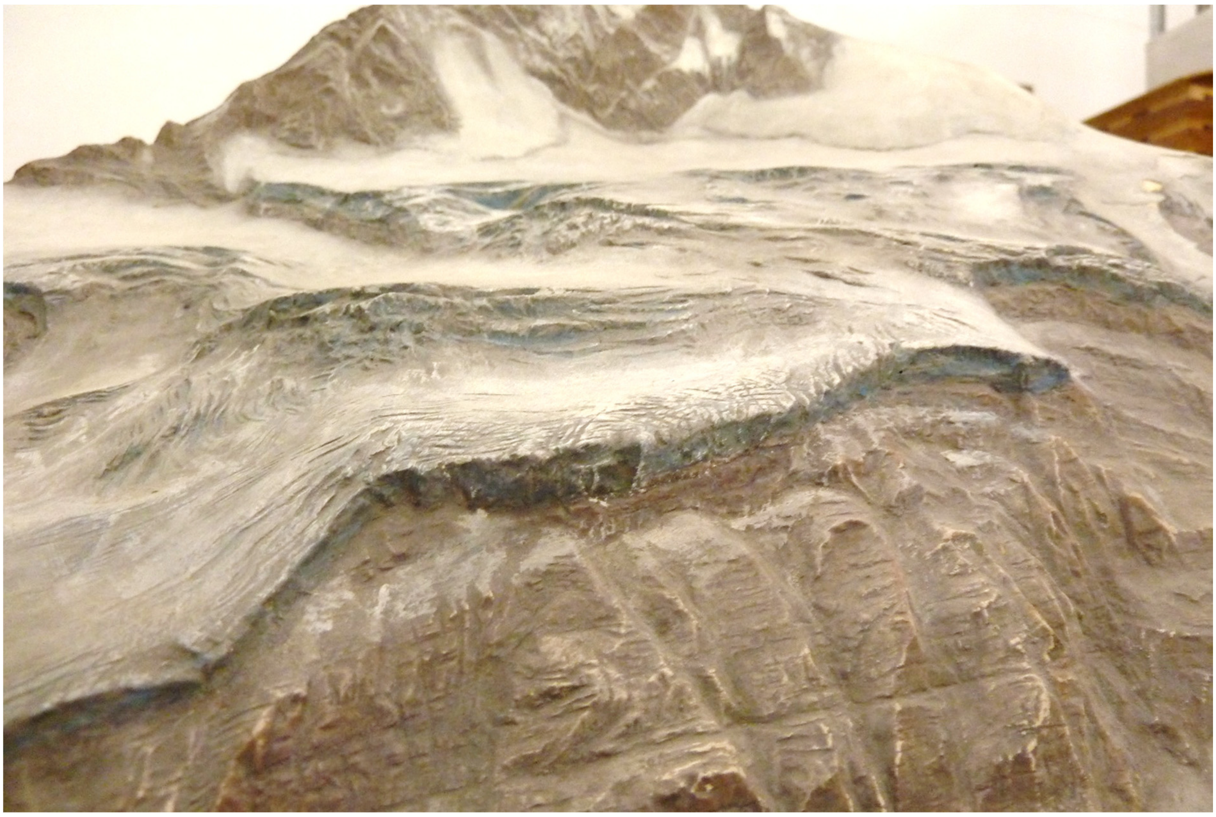

Figure 8: Detailed view ice falls, crevasses and rocks © Katharina Biedermann 2016.

The second examined terrain model represents the Eiger at a scale of 1:12,500 (Figure 9). This model was produced by Mika Semann in the course of his diploma thesis at the Polytechnical University in Karlsruhe, Germany, in 1998. He created it with rapid prototyping (an efficient method utilizing CAD data) with a digital terrain model as input. This model was generated through stereo imagery accessing about 200,000 measured points from aerial images of the Swiss Federal Office of Topography. The resulting dot matrix and break lines as well as ground points were then put together to generate a digital terrain model (Semann 1998, Hell 1999).

Due to the fact that some areas were concealed on the aerial images, the DTM had to be improved applying terrestrial photogrammetry (Semann 1998, Hell 1999). The model was subsequently transformed to a Triangulated Irregular Network (TIN) and then converted into a stl-file for 3D plotter usage. The construction of the relief model itself took about 28 hours utilizing the procedure of stereolithography. Thereby series of layers were added on top of each other, while the worktable was gradually lowered. This additive 3D printing method uses a liquid photopolymer, which hardens under ultraviolet light. As soon as one layer dries the next layer is added. This technique is also called selective curing. After the terrain model was constructed it had to be put into an oven for post-curing since the model only hardens to 95% under UV laser treatment. The finished terrain model possesses a layer thickness of 0.15 mm and measures 50 cm by 20 cm. This was also the maximum size, which the plotter was able to create (Semann 1998, Hell 1999).

In order to visualize rock structures or small morphological features they had to be larger than 5 to 8 meters in nature due to scale constraints. The only manual intervention on this computer-generated model was the colorization (Semann 1998, Hell 1999). Figure 10 shows the cured raw model. The layers and honeycomb-like structures are clearly visible. However due to the manual paintwork the distracting structures are not so dominant (Figure 11). Since only a few points on the glaciated areas could be measured photogrammetrically the terrain there had to be interpolated in order to construct the DTM – which is also clearly visible on the finished model. Furthermore vertical areas such as rock faces feature less details (see Figure 12: center, on the left) opposed to flatter terrain.

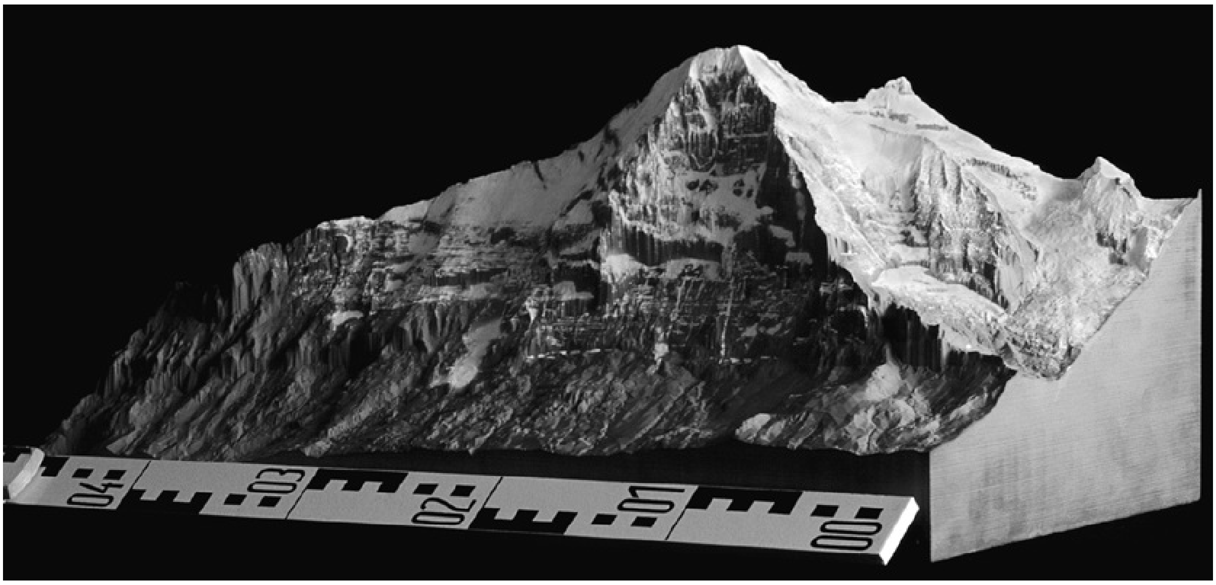

Figure 9: Relief Model Eiger, scale: 1:12 500, 1998, dimension: 50x20 cm © Mika Semann.

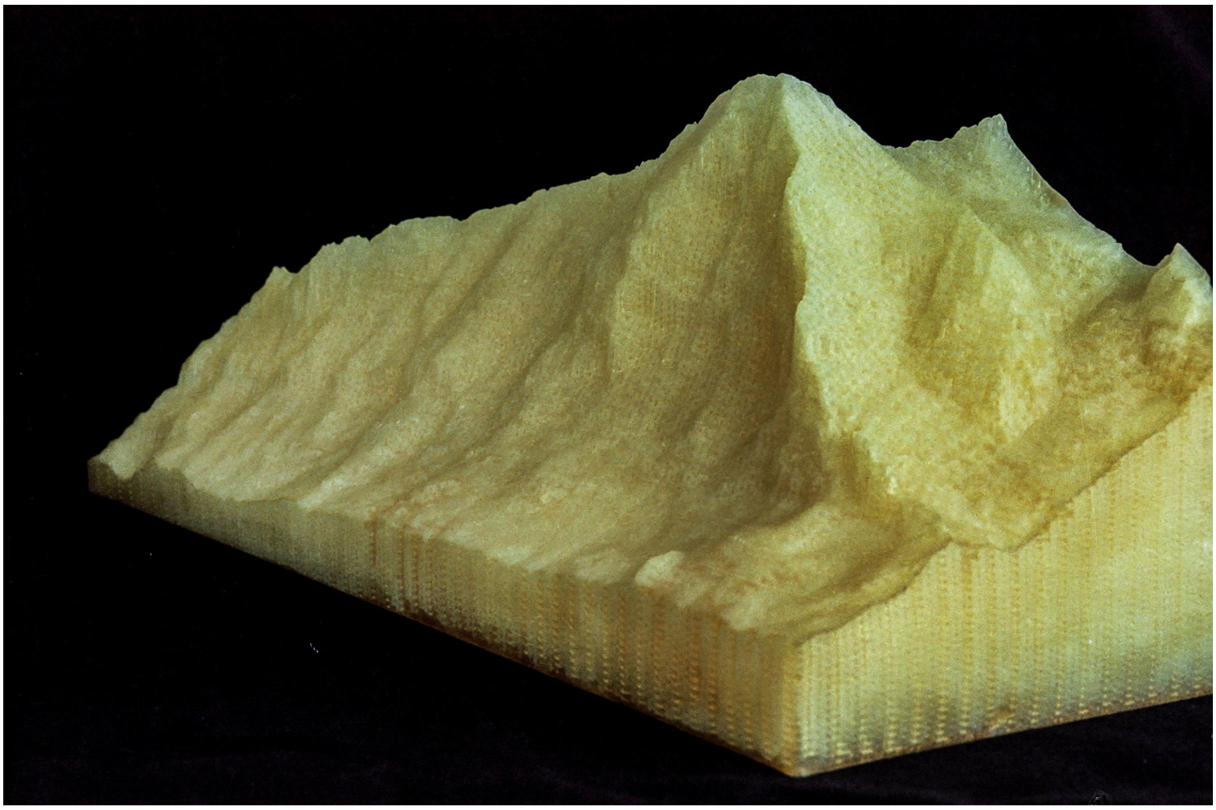

Figure 10: Raw Model © Mika Semann.

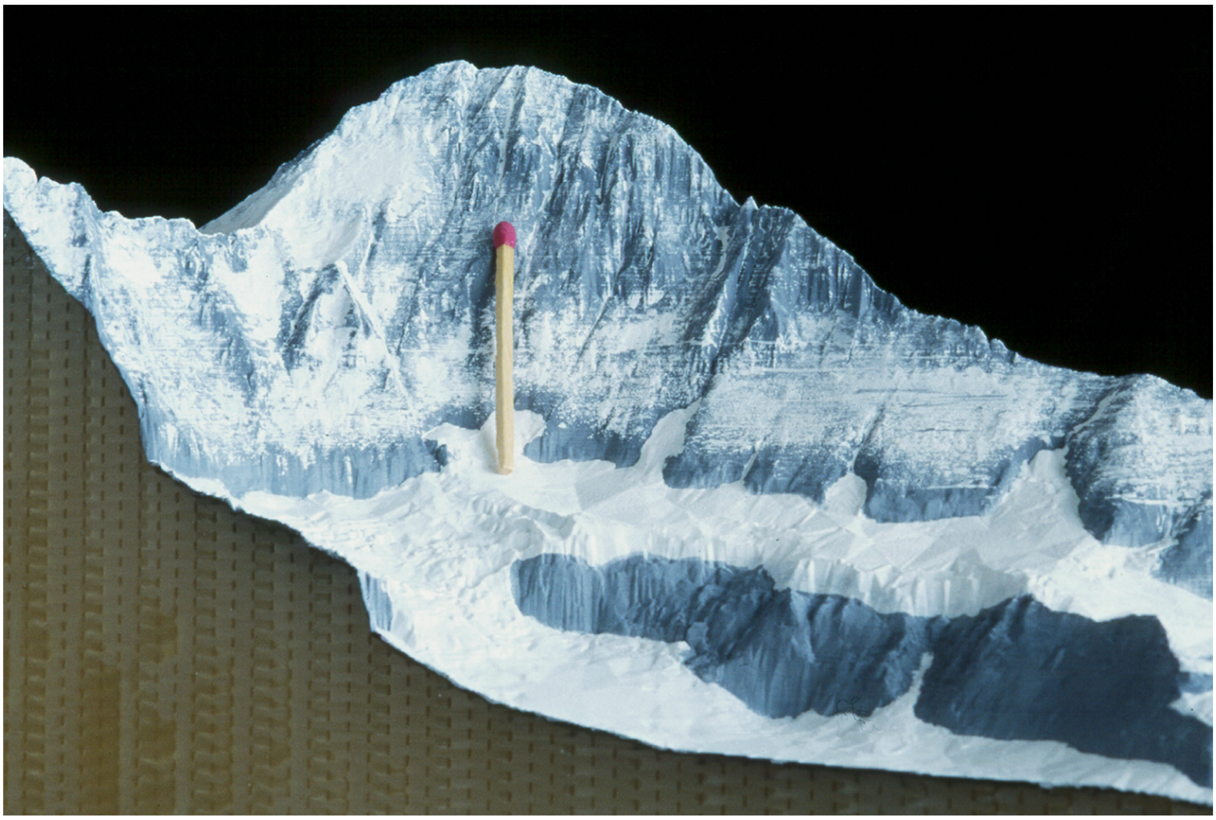

Figure 11: Painted Modell © Mika Semann.

Figure 12: Detailed view of the Eiger north face © Mika Semann.

Comparing the advantages and disadvantages of the two manufactured models differences concerning the data basis, material, technique, resolution and accuracy can be detected. Imfeld used contour lines from analogous maps as well as points from a geodetic survey, photographs and drawings as data basis. On the contrary Semann took advantage of a digital terrain model based on aerial images. Imfelds final replica of the Matterhorn was made out of plaster. However additional materials such as cardboard, metal pins, cement as well as plastilina clay were necessary for the raw model before a plaster cast could be produced. Semanns Eiger model consists of photopolymer and does not need any "pre-models" or casts. Imfeld constructed his relief completely manually. The Eiger model was generated entirely computer-based except for the coloring that was carried out manually. Imfeld was able to carve fine rock structures as well as crevasses into the plaster with his engraving knives. Compared to that the Eiger model appears to be a bit coarse due to the fact that it can only depict structures not smaller than five to eight meters in nature. Due to this fact the level of detail depends on the resolution of the DTM. The manual manufacturing process is currently still superior to the rapid prototyping procedure as related to the resolution and the level of detail. However, Semanns computer-based Eiger model shows a higher geometric precision. Keeping in mind that higher and more accurate DTMs are becoming available the level of detail for computer-based relief manufacturing is increasing. However there will be need for model generalization to preserve the global structural view on the one side and on the other side the integration of fine structures that are present in high-accuracy DTMs.

5 SUMMARY AND OUTLOOK

Every method has its own characteristic features that manifests advantages as well as disadvantages. However the classic manually produced plaster terrain models still have a higher optical appeal and fascination compared to digitally constructed 3D printer models even though these computer-based representations display higher geometric accuracy. Imhof once described these manually produced "plastic reliefs" as "monstrosities of a bad topography" (Imhof 1972), but there is no question that this is not true today. These computer-based techniques are primarily suitable for mass production of cost-efficient models. For example, a negative cast can be easily printed and then manually refined. However, the currently available 3D printing methods are not suitable yet for the creation of individual high-quality reliefs, such as the models created by one of today's most famous and talented relief builders, Wolfgang Pusch (Bergmodelle 2017a).

Figure 13 shows a model of the Matterhorn at a scale of 1:50,000 (10x10cm) created by Pusch utilizing the current rapid prototyping method. Layering that is produced by the 3D printer is clearly visible. Even if the resolution of the digital data is less than 2 meters, the current rapid prototyping manufacturing method is not yet able to represent moraines or fine rock structures. Therefore the creation of a completely computer-generated high-resolution relief without any manual post-processing does not yet provide the desired results. Almost two decades after the construction of the Eiger relief current 3D printing methods, such as the stereolithography, still show some weaknesses concerning resolution and level of detail.

According to Pusch, there is currently no computer-generated relief model based on digital data, which can keep up with the quality of a handmade terrain model of Xaver Imfeld, Eduard Imhof or Toni Mair that all stand out through accuracy, artistic appeal, impression and detail. The lacking quality therefore forces to work manually. In addition, the time factor is also an issue. According to Pusch, the saved time during computer-aided construction instead of building a terraced model, is needed for data acquisition, manipulation as well as construction of the DTM and manual post-processing of the plaster cast. Therefore, Pusch still relies on the same methods once Toni Mair used. However, he also works digitally primarily in the planning phase defining the area, size and scale of the relief model. On the other hand he generates contour line maps, which are mainly derived from Shuttle Radar Topography Mission (SRTM) data. Currently digital methods offer an excellent supplement to the classic analogous manufacturing approach. A detailed description of this method can be found on Pusch's homepage (Bergmodelle 2017b) as well as in Katherina Biedermanns Master thesis that is currently being finalized.

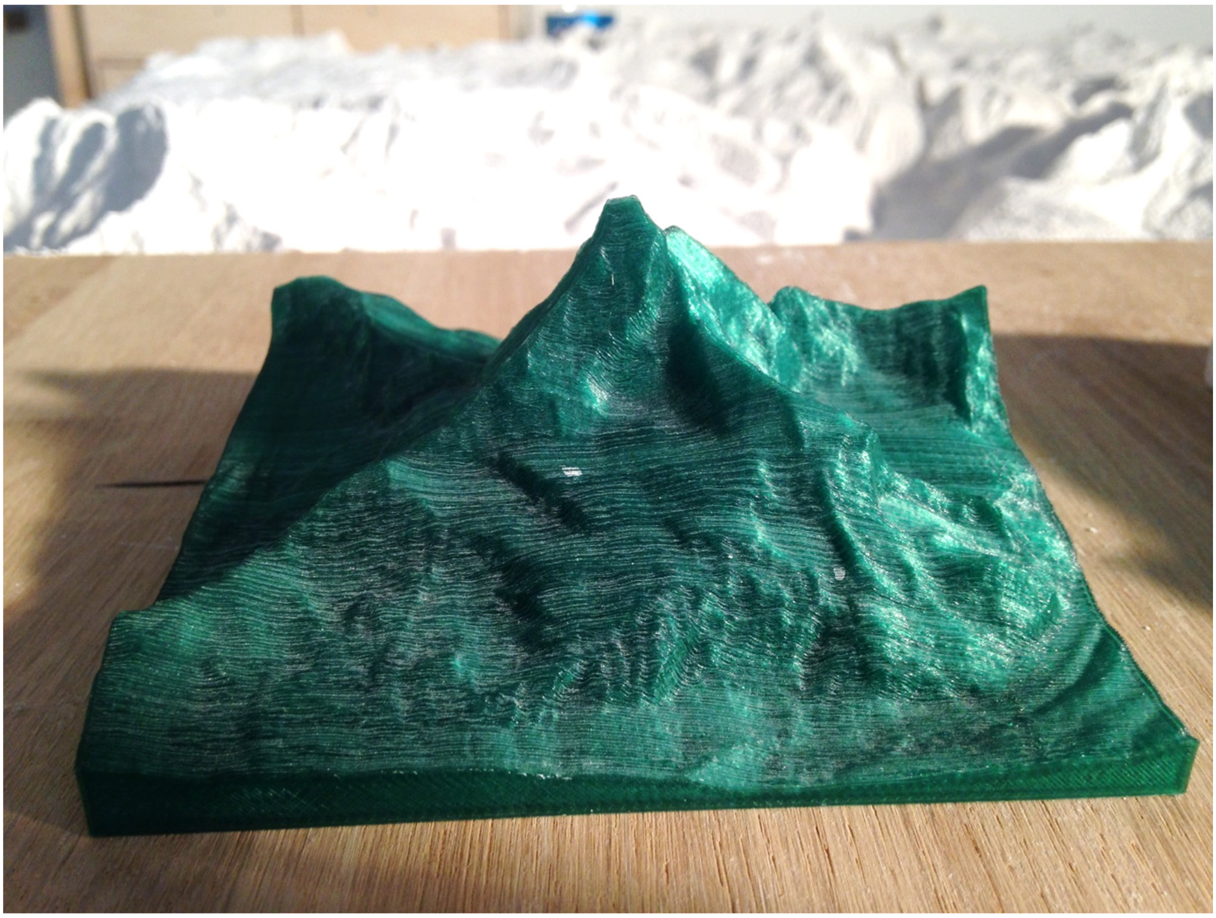

Figure 13: Pusch Wolfgang, Matterhorn, scale: 1:50,000, dimension: 10x10 cm © Katharina Biedermann.

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RELIEF ASPECTS

A METHOD FOR CREATING PAPERCRAFT RAISED RELIEF MAPS FROM DIGITAL ELEVATION MODELS

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ABSTRACT

Raised relief maps provide a particularly intuitive and engaging way to represent topography. Depending on the intended use of the map, different methods are used for producing raised relief maps. These include manual sculpting and painting of plaster models, manual or semi-automatic construction from wood or cardboard layers, and automatic production using a 3D printer. These methods vary in terms of accuracy and realism of the final product, the cost, effort and skill involved in the production, and in the suitability for reproducing different types of topography. In general, the production of raised relief models is either expensive, difficult, or labour intensive.

We present a method for producing low-cost full-colour raised relief maps from digital elevation models (DEMs) by creating a papercraft model of the DEM. The method involves the following steps: converting the DEM to a triangulated irregular network (TIN), unfolding the TIN, printing the unfolded TIN on paper, and assembling the printout into a physical 3D model. This method allows for the production of raised relief maps without the need for specialised equipment or extensive training and experience. The degree of realism of the resulting maps is similar to that of wood layer models.

The quality of the final raised relief model depends crucially on the characteristics of the TIN. We discuss the requirements that make a TIN suitable for use in a papercraft raised relief model and present a novel algorithm for converting a gridded DEM to a TIN that takes these requirements into account.

Keywords: raised relief map, paper model, triangulated irregular network

1 INTRODUCTION

Raised relief maps, also called terrain models or relief models, are the most immediate way to represent topography. In conventional maps, the elevation information has to be encoded in the form of spot heights, contour lines or relief shading, which requires knowledge and experience in order to be decoded by the viewer. By contrast, raised relief maps, as three-dimensional models of the physical landscape, convey the elevation information directly and can thus be understood by the viewer without special training or explanation. It is this immediate representation of physical features and the provision of a bird's eye view that makes raised relief maps so fascinating and attractive.

Merely looking at a raised relief map already fosters an understanding of the topography that would be hard to achieve with topographic maps alone, but going through the process of constructing a raised relief map does even more to enhance the understanding of the landscape and of the map that represents it: Eduard Imhof gives the advice that "at least once in their early years, cartographers, topographers, geographers, and geologists should construct a terrain model based on an interesting contour plan" (Imhof 1982). Today, digital elevation models have taken the contour plan's place as the method of choice for storing and transmitting elevation information, and so the recommendation might now be that at least once should we turn the digital elevation data we are working with into a physical artefact that we can hold in our hands. In this paper, we present a method for following this advice by creating papercraft raised relief maps from digital elevation models.

A vast array of methods for creating raised relief maps exist, varying in accuracy and realism of the final product, the cost, effort and skill involved in the production, and in the suitability for reproducing different types of topography. The website terrainmodels.com provides a good overview of the different methods and showcases a large number of different raised relief models.

Among the most realistic raised relief maps are hand-made plaster models. Professionally made plaster models are mainly used for touristic and educational purposes in museums, exhibitions and visitor centres (Räber and Hurni 2008), where they often form the centre of attention (Buchroithner 2007). The process of creating such models is very involved and takes years to master (Mair 2012), making it infeasible for many applications.

A much faster and more affordable way of creating detailed raised relief maps that has been gaining traction is the use of 3D printers (e.g. von Wyss 2015). Currently, most consumer grade 3D printers can only produce relatively small uncoloured models.

The simplest and most wide-spread type of raised relief map is the layer model or step model, which consists of a stack of thick paperboard or wood layers, each layer corresponding to a contour line on a topographic map. These raised relief maps are popular for use in architectural models, because their production is comparatively easy and inexpensive, and because the resulting horizontal surfaces allow for the simple addition of building models. Layer models are mainly useful for depicting gentle terrain types. For areas with steep terrain and several isolated peaks, the number of layers and layer parts that need to be cut, positioned and glued quickly makes the construction cumbersome.

A different approach for creating physical 3D models without specialised equipment is to cut out pieces of paper that can be glued together to form a hollow body in the shape of the object to be modelled, resulting in a "papercraft" model. In order to use this technique for creating a raised relief map, a suitable representation of the landscape surface has to be found that can be cut from paper sheets. One way to generate such a representation is to use a manifold of triangles approximating the surface, similar to the way 3D objects are represented in computer games. Using only a small number of triangles results in a faceted appearance, the "low-poly aesthetic" that is found in the work of visual artists since the early 2010's, where low numbers of polygons are used not due to technical limitations, but as an artistic technique (Schneider 2014). The work of Timothy Reynolds is an example of this visual style where the structure of the underlying 3D models is deliberately made visible (Figure 1).

a) *Map Wars*, 2013.

b) *Untitled*, 2014.

Figure 1: Examples of "low-poly aesthetic" artwork by Timothy Reynolds, where the individual polygons of the underlying 3D models are deliberately made visible. Reproduced with permission by the artist.

The process for creating a papercraft raised relief map from a digital elevation model consists of the following steps, which will be described below:

- creating a 3D triangle mesh that approximates the digital elevation model
- optionally adding a texture to the mesh
- unfolding the mesh to a 2D representation
- printing and cutting the unfolded mesh
- assembling the cut out mesh into a physical 3D model.

2 CREATING THE MESH

2.1 MESH PROPERTY REQUIREMENTS

In order for the mesh to be suitable for constructing physical paper models, the triangle elements of the mesh need to fulfill a number of quality criteria.

High fidelity of the approximation: The triangulation should be as faithful to the digital elevation model as possible, that is, the overall error between the approximation and the full gridded terrain model should be as small as possible. There are different ways of measuring the approximation fidelity, with the two most common error metrics used for assessing the quality of a surface approximation being the maximum vertical distance between the grid and the mesh, and the root mean square of the vertical distances (Heckbert and Garland 1997). These metrics have the advantage of being fast to evaluate, but they are overly sensitive to horizontal errors. A more robust method is the sampled symmetric closest distance described in Garland (1999): for every point in the original grid, the distance to the closest point on the grid-sampled triangle mesh is calculated, and conversely for every point on the grid-sampled triangle mesh, the distance to the closest point on the original grid is calculated; since these distances are not generally the same, the average of both values is taken.

Small number of triangles: When constructing the paper model from the triangulation, every triangle requires a certain amount of time: it needs to be scored, cut, folded and glued. The construction process also becomes more complicated with increasing numbers of triangles, since the number of possible combinations rises, and the overall accuracy of the paper model decreases, since inaccuracies in gluing parts can accumulate. Therefore, in order to ensure that the construction process remains possible in practice, the number of triangles in the triangulation needs to be limited. Takahashi et al. (2011) suggest an upper limit of 500 triangles. Generally, the smaller the number of triangles, the faster, easier and more accurate is the construction process.

Similar triangle size throughout the mesh: In triangle approximations, areas of the original mesh that are planar can be represented using only a few large triangles, while strongly undulating areas need to be represented using many small triangles. For most applications, this adaptive nature of triangulated irregular networks is a desirable feature, since it reduces the storage size of the network by eliminating redundant information. However, from an aesthetic point of view, meshes with large variations in triangle size are undesirable. The difference in triangle size draws unwanted attention to the nature of the approximation and distracts from the object being portrayed. While from a mathematical point of view it might not be necessary to split up large planar areas into smaller triangles, it helps the viewer to better understand the landscape features when there is a relatively homogenous "resolution" to the model. A single large triangle next to many small ones tends to look like an error or a patch of missing data; splitting that triangle up into several smaller triangles, while effectively resulting in the same surface, communicates to the viewer more clearly that the planarity of the area is indeed an accurate representation of the underlying data, and not merely an artifact introduced by the triangulation.

Good triangle shapes: The shapes of the triangles have a large impact on the ease of construction of the resulting paper model. Long, narrow "sliver triangles" are problematic for constructing paper models for several reasons: they are more sensitive to inaccuracies when cutting or scoring the triangle edge, as a small angular deviation from the correct direction results in a large relative error of the resulting triangle's area and edge lengths; they are harder to fold along the edge, since the narrow tips have a tendency to bend instead of fold; and they offer only small area for attaching the glue tab of a neighbouring triangle, making the connection less secure. The ideal triangle element for our application is an equilateral triangle. Deviations from this ideal shape can be measured in a number of ways (Shewchuk, 2002), one useful metric being the shape reqularity quality *q* proposed by Bank and Smith (1997): for each triangle, we calculate the ratio of the triangle area and the sum of the squared edge lengths, normalised to equal one for an equilateral triangle and approach zero for a degenerate triangle.

2.2 PREVIOUS ALGORITHMS

A vast number of algorithms have been proposed for generating polygonal meshes from high resolution data. For good overviews of the topic, see Heckbert and Garland (1997) and Luebke (2001).

For the application of creating papercraft raised relief maps, we considered a number of existing algorithms. We briefly describe the algorithms, and show the result generated when applying them to the same elevation dataset of the Matterhorn, specifying a target triangle count of 150. The elevation dataset has a resolution of 400 x 400 pixels, covering an area of 2,000 m x 2,000 m (Figure 2a).

The most straightforward way of triangulating a gridded elevation dataset is to create a downsampled version of the original grid and then create a regular grid triangulation (Figure 2b). Generally, this algorithm leads to a poor approximation fidelity, because there is no mechanism for including important characteristic points of the terrain in the triangulation, so peaks, valleys and ridges are easily missed.

In order to improve the approximation fidelity, the points to be included in the triangulation should be chosen not by using regular sampling, but based on their contribution to the overall terrain shape.

One popular method for choosing the points is the greedy refinement algorithm described by Garland and Heckbert (1995). It starts with a triangulation consisting of the four corner points of the domain. In each step, the vertical errors between each grid point and the triangulation are calculated, and the point with the largest vertical error is added to the mesh (Figure 2c). This algorithm is extremely fast, but because it only regards the largest vertical error it does not typically lead to results with low overall errors, and because it does not take the shapes of the resulting triangles into account when choosing which points to add, the resulting triangulation often includes many sliver triangles and triangles of uneven sizes.

Instead of iteratively refining a simple mesh, decimation algorithms start with a full triangulation and iteratively simplify the model. The popular QSLIM algorithm (Heckbert and Garland 1999) simplifies the model by merging the vertices of edges, starting with the merge operation that has the smallest impact on the overall error. This algorithm typically performs much better than the greedy refinement algorithm in terms of approximation fidelity and triangle quality, but still misses some characteristic features of the terrain and includes narrow triangles (Figure 2d).

None of the surveyed methods were found suitable for the specific purpose of generating meshes for building papercraft models. We therefore propose a new method using an optimisation approach that takes into account all of the requirements described in section 2.1.

2.3 PROPOSED OPTIMISATION ALGORITHM

In an optimisation algorithm, an initial solution to a given problem is iteratively improved by making small adjustments, evaluating the quality of the adjusted solution according to some objective function, and using the new solution as the starting point for the next iteration, approaching an optimum solution over time.

The objective function forms the heart of any optimisation algorithm. It is important that it captures the essence of the problem, but approximations may be necessary to reduce the computational cost of evaluating potentially thousands of solutions. In our proposed method, we use an objective function, described below, that evaluates the approximation fidelity and the quality of the triangle shapes. The number of triangles is specified by the user, and the desired similarity in triangle sizes is implicitly accounted for by the triangle shapes and by the initial solution.

Our method starts by generating a mesh with a specified number of triangles using a greedy algorithm (Stage 1) and then attempts to improve it iteratively by repeatedly adjusting either the mesh connectivity (Stage 2a) or shifting node positions (Stage 2b). Throughout stage 2, the number of triangles as well as the number of nodes on the boundary and inside of the DEM domain remains unchanged. In each iteration, changes to node position or connectivity are evaluated by this objective function and accepted only if they yield an improvement.

2.4 STAGES

Stage 1: Initial Vertex Distribution

Areas of large variation in the terrain will require a higher relative density of nodes than flat areas. The initial vertex placement is critical to the final result of our optimisation algorithm because it will only proceed with changes if they bring an improvement to the objective function M_T and it is difficult to escape from a local optimum.

Our meshing starts with four points placed on the corners of the domain, yielding two triangles. For each additional point P_B on the boundary we gain one additional triangle while each point P_I on the interior of the domain yields two additional triangles. The number n of triangles can be computed as $n = 2 + (P_B - 4) + 2\ P_I$ (de Berg 2008: 193).

As we have two independent variables, many solutions may be possible to obtain a certain number n of triangles. We introduce a new constraint: assuming all triangles had the same size, each would cover an area $A_T = A_D/n$, where A_D is the total area of the domain. The edge length a_T of an equilateral triangle with area A_T is given by $a_T = \sqrt{4\,A_T/\sqrt{3}}$. Dividing the boundary of the domain a_D into segments of length a_T gives the number of nodes to be placed on the boundary, P_B. The number of nodes to be placed inside can now be calculated as P_I= round(½ $(n + 2 - P_B)$). If needed for achieving the specified number of triangles, one additional node is added to the boundary.

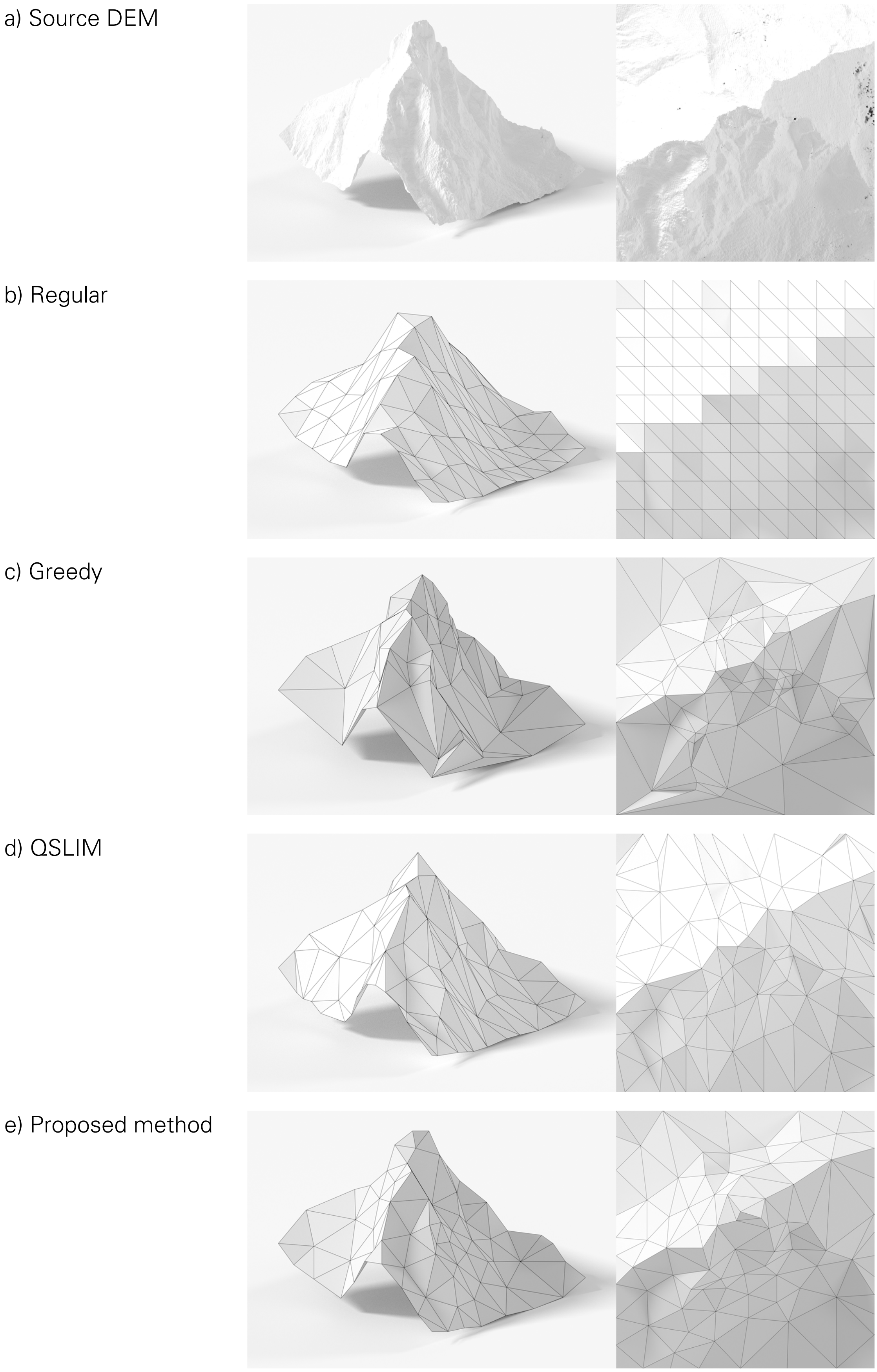


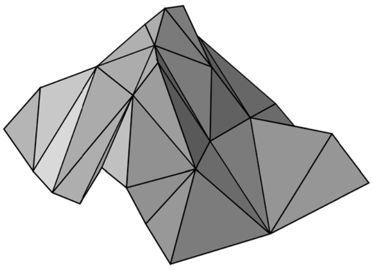
Figure 2: Comparison of the triangle meshes generated using different existing algorithms and the proposed method, showing an oblique and a top-down view.

To distribute the additional points, a method similar to the greedy algorithm described in section 2.2 is used. However, instead of using just the vertical error for determining which point to add, we first weight the error using the maximum local absolute Gaussian curvature to identify important features such as peaks, ridges and gullies, as described by Leonowicz (2010). The search for the point with the largest vertical error is constrained to the domain boundary until all P_B boundary points have been added. The internal points P_I are then distributed in a similar fashion, however this time excluding the domain boundary from the candidate search. This two-stage approach reduces the risk of creating sliver triangles along the domain boundary.

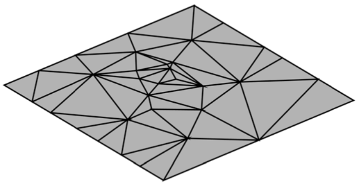
Objective Function: We define two competing measures for our objective: the average terrain fidelity and the average triangle shape quality.

For calculating the terrain fidelity M_F, we use the average vertical error over all grid points, normalized by the variance of the terrain grid, and weighted using the inverse of the horizontal distance from the point to the edge of the corresponding triangle. The distance is measured as the minimum of the barycentric coordinates of the point raised to a power p=2, plus 1, then scaled to a mean of 1, which assigns greater weight to points on the triangle edges, since these have a greater impact on the appearance of the model (Figure 3).

a) Oblique view of a triangle mesh



b) 2D projection of the mesh



c) Weight map for the the vertical errors. Errors on triangle edges are weighted more strongly than errors in triangle interiors

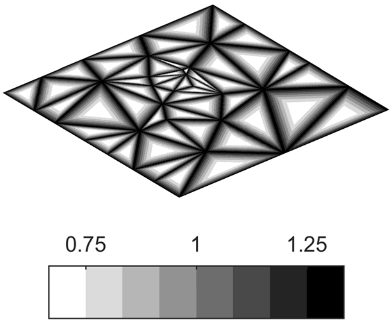


Figure 3: Vertical error weighting.

The triangle shape quality q described in section 2.1 is averaged across all triangles to yield an overall shape metric M_S, with all triangles contributing equally to the overall score, regardless of their area. By penalising triangles with small angles, large variations in triangle area between neighbouring triangles are implicitly penalised as well.

To combine the fidelity and shape metrics into an overall objective function, a weighted average M_T for the whole triangulation is computed as $M_T = c\, M_F + (1-c)\, M_S$ Values of c=0.8-0.95 have yielded good results in our experiments.

Stage 2a: Quad Flipping

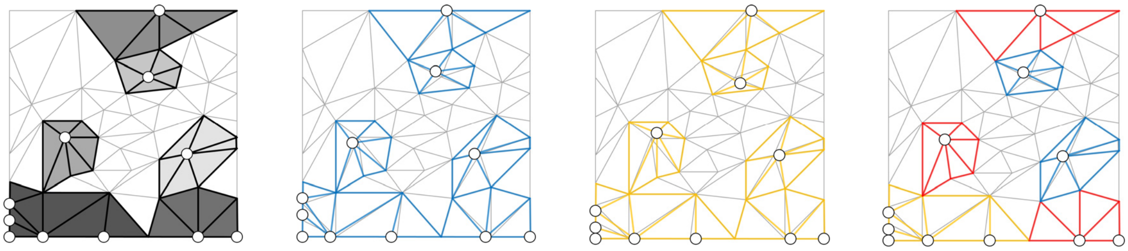
For any pair of adjacent triangles (quads) that form a convex boundary in 2D there are two alternative connectivities where the triangles do not overlap. Unless all points are in the same plane, these yield different surfaces – one with a ridge, and the other with a valley. Our first step in each iteration is to check if flipping any quads yields an improvement in the objective function. Quads that rank the poorest in contribution to the objective function will be checked first. After a flip all quads of the new mesh are ranked again and the process is repeated until no further improvement can be obtained through flipping.

Stage 2b: Node Shifting

After the quad flipping stage, the positions of a randomly selected set of nodes are slightly shifted horizontally and assigned the elevation values of the gridded dataset at the corresponding new position. For shifting the node positions, we used a method based on the concept of *Simultaneous Perturbation Stochastic Approximation* described by Spall (1998): in each step a perturbation of the mesh is performed in opposite directions, and the direction yielding the best improvement of the total objective M_T is selected. If neither perturbation improves the objective another random perturbation is generated (Figure 4).

In our implementation, when a certain number of unsuccessful perturbations has been reached we reduce the number of randomly selected nodes that are perturbed, which allows discovery of more localised improvements as the groups become smaller. The optimisation ends when the number of perturbed nodes falls below a certain threshold.

Perturbations can be larger than the length of a single grid cell, which makes it possible to overcome local minima by skipping some cells. To improve convergence, the nodes' perturbations are grouped into independent areas, and each group is evaluated and improved separately.



a) Input mesh and 11 randomly selected nodes, forming 6 groups.

b) Random perturbation of the selected nodes in '+' direction.

c) Opposite perturbation, designated '–' direction.

d) Combination of best '+' / '–' perturbations of the individual groups. Red groups did not improve with perturbation.

Figure 4: *Simultaneous Perturbation Stochastic Approximation* of 11 randomly selected nodes forming 6 groups. Constraints are enforced on edge and corner nodes. Perturbations that would change the orientation of a triangle are dismissed. Notice that the perturbation at each node can have a different magnitude and direction, independent of the others.

2.5 COMPARISON OF RESULTS

From visual inspection of the meshes shown in Figure 2, one can see that the meshes resulting from the different algorithms have very different characteristics. These differences are also evident when analysing the quality criteria set out in section 2.1.

The approximation fidelity metrics of the meshes generated using the different algorithms are shown in Table 1. The proposed method performs best in terms of all error metrics apart from the maximum vertical distance, where the greedy algorithm performed slightly better. This is to be expected, since the objective function of the proposed method does not take the maximum vertical error into account, while the greedy method uses the maximum vertical distance as the sole driving factor. Generally, the average metrics (mean absolute error and root mean squared error) are more meaningful for assessing the overall shape fidelity, with the maximum error primarily being used as an indicator for the presence of outliers.

Table 1: Error metrics for the meshes generated using different algorithms: maximum error, mean absolute error (MAE), root mean squared error (RMSE)

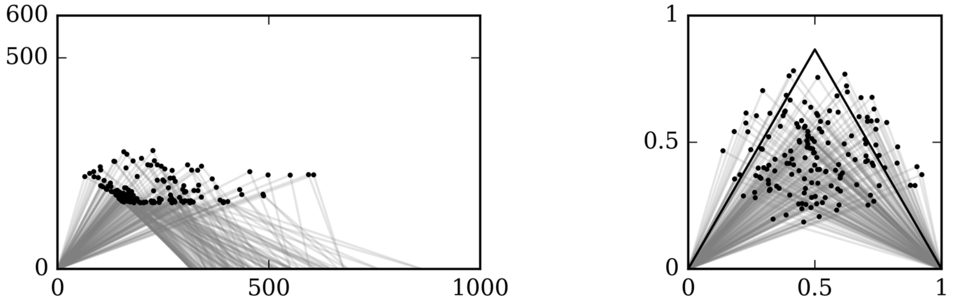
	Vertical distance (m)			Symmetric distance (m)		
Algorithm	Max	MAE	RMSE	Max	MAE	RMSE
Regular	339.9	53.9	70.3	110.2	29.8	35.8
Greedy	199.8	26.8	34.9	86.4	17.0	22.0
QSLIM	215.4	25.7	34.4	77.4	15.4	19.3
Proposed method	202.7	19.4	25.6	53.9	11.9	14.4

To assess the triangle shape quality and the similarity in triangle sizes of the different meshes, all triangles of each mesh are plotted in Figure 5. In the left column, the unscaled triangles are shown: the range of triangle sizes of the regular method and the proposed method are similar, while both the greedy and QSLIM algorithms generate triangles with a much wider range of sizes. The shapes of the triangles can be assessed by normalising the triangles so their widest side has a length of 1 and comparing them to an ideal equilateral triangle, shown in the right column. It can be seen that the triangles generated using the proposed method are generally more similar to the ideal triangle, and don't vary in shape as much as those generated using the other methods.

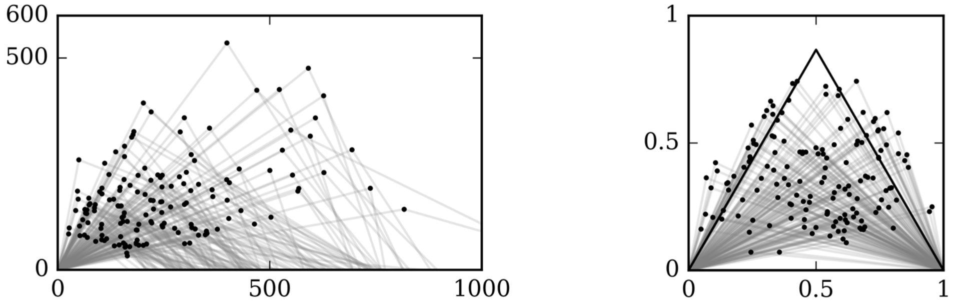
3 TEXTURING THE MESH

The paper model can either be left uncoloured, or a texture can be applied before unfolding and printing the mesh. Since the model does not contain any overhangs or vertical faces, an image such as a topographic map, a satellite image or an orthophoto can simply be vertically projected onto the mesh. It should be noted that in steep areas of the model, the image is stretched, so the image needs to be of a higher resolution than would be necessary for strictly vertical viewing. This problem could be mitigated by using terrestrial imagery for the steep areas, or by using a vector topographic map instead of a raster image.

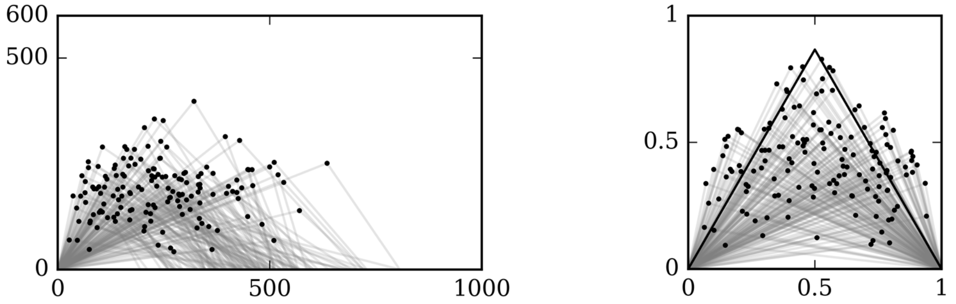
a) Regular



b) Greedy



c) QSLIM



d) Proposed method

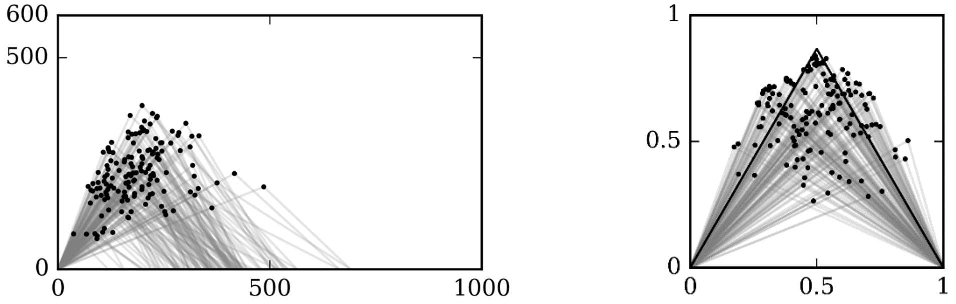


Figure 5: Comparison of the triangle shapes of the triangulations generated using different existing algorithms and the proposed method. Triangles are rotated to have their longest side aligned with the horizontal axis. In the left column, the triangles are unscaled, in the right column, each triangle is scaled so its longest side has a length of 1. For orientation, in the right column an equilateral triangle is plotted in black.

In our experience, satellite or aerial imagery tends to work better for texturing the model than topographic maps: due to the geometry simplification, contour lines of topographic maps will generally not lie strictly at the same level when projected onto the mesh, which can be confusing to the viewer. Similarly, for models with sharp peaks and ridge lines, satellite or aerial imagery taken under strongly oblique lighting conditions is less suitable, because it tends to make the geometry simplification stand out along edges with changes in incident light angles.

4 UNFOLDING THE MESH

In order to print the model, it needs to be unfolded so all the triangles lie in the same plane. To make the model unfoldable, some edges of the mesh need to be cut in such a way that the triangles are only joined along a spanning tree of the original mesh and none of the unfolded triangles overlap (Straub 2011). For the latter requirement, it can be necessary to split the model into separate groups of triangles, so-called islands, that are not connected to each other. Splitting an island further is also necessary if it is too large to fit on a single paper sheet for printing. A naive approach would be to simply cut all edges, resulting in a set of islands each only containing one triangle. However, after printing and folding the model, the cut edges need to be glued back together, which is the most labour intensive part of the model building process. It is therefore desirable not to introduce an unnecessarily high number of cuts. Takahashi et al. (2011) presented a genetic algorithm that attempts to find an unfolding that results in a single island containing all triangles. While this tends to reduce the number of cut-and-glued edges, it also results in a rather unwieldy cut-out that is hard to assemble. We found island sizes of 5 to 20 triangles to generally be the easiest to work with. To unfold the models, we used the "Export paper model" software (Dominec 2016), which prioritises which edges to cut according to a weighted score consisting of the edge length and the angle between the two triangles. The software also automatically generates labelled glue tabs for assembling the model. Some manual editing of the automatically placed cuts can be helpful in order to obtain island shapes that can be more economically arranged on the pages for printing, but in general we found the algorithm to produce satisfactory results without manual intervention.

5 PRINTING, CUTTING AND GLUING THE MESH

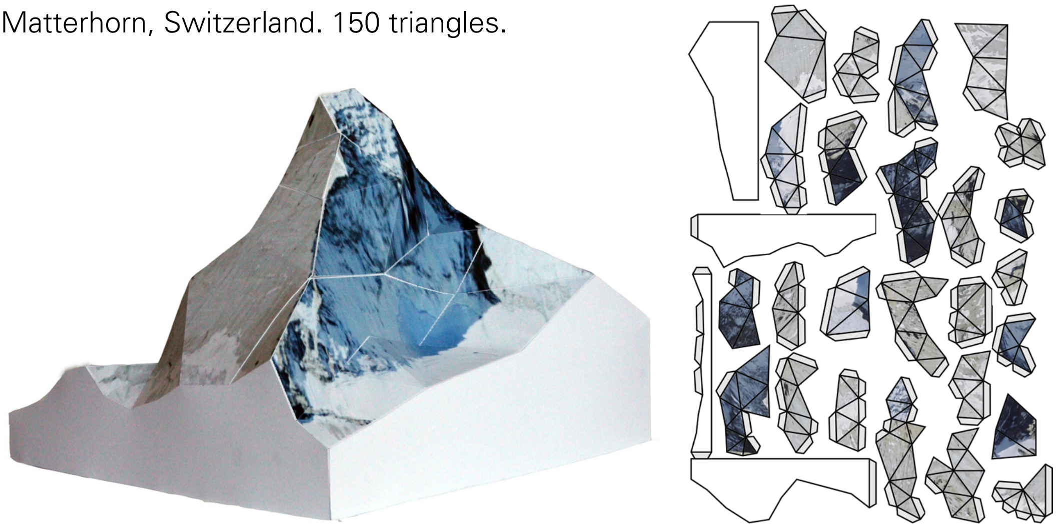
The unfolded islands could be printed on standard office paper, but depending on the size of the final model, stronger paper with a weight of 120 g/m^2 tends to lead to better results. After printing, the islands are cut out and the folding edges are scored in order to obtain a more precise fold. Cutting and scoring can be done manually using a craft knife and a metal straightedge. There are also consumer grade cutting plotters available which can automate the cutting and scoring to some degree. Models which can align the cutting paths with the printed pattern are available for under EUR 200.

After cutting and scoring the islands, the model is folded and the cut edges are glued together. For this step, we found it helpful to have the 3D model available on a computer screen in order to check how the parts need to be folded and joined. Generally, it is advisable to start the assembly process in model areas with sharp folds, as these are harder to assemble at the end.

6 RESULTS

The method described above was used to create papercraft raised relief maps of several topographic features. Figure 6 shows some of the completed models and the unfolded triangles meshes used for constructing the models. The parameters used in the algorithm for converting the gridded elevation data to triangle meshes were kept identical for all three models, only the number of triangles varied.

a) Matterhorn, Switzerland. 150 triangles.



b) Uluru, Australia. 200 triangles.

c) Tre Cime di Lavadero, Italy. 200 triangles.

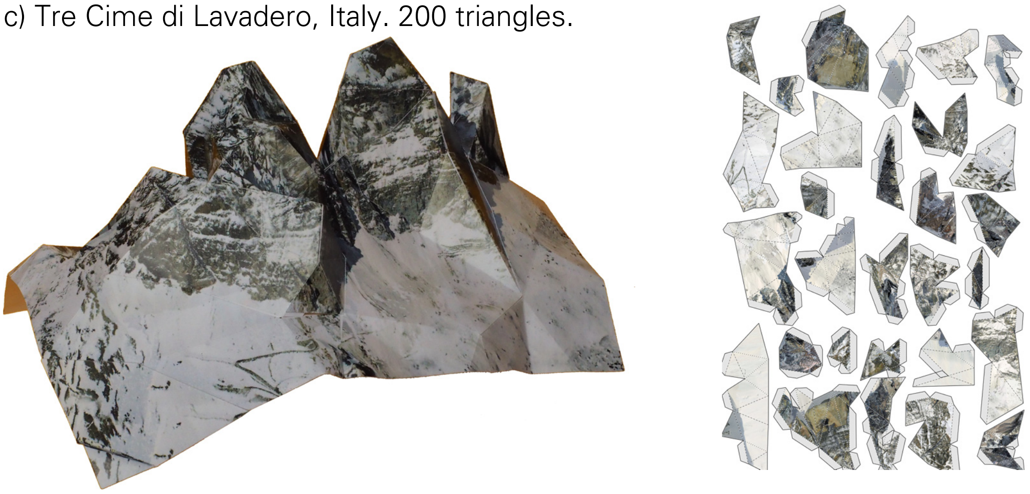


Figure 6: Examples of finished papercraft raised relief models (left column) and the unfolded triangle meshes used for their construction (right column).

7 CONCLUSION

Raised relief maps are a highly intuitive way to represent topography, and making a model is an instructive way to engage with the object being modelled. The presented approach is a practical way to quickly generate low-cost, full-colour models that can be built without requiring intensive training and do not require specialised equipment. The proposed algorithm for converting gridded elevation data to triangulated meshes suitable for papercraft modelling addresses the specific requirements of this application, and produces useful results for a variety of terrain types.

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RELIEF ASPECTS

COMBINED SHADING USED FOR SMALL SCALE PHOTOGRAPHIC MAPS

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ABSTRACT

The paper describes a method for making elevation data visible on a small scale photographic map based on SRTM digital elevation models and MODIS images. Visualizing elevation data can be a problem, because classic oblique hill shading highlights strong inclinations but largely ignores flat areas. Meanwhile, areas of low slope and flatness occupy important parts of the area shown on the map. Analysis of SRTM 3 arc-second digital elevation models indicate that these data contain detailed information about slopes not only in mountainous regions but even in nearly flat areas. This is interesting, especially in comparison with models derived from contour maps for flat areas. Such maps show omissions, simplifications, and errors, which only demonstrates the difficulty of displaying elevation surveys in planar regions. To better depict this unique information, different hillshading techniques were attempted that are more sophisticated than standard oblique illumination. Studies have shown that for the visualization of areas of low slope a shaded relief image can be used with a custom sun height parameter (or inclination) of $h = 90°$, a vertical illumination direction. Such an image is not actually a shaded relief image but rather a map of mountains similar to maps with hachures. Several trials proved that it is possible to combine the two techniques of hill shading, oblique and vertical, which has the advantages of both forms of visualization, namely it keeps the optical illusion of 3-dimensional relief. This approach simultaneously depicts the topographic diversity of both mountainous and nearly flat areas.

Keywords: MODIS, SRTM, elevation data, digital elevation model, shaded relief, hill shading, visualization, photographic map

1 INTRODUCTION

The emergence on the internet of free SRTM elevation data and MODIS land cover data spurred a desire to develop a map combining hill shading with land cover data, moving beyond the world depicted in abstract hypsometric colours. Considering that a map is the most appropriate way to visualize geographic data, I sought a new method that would provide the reader with insights and an improved understanding of the terrain. Departing from traditional relief depiction methods was necessary to achieve this goal.

By blending elevation data and land cover data it is possible to produce a natural colour image of Earth's surface. The blending was performed in Photoshop software using several iterative procedures that eventually yielded satisfactory results. The optimal procedure involved the combination of slope shading and oblique shading.

Combined shading was a characteristic of obliquely shaded hachure maps, commonly used in 19th and early 20th centuries. Of note are the very popular Arrowsmith family of maps (which can be viewed online at the David Rumsey Map Collection, http://www.davidrumsey.com). Traditional relief shading, oblique, slope or combined, was for a long time difficult to reproduce in printing.

The experiments of Colonel Goulier from the French Service Geographique were based on printing two types of shading on one paper sheet in slightly different tints. By blending prints he could obtain combined shading in the final result. Eduard Imhof, in his hand drawn relief shading maps, could make use of combined shading together with other techniques of making the image of the mountains appear similar to a physical, plastic model. Current computer technology together with abundant height data make shaded relief mapping very sophisticated, eliminating the need for manual drawing. At present, blending images to produce combined shading is not overly challenging; however achieving exemplary results remains difficult.

2 PLANNING THE RESEARCH

The research has the goal of finding the "best" technique for producing a map with colour shaded relief combined with natural land cover data derived from MODIS. The shaded relief images were produced in Surfer software with the simulated illumination azimuth fixed to northwest and its height or inclination above the horizon varying from 30° to 90°.

The aim was to produce shaded relief without too great of contrast; areas of pure white and black were to be avoided. I also wanted a relief image that was not monotonous, with enough highlight and shadow interplay to be intriguing. Achieving this goal involved a series of attempts at rendering shaded relief images and blending them in different orders before a satisfactory procedure was settled upon.

While classic shaded relief shows three-dimensionality when illuminated by a light source (usually from the northwest), it also has grey values in flat areas that can cause problems when the relief is combined with land cover. The grey values muddy the land cover. Imhof, however, believed that a map background need not have to be white, and grey background tints did not bother him because they are similar to those found in aerial photographs. Nevertheless, white backgrounds are advantageous for superimposing other elements, such as land cover.

Oblique hill shading is easily comprehended because it looks like natural terrain. But there are flat areas too and they look gloomy. There is another disadvantage of oblique shading: the look of the mountains varies greatly depending on the direction of illumination and one is never sure which representation is the best.

Slope shading shows the steepness of slopes, according to the rule "the steeper, the darker," leaving flat areas white, which essentially classifies the landscape into areas with and without relief. Without even slight terrain details, there is no directional orientation in the flat areas.

When creating the combined shaded relief, the visual assessment of different variations was guided by a subjective process based on a sense of aesthetics, experience, intuition, and a vision of what intended map should look like. Avoiding excessive contrast - areas of pure black and white - was important.

Technically, the research consisted of producing relief shading images in Surfer software in the same geometry and projection. The DEM was used at full resolution in order to represent each elevation value included in the DEM graphically in the image. The images in tiff format were then combined in Photoshop software. The procedure involved copying and pasting geometrically matched images as consecutively stacked layers. Each image could then be blended into the images below at varying opacities (starting at 100%), or by applying different blending modes between layers, such as multiply, overlay and screen.

3 RESEARCH

Starting with oblique shading using an azimuth fixed to NW, three images were produced with varying illumination heights A: 30°, B: 60° and C: 90°, all with the same scale factor z= 0.00005 (Figure 1). Enlargements are shown in Figure 2. The image with illumination height A: 30° was deemed best and selected for further use as a typical relief shading. By contrast, image C: 90° looked strange and image B: 60° appeared as a combination of both.

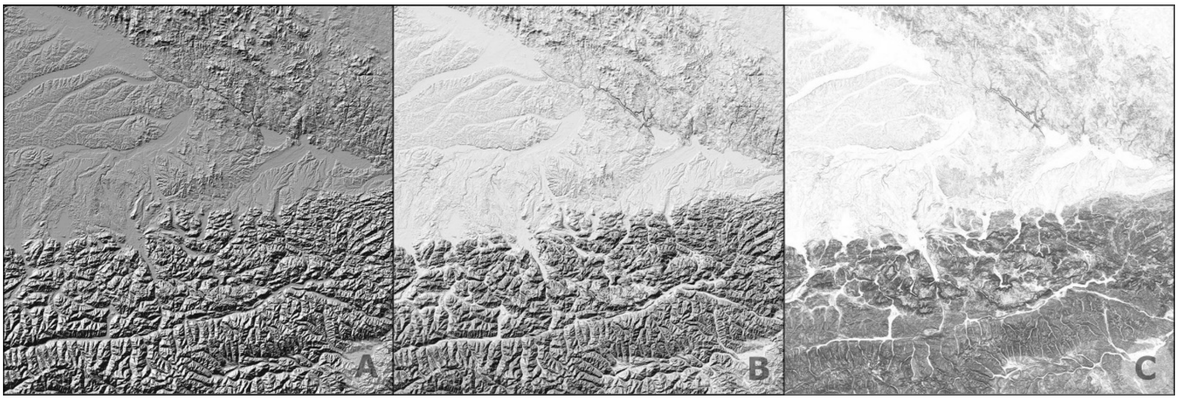

Figure 1: Comparison of shaded relief made for different illumination height A: 30°, B: 60° and C: 90°.

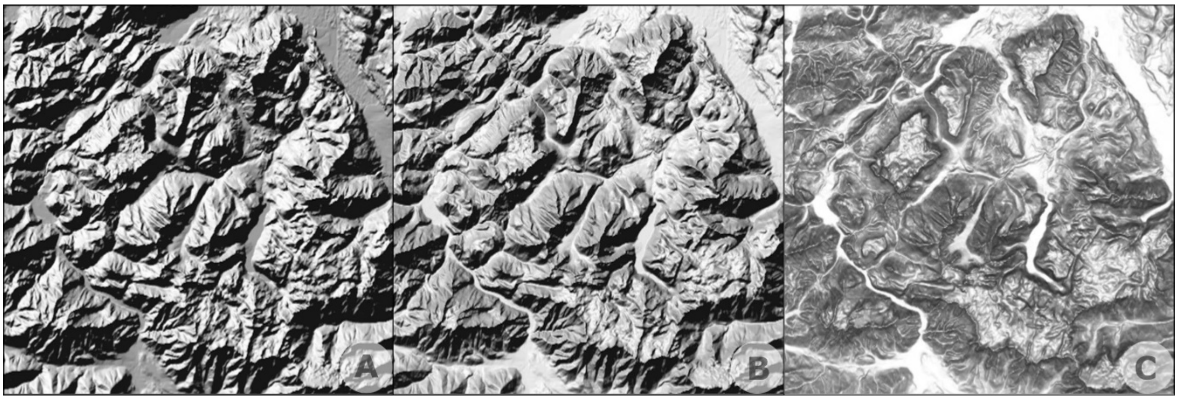

Figure 2: Comparison of shaded relief made for different illumination height A: 30°, B: 60° and C: 90° (enlarged fragments of images from Figure 1).

Regarding slope shading when the light source is directly overhead, fixed at 90°, the only adjustable parameter is scale factor z, which was investigated to produce an optimal image. For z = 0.00001, the image is barely visible and too light, and for z = 0.001 the image is almost black. Figure 3 shows images for z = 0.00005 and z = 0.0005, both in the useful range. These two images were selected because the mountains appear clearly, one better in bright areas and the other in dark areas. After mixing the two, the slope shading was good at both locations (Figure 4). This was achieved by placing the bright image over the dark at 70% opacity.

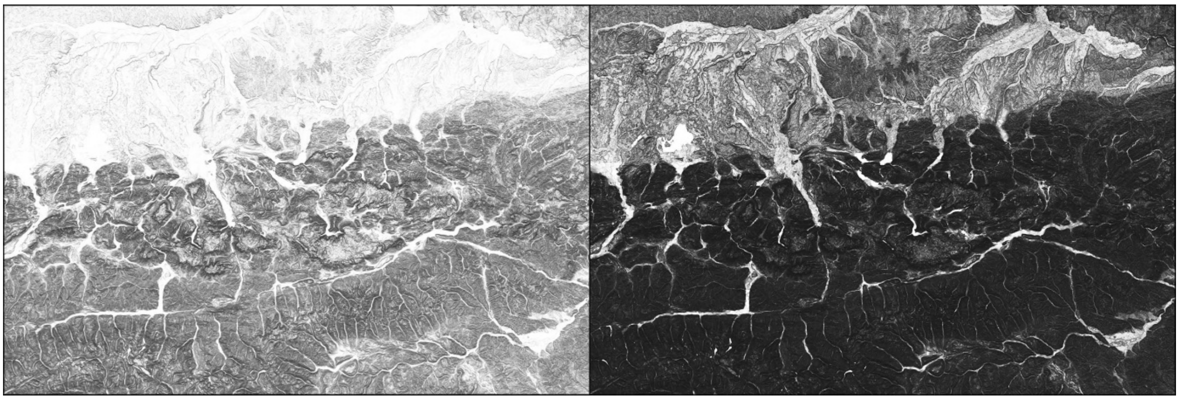

Figure 3: Slope shading with different scale factors: z =0.00005 (left) and z = 0.0005 (right).

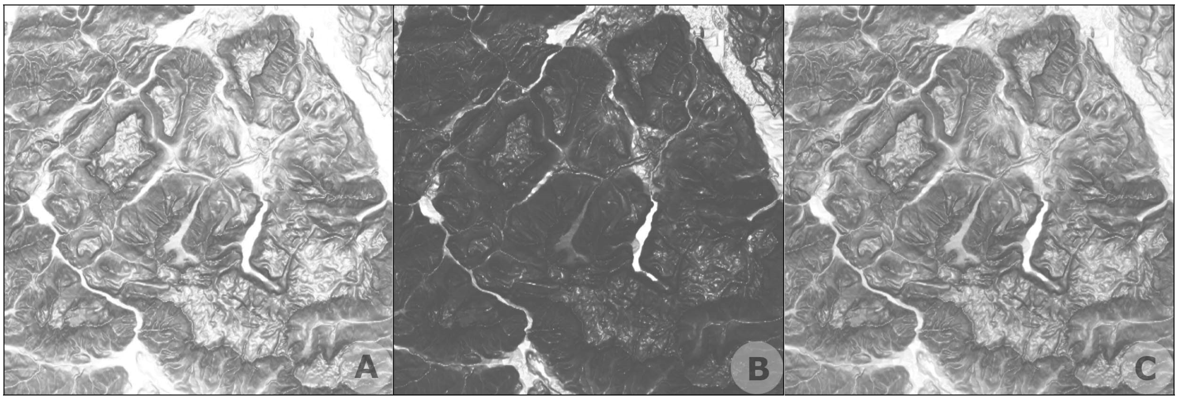

Figure 4: Slope shading C obtained by blending A: z =0.00005 and B: z = 0.0005.

The resultant slope shading presented in Figure 4 was used in combination with oblique shading to create the combined shading. This was done using multiply function with 100% opacity. The result is shown in Figure 5.

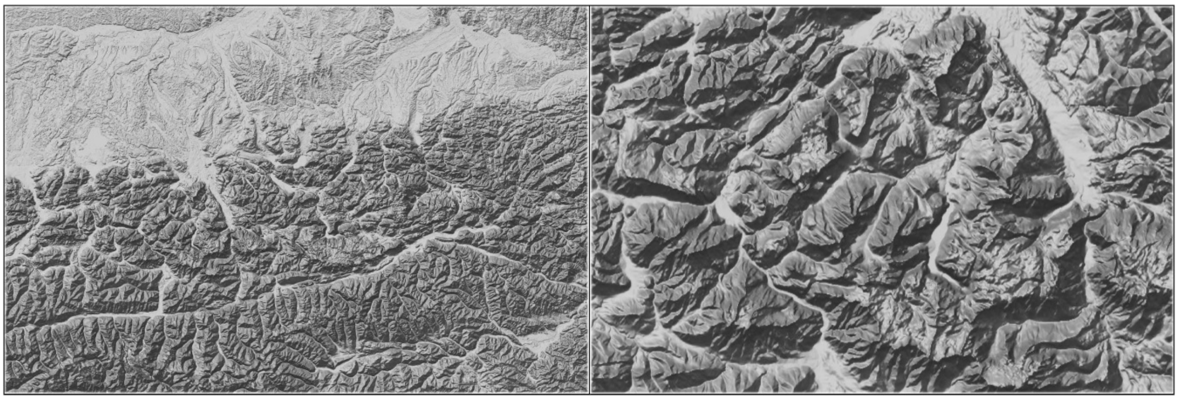

Figure 5: Slope shading in combination with oblique shading (left), enlarged fragment (right).

4 RESULTS

Compared to classic hill shading illuminated from the NW, the combined shading appears more visually interesting and better depicts the terrain in both mountainous and flat areas. It also better resembles a natural view, although this a subjective impression. I nevertheless found this unexpected result intriguing, as seen in Figure 6, which compares images of oblique shading (left) and combined shading (right).

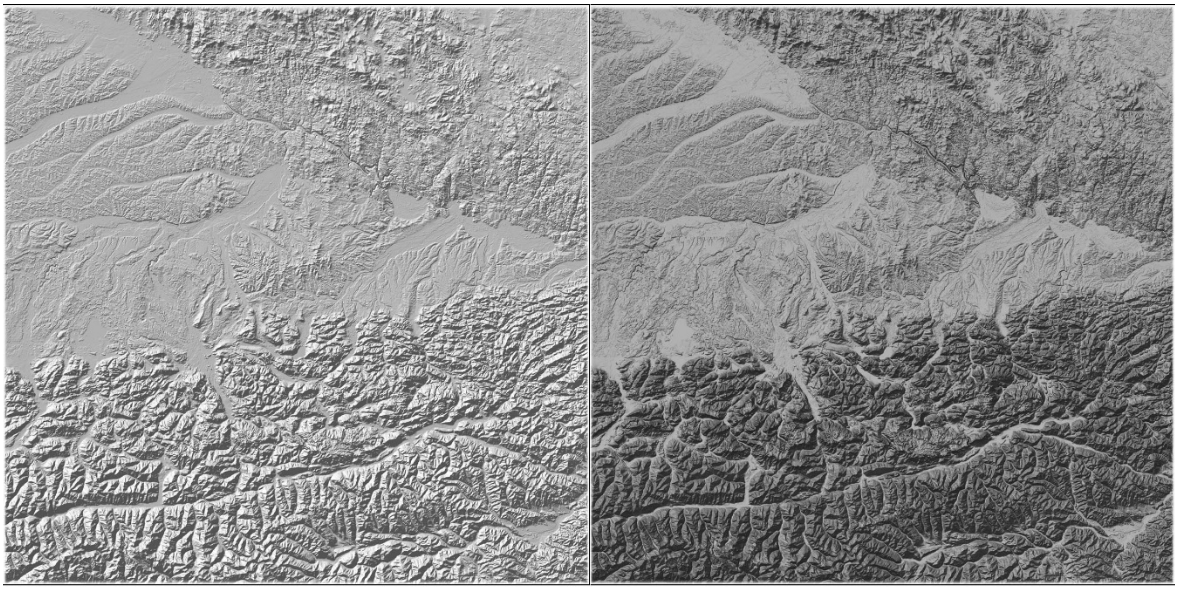

Figure 6: Comparison of oblique shading (left) and combined shading (right).

It is common practice to regard oblique shaded relief and slope shading as stand-alone products, which may explain why the combined images work surprisingly well. It was not a mystery to Imhof who used this combination in his studies on drawing mountains and not a mystery to many other cartographers interested in representing landscapes on maps as realistically as possible.

More importantly, the combined image was inspiring and prompted further research on how to make a colour image of the terrain. When blended with MODIS land cover, the combined relief image works better than conventional oblique shading and offers improved colours, as is shown in Figure 7 and Figure 8 (enlarged).

Worth noting is the later observation that the laboriously obtained image of combined shading is very similar to the B version of oblique shading (60º) from Figure 1 (Figure 9).

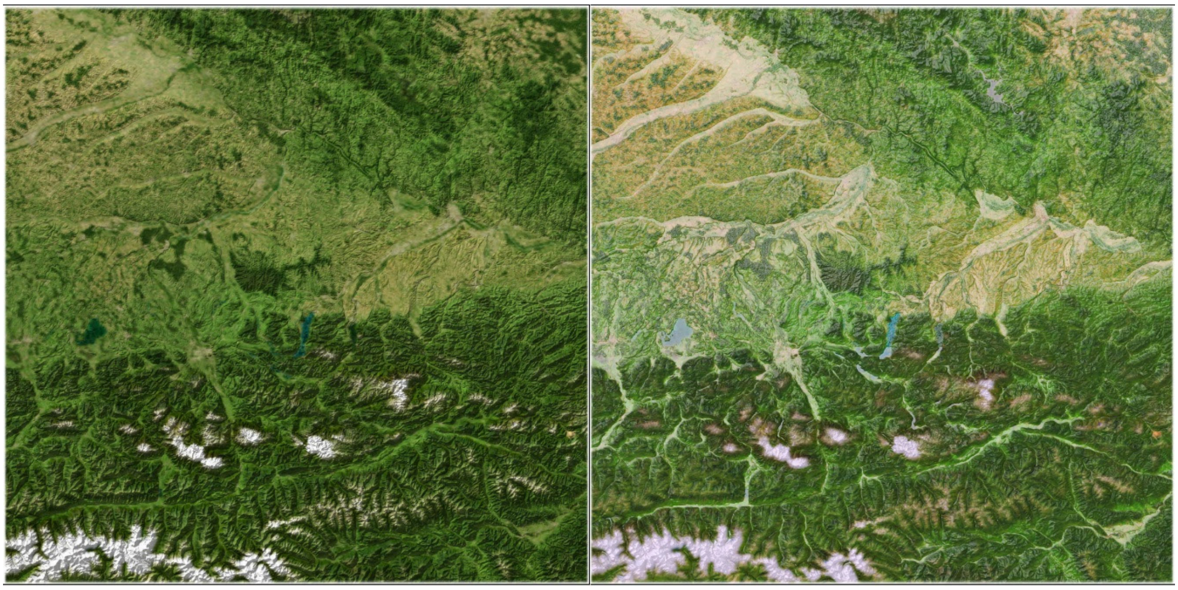

Figure 7: Comparison of oblique (left) and combine (right) shadings blended with MODIS image.

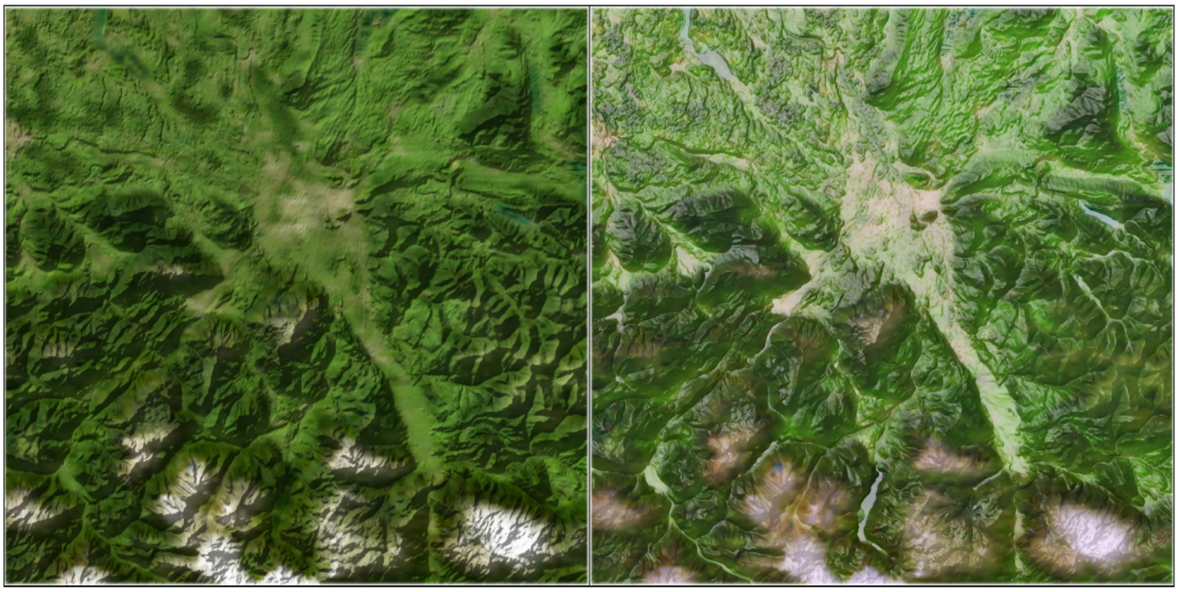

Figure 8: Comparison of oblique (left) and combine (right) shadings blended with MODIS image (enlarged fragment).

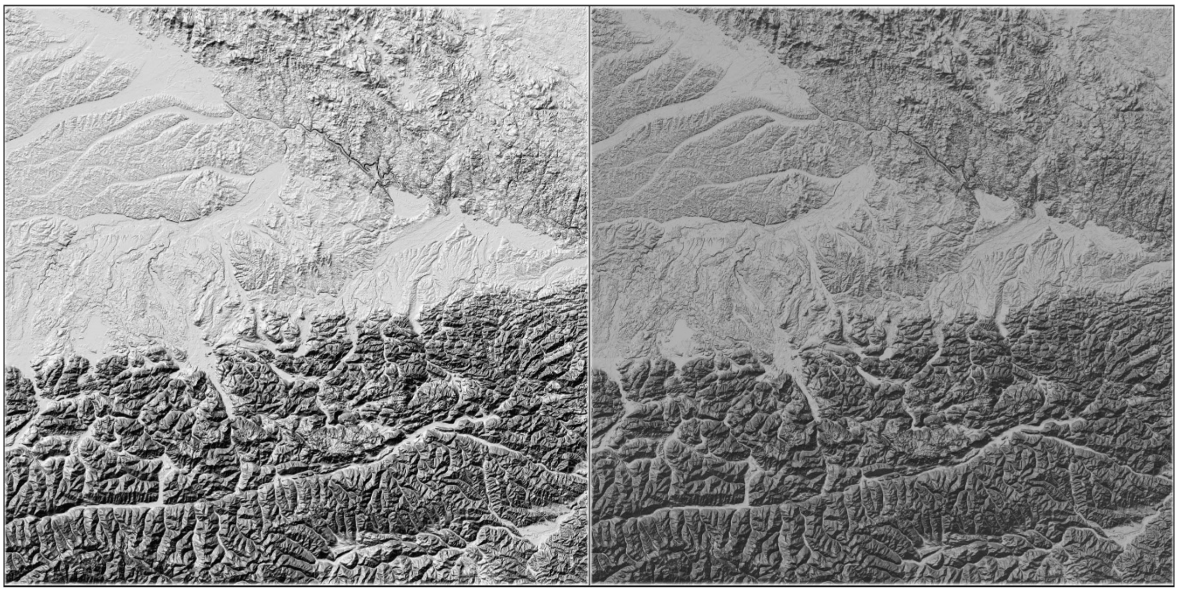

Figure 9: Comparison of oblique shading (60°) from Figure 1(left) and combined shading from Figure 6 (right).

5 CONCLUSION

The similarity of two images of relief shading presented in Figure 9 should not be surprising because it is logical that the intermediate variant of oblique shading calculated by software resembles an intermediate variant produced graphically. To some extent, this condition facilitates the interpretation of the blended shading image, which is an advantage. Of course we must heed Imhof's observation that a shaded relief rendered with a light elevation of 60° has no metric accuracy, but visual character.

Research has shown that reasoning does not always run the shortest path to the target, and sometimes to achieve a desired goal it is necessary to modify the research direction. Being open-minded and flexible is key. Regarding the search for the best graphic effect, which is highly subjective, blending images in Photoshop is slightly like mixing prints by Colonel Goulier from Service Geographic or like the hand drawn relief shading of Imhof. In matters of taste, differences of opinion will always exist between any two people.

In drawing shaded relief maps by hand, the artist could vary vertical and oblique illumination in all possible combinations, evaluating the results by eye based on "how it looks as seen from above" (although no one could yet fly). Criteria to imitate nature and to draw terrain "as you can see" or "as it looks", was always essential, because it guaranteed legibility of relief maps by simple associations.

As the accuracy of elevation source data improved, the discussion shifted to producing maps that were both accurate and pleasing to the eye. Principles of drawing accurate maps of mountains were offered by Saxon cartographer J.G. Lehmann who developed rules of hachuring in his work from 1799: "Darstellung einer neuen Theorie zur Bezeichnung der schiefen Flächen im Grundriß, oder der Situationszeichnung der Berge" (theory of drawing mountains). Theoretically, Lehmann's drawing enabled the map user to interpret elevation, but practically, the drawing was almost illegible in mountainous areas and completely devoid of visual expression. After Lehmann, a movement began to apply scientific methods to the drawing of the terrain on maps.

Research by Viennese cartographer Karl Peucker, included in the work Schattenplastik und Farbenplastik, noted that the plasticity of the mountains can be achieved not by unscientific hachures or relief shading, but by hypsometric colours. In Peucker's scheme, red was reserved for the highest mountains because in the visual spectrum red is perceived as closest to observer and blue as the farthest away, which enhances the effect of three-dimensional convexity (or plasticity). Popularized by scientists, the so-called hypsometric map influenced the imagination of many generations of readers and has been challenged only in recent years by natural colour photographic maps, first developed in 1997 (Drachal 2007).

Imhof had the following opinion about the daily work of cartographers: "the passion for making simple things appear profound is widespread in many sciences, and the science of mapping is no exception" (Imhof 1982). During this time of accurate maps and measurable images of Earth's surface, following the old criterion of imitating nature could result in criticism. As Polish cartographer Stanislaw Pietkiewicz, a contemporary and friend of Eduard Imhof, describes in his work, Les Méthodes Du Figuré Du Relief Sur Les Cartes, disputes on how to represent the terrain on maps was very much alive at that time. He called it the fight between beauty and truth, himself favoring the side of beauty, but hoping for an ending of this dispute which valued both ideals.

Peucker challenged the great achievements of Swiss cartography, saying that the beautiful Swiss map is not a map, only a painted view in a vertical projection. He went on to say that praising a relief map is inappropriate. Famous Polish cartographer Eugeniusz Romer believed that the map of Dufour and modern Swiss maps produce objectless images and exaggerate and falsify the essence of the shape of the Alps. The Swiss were not indifferent to the critical reviews, for example, Fridolin Becker suggested that surveyor and mathematician stop thinking that they are the cartographers. While working on his maps, he said with conviction that this is the image that is the most similar to a direct observation in nature, made with signs that explain themselves (Pietkiewicz 1930).

Nowadays the dispute no longer exists. The defense of measuring the image of Earth's surface as the main goal of mapping by Romer is longer the only goal, and Swiss-style maps are a model for the whole world. With computers now handling all measurable attributes of mapping, such as projections, cartographers can focus more attention on the visual, affect the senses and thus the imagination, stimulate and inspire, and promote understanding of a place. The map is currently not often used for measuring but for displaying the Earth, and all the abstract representations of the terrain on maps are replaced by the increasingly popular image of the earth in natural colours, which is a return to the criterion of "so as you can see".

The image of the terrain shown here certainly have no importance to the measurability of the image of the Earth's surface and it could not be Romer's accurate map as it would be difficult to interpret the different shades of colours. It is, however, the result of a logical combination of images of the terrain's relief and a simplified coverage of that area (vegetation or lack of it). Such combinations portray the basic physical characteristics of this place (formerly the name physical map was used), or to switch from a Greek to Latin term, portrays nature. For the author and colleagues, this representation of land is inspiring, shows things that have not been noticed before, and also piques the imagination with the true colours of our planet. The colourful image of the terrain shown in Figure 7 can be made more legible and closer in appearance to a traditional map with the inclusion of other data e.g. urban areas, rivers, lakes and country borders. A sample photographic map is shown in Figure 10.

Preconceived notions limit the imagination and so it was with the set of Peucker's colours and a conventions created with them. Displaying the Earth in natural colours can affect our relationship to it, which would become more natural, familiar and compassionate rather than abstract, utilitarian and exploitive. According to Montello (2002), we should not be indifferent to the maps we are making, because they affect the image of the world in our minds.

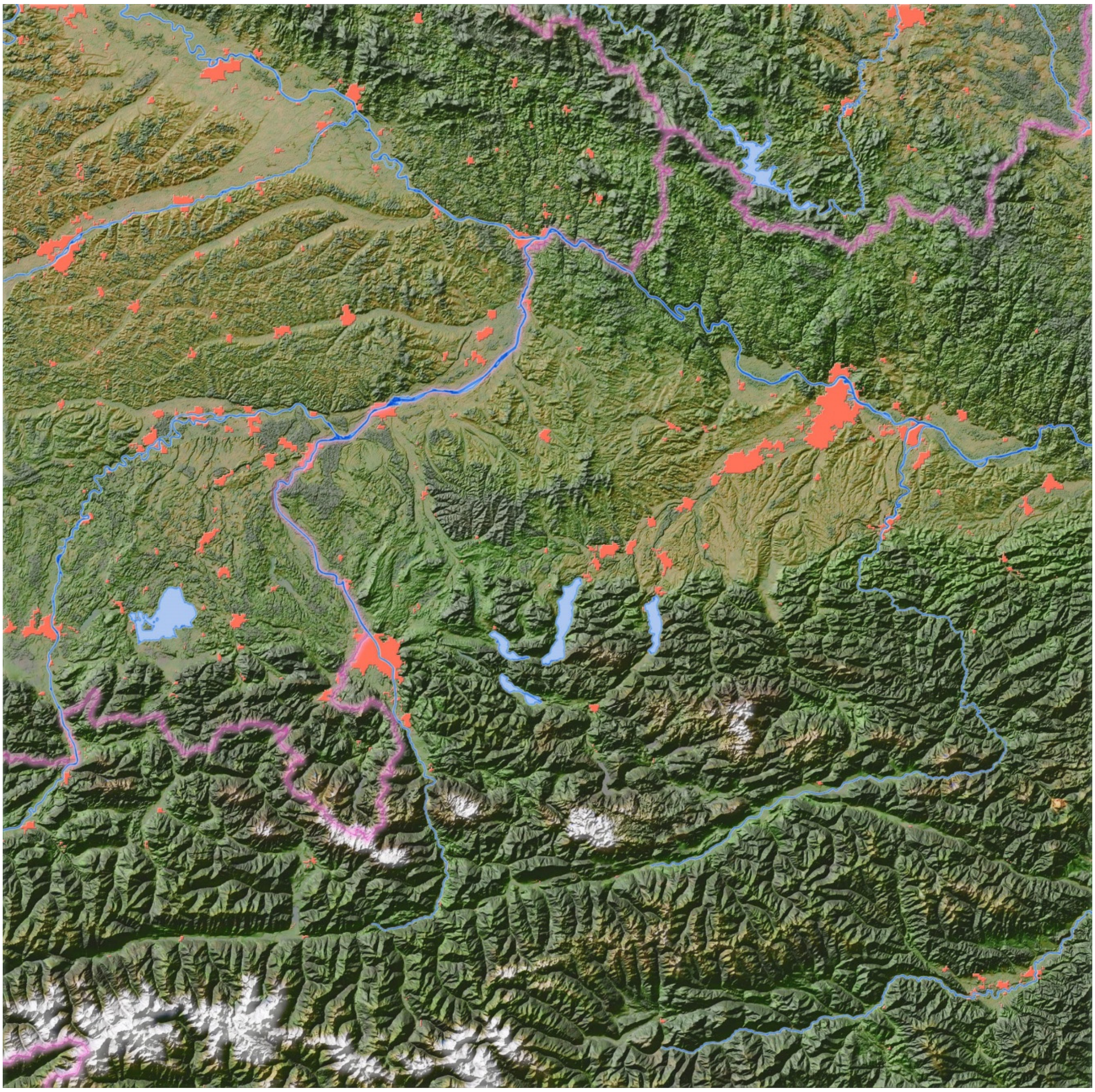

Figure 10: Sample piece of a photographic map based on SRTM and MODIS data.

6 ACKNOWLEDGEMENTS

Image of MODIS was downloaded from "a catalogue of NASA images and animations of our home planet" http://visibleearth.nasa.gov/view.php?id=74117.

SRTM data were downloaded from NASA page http://dds.cr.usgs.gov/srtm/.

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MOUNTAIN AND HIKING CARTOGRAPHY

AUTOMATION OF CARTOGRAPHIC GENERALISATION OF CONTOUR LINES

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ABSTRACT

The paper gives an overview, results and open issues in connection with a new approach to the problem of the automating the cartographic generalisation of contour lines. Research was conducted in several phases over almost a decade at the University of Zagreb's Faculty of Geodesy. The properties of manually generalised contour lines on series of official topographic maps were analysed first. Based on the findings, new algorithms for simplification and smoothing were designed, with the distinct property of area preservation. Parameter values were also calibrated using contours from topographic maps, which enabled map scale to be defined as a primary parameter of the algorithms. Algorithms were first applied in the classroom, and later used in the production of topographic maps. The results prove that this approach can substantially improve the process of preparing contours for maps. Nevertheless, there is room for further improvements and future research.

Keywords: contours, cartographic generalisation, map production

1 INTRODUCTION

Geoinformation (spatial data) generalisation can be divided into model/data generalisation (i.e. obtaining a less detailed database from a more detailed one) and cartographic generalisation (deriving a map in a smaller scale from a database or map in a larger scale) (Brassel and Weibel 1988, Haunert and Wolff 2010).

The most common type of isolines on topographic maps are contours and isobaths, i.e. lines joining points of equal terrain height and depth, respectively. Historically, they have been applied to portray relief since the early 18th century, but have been used more widely on topographic maps for almost a century and a half (Evans and Frye 2009). While they represented an irreplaceable way of portraying and interpreting terrain accurately for the most of that period, their role has changed in the last few decades.

Line and contour generalisation have attracted a great deal of attention in the cartographic community over the past years. At some point, the focus on the algorithmic approach to line generalisation decreased, and the cartographic community, (especially GIS) accepted the few existing algorithms as standard, notably the Douglas-Peucker line simplification algorithm. Not many cartographers would use the direct results of this algorithm for map production, because of the sharp corners of the lines. It is hard to find any GIS software, spatial data libraries or spatial databases which do not provide line simplification using this algorithm. A potential problem arises when this is the only algorithm offered, and users are not encouraged to search for alternative solutions to the problem of the generalisation of contours.

Of late, authors have been returning to this problem. After years of GIS ‘euphoria’ and a focus on its analytical aspect, GIS has started to develop strongly in visualisation functions. Many mapping problems in the digital environment have been solved and standardised. Maps remain the best means of spatial data visualisation, and making high quality maps has again become a great professional concern (e.g. Ungvári et al. 2013, Gökgöz et al. 2015).

2 A BRIEF HISTORY OF CONTOURS

In the era before Digital Terrain Models (DTMs), contours represented the most valuable analytical means for a variety of tasks connected with terrains. Their role is changing, so that visualisation and human interpretation of terrain by map reading are the main purposes they serve today. Now, most professionals solve tasks connected with terrain analysis by using DTMs, and occasionally generate contours for visualisation purposes.

The history of map contours can be divided into three main periods:

1. the period of paper maps (up to the 1970s)
2. the period of contour digitalisation (up to 2000)
3. the period of DTMs (after 2000).

The period of paper maps was characterised by field surveying (usually of points) needed to interpolate contours (e.g. linear interpolation). Later, stereo photogrammetry was the preferred method for surveying terrain, as the user could draw contours directly from the stereo model. All analytical calculations (e.g. profiles, slopes, distances, volumes, lines of sight etc.) had to be done by reading and using the map (Figure 1). For the heights of points between contours, some type of interpolation was applied.

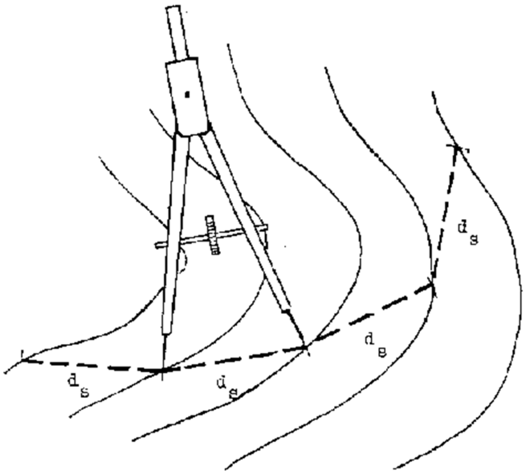


Figure 1: Drawing a Zero Line on a Contour Map with a Divider (FAO, 1998).

The second period, which started with the application of computers in cartography, was characterised by converting contours from maps into digital form, creating DTMs using interpolation methods. A number of interpolation methods were developed (e.g. Kriging, Inverse Distance Weighted, Linear, Splines etc.) but most of them treated contours as sets of points. Less often, an approach used in the analogue age is tried, for example, the algorithm implemented in GRASS GIS command *r.surf.contour* (GRASS GIS 2012) (Figure 2). It uses rasterised contours, and the same approach based on vector contours was tested in Kuveždić et al. (2008) (Figure 3).

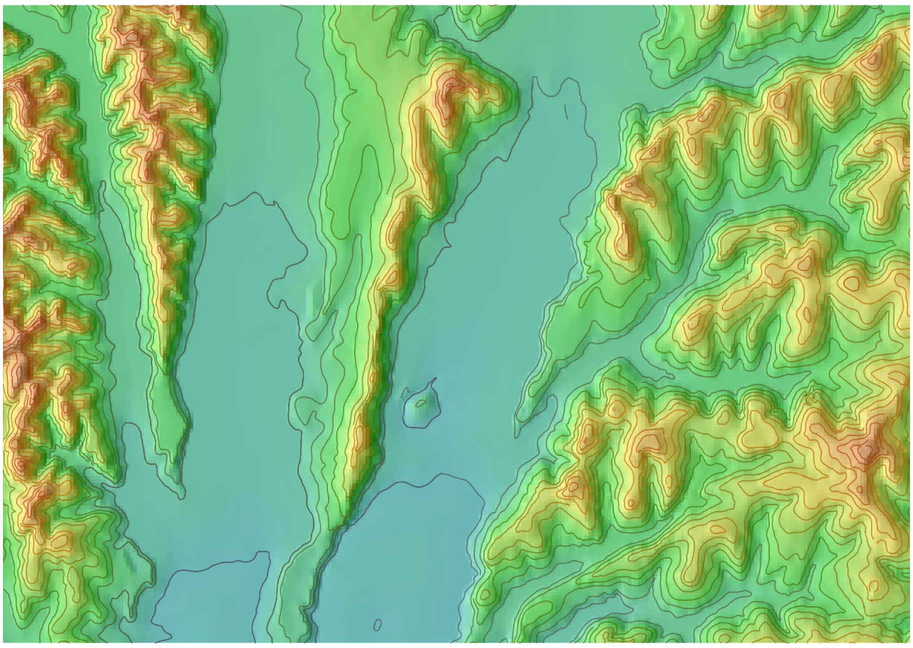


Figure 2: DTM obtained from rasterised contours using GRASS GIS function *r.surf.contour* which interpolates heights similar to manual methods from maps.

In this period, contours from maps were one of the primary sources of DTM generation. Alongside gridded DTMs, the Triangular Irregular Network (TIN) model was another way to create a DTM from contours while preserving the original data in the model. Many algorithms for solving tasks were developed on the basis of DTMs. In terms of surveying the terrain, there were no key advances.

The final period is characterised by new methods of surveying, primarily by remote sensing techniques based on radar (sonar) and laser sensors. A DTM is a direct result of measuring, and contours do not appear in the process of its creation. All traditional analytical tasks can now be solved directly using a modelled terrain surface, and generating contours is only one of them. The main purpose of contours is now the visualisation of the terrain and visual interpretation from maps (both digital and paper). Creating the contours for a certain map scale from high resolution DTMs involves the issue of the cartographic generalisation of contour lines (Figure 4).

Figure 3: A DTM overlaid with a topographic map. The vector contours from the topographic map were used as input for DTM generation by interpolation similar to manual methods from maps (Kuveždić et al. 2008).

Figure 4: Contours generated from a DTM with resolution of 25 m (blue) and contours on a topographic map in the scale 1:500,000, manually generalised from a larger scale topographic map (red).

3 THE NEW (OLD) ROLE OF CONTOURS

Understanding the principle of contours is widely accepted, since it is taught in geography lessons in elementary and high schools. For example, in Croatia, pupils are first introduced to contours in the third grade (at 9 years of age), and then again in the eighth grade (14 years of age). Nevertheless, a more thorough understanding of contours for terrain interpretation can only be achieved by studying certain disciplines, e.g. the military, urban planning, engineering, geography, geodesy, etc., and is provided by higher education institutions or specialised courses. The general population is probably not very familiar with reading contours. Mainstream internet world maps did not at first include contours as primary features, and often still do not provide them, by default, or indeed at all. For example, in Google Maps, the user needs to configure the map in order to find contours in larger map scales. OpenStreetMap does not have contours, but there is OpenCycleMap, based on OpenStreetMap data, which shows contours by default in larger scales. It seems that contours still cannot be replaced when it comes to interpreting the terrain for most outdoor activities that require maps.

Map graphics should meet various demands, of which the three principal ones are legibility, easy reference and accuracy. In addition, map graphics should meet the demands required of any graphic presentation, including maps. The following are the most important to map graphics: clarity, aesthetic quality and reproducibility (Frangeš 1998).

4 ALGORITHMS FOR CONTOUR GENERALISATION

Most of the available generalisation algorithms which are used for contour generalisation (especially the most widely accepted and implemented Douglas-Peucker algorithm) are concerned with producing a less detailed representation by reducing the number of points. The success of the results obtained is usually addressed through an analysis of legibility and accuracy. Algorithms which tend to focus on these demands and aesthetic quality at the same time are rarer.

The manual cartographic generalization of contour lines is a time-consuming process in map-making. While the algorithms of GIS software have partially solved the problem, there is still a lack of adequate aesthetics required for maps. Recently, Ungvári et al. (2013) compared two methods of line generalization, the conventional, and the well-known Douglas-Peucker algorithm, with a statistical method, the linear regression, and its use in line generalization. The authors then replaced the simplified polylines with Bézier curves to achieve the appropriate aesthetic requirements. They concluded that automatic generalization methods cannot replace human thought processes, therefore they may never be perfect, but they can help reduce working time.

Most of algorithms, including the presented one, fall into a group of geometrical operators for contour generalisation, which selectively filters contour lines. For more advanced contour generalisation, heuristic approaches are developed. Contours are no more treated only as a set of geometries, but as features composing the terrain. Generalisation is then composed of more interconnected individual operators that allow us to model constraints related to the purpose of the map and the relation with other objects portrayed on the map (Guilbert et al. 2014). One example when special constraints related to the map purpose are of the utmost importance, is generalisation of isobaths on nautical charts. It is crucial that depths depicted on a map are not deeper then real depths, leading to set of special constraints for such generalisation (Guilbert and Zhang 2012). Second example, when relation of contours with other objects on the map is important, is portrayal or river network. Rivers are considered to flow in direction of lower heights, but separate generalisation of contours and rivers can break this constraint. To preserve this property of rivers, as well as other objects relations, special constraints has to be defined and applied during generalisation (Gaffuri et al. 2008).

5 AREA PRESERVATION APPROACH TO CARTOGRAPHIC LINE GENERALISATION

At the Institute for Cartography, Photogrammetry and Remote Sensing of the Faculty of Geodesy, University of Zagreb, research was carried out on this topic. Through an analysis of manual contour generalisation on topographic maps, a new approach was developed. First, it was proved that in manual generalisation, areas inside contours tend to be preserved across a wide range of map scales (e.g. 1:10,000 to 1:1,000,000). Contour lengths are shortened in smaller scales, so logarithmic function is a good choice for modelling the functional relation of the contour length and map scale (Tutić et al. 2007) (Figure 5).

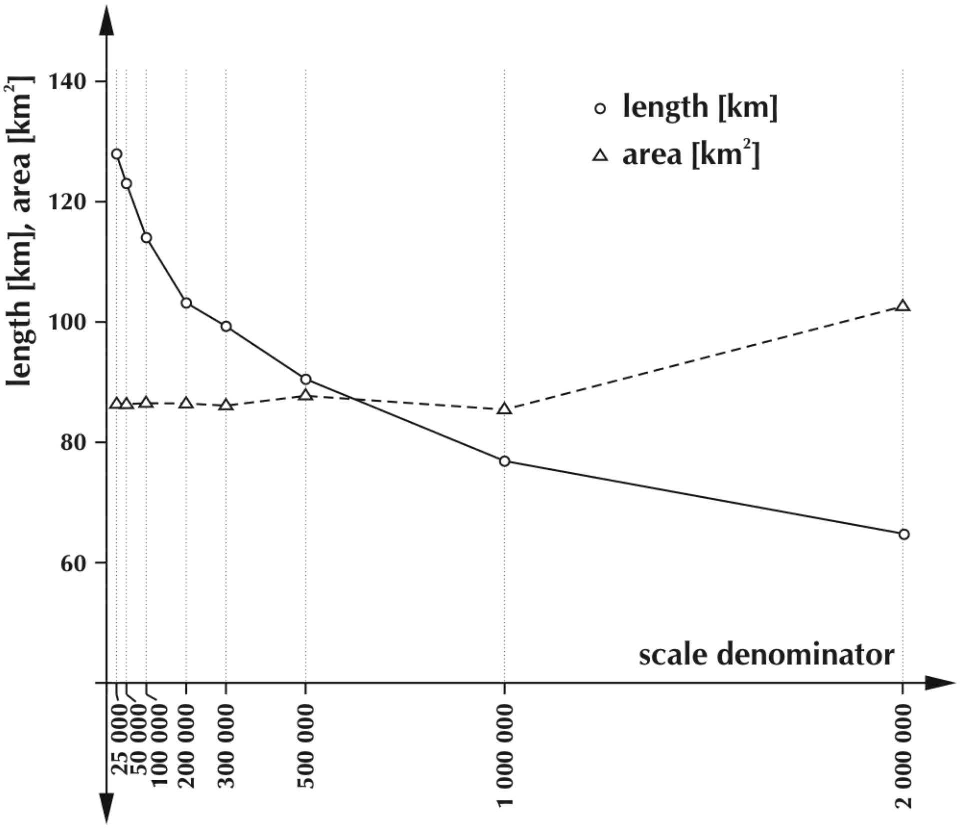


Figure 5: Area and length change of contour line with map scale on manually generalised topographic maps (Tutić et al. 2007).

An algorithm for line simplification which preserves areas was designed (Tutić and Lapaine 2009). It has been shown that this approach can yield good results, but as with any simplification algorithm, it can result in lines which are not acceptable aesthetically.

The next step was to design an algorithm for line smoothing, again with an area preservation property. These two algorithms combined should yield more plausible (and accurate) results (Tutić and Lapaine 2010) (Figure 6). Special care was paid to the parameters of the algorithms.

We decided that the user (or system) should give only one parameter - map scale. In order to do this, we used data from existing topographic maps to find a functional relationship between the map scale and the internal parameters of the algorithm. Line length was used as a parameter of this function (Tutić et al. 2009).

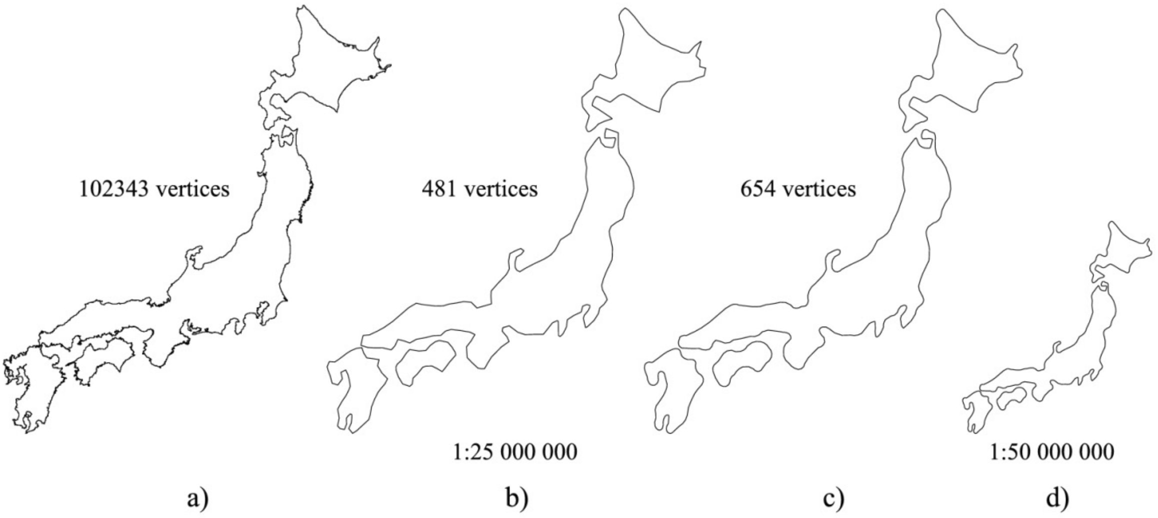


Figure 6: The application of the smoothing function to the generalized coastline of Japan's four largest islands of Japan; a) source polylines, *GSHHS – A Global Self-consistent, Hierarchical, High-resolution Shoreline Database* (NOAA 2014), level F; b) generalized polylines by an area preservation algorithm; c) smoothed polyline b by an area preservation algorithm; (d) polyline c in a more appropriate map scale.

Having defined both algorithms, the next step was to test them for map production. In order to reach map producers, the algorithms were implemented behind a WPS service, making it available to all systems with WPS clients (Tutić 2014). The showcase data used were GSHHS (Global Self-consistent, Hierarchical, High-resolution Shoreline Database), and data and generalised datasets for various scales were created and made available for download (Figure 7).

The first wider use of this approach was in the classroom. From the academic year 2013/14, students have been using it as part of the Digital Cartography course for the Master's programme in Geodesy and Geoinformation, via the WPS in QGIS. The task during 30 hours of exercises is to make a paper geographical map of one country in A4 format. The maps are usually in smaller scales, and contours are not usually represented, except for coastlines. However, all other linear features are generalised using this algorithm. For example, rivers can be seen as lines 'perpendicular' to contours. Administrative borders often follow natural objects which have similar geometrical properties to the contour lines. Roads or railways usually have fewer details, but again, generalisation usually leads to improved line shapes for the given map scale. Drawing geometrically and visually acceptable lines by automatic methods provides a good starting point for manual generalisation, or other automatic generalisation operators (e.g. correcting topological errors, displacement, filtering etc.). If the source data are very detailed, then generalisation also improves system performance, due to lower memory and rendering requirements. All this can save time, because there is less manual map editing of line features, leaving more time for other generalisation and map-making operations (Figure 8).

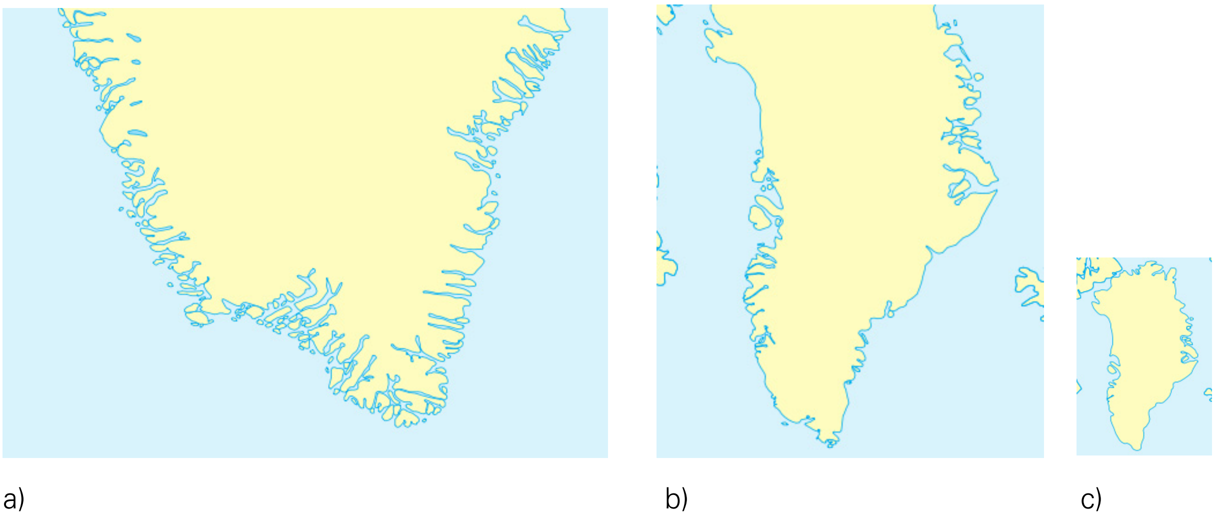


Figure 7: Greenland's coastline for a paper map at the scale of a) 1:10,000,000, b) 1:50,000,000 and c) 1:100,000,000.

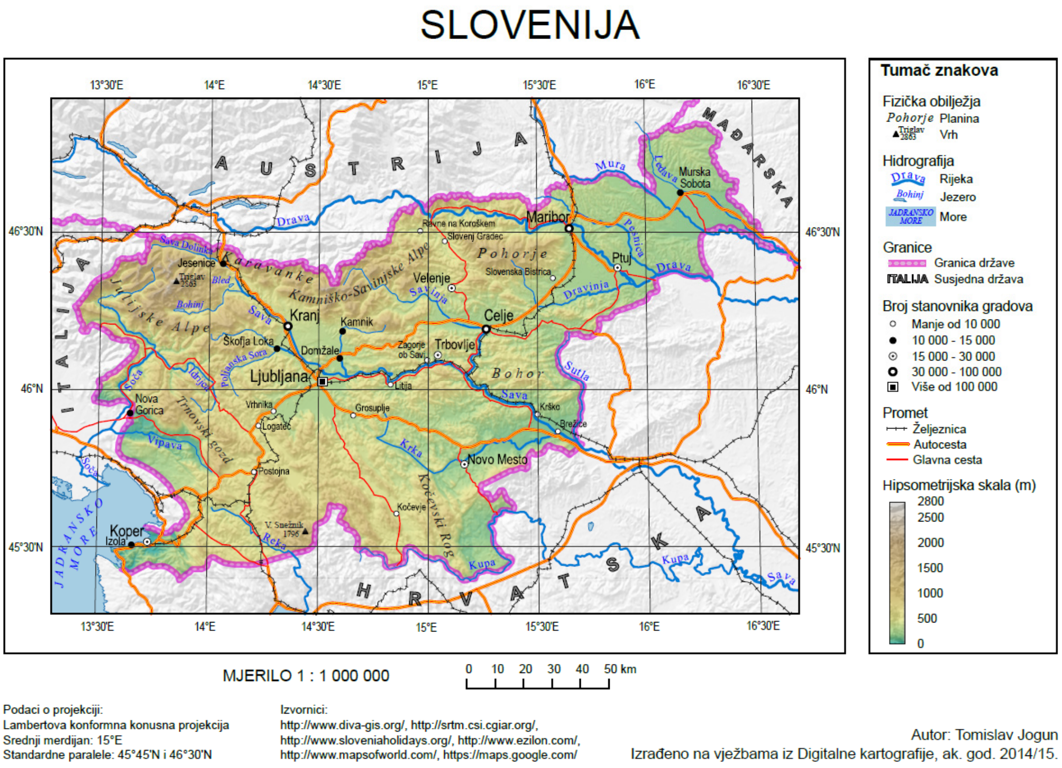
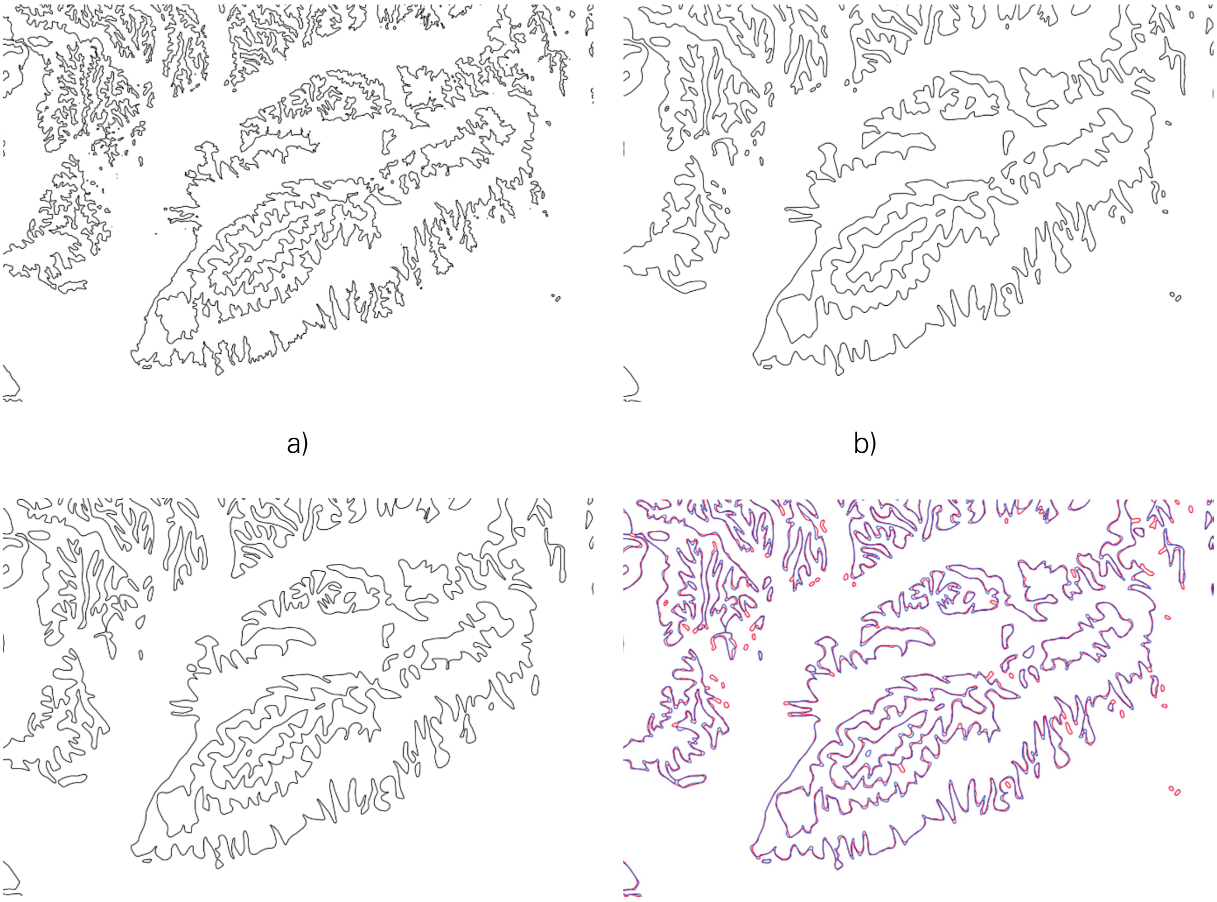


Figure 8: Example of a map, the result of 30 hours of student work during the Digital Cartography course. For the generalisation of line features, our algorithm was used over WPS.

Recently, an algorithm was also used for more demanding tasks, that is, contour preparation for official topographic maps of Croatia in the scales 1:250,000 and 1:500,000 from modern DTMs (SRTM and ASTER). The reference level of details and contour shape can be found on topographic maps from the analogue production process, when cartographic rules were applied by trained cartographers and map drawers. Relief is not subject to great deal of change over time, especially when represented on smaller scale maps. Therefore, one solution might be to use contours from old maps, with updates where necessary. In this case, this was not an option, due to a change in a vertical datum and the demand for different equidistance than the old maps.



a) b)

c) d)

Figure 9: a) Contours generated from DTM with resolution of 25 m (source data: SRTM and ASTER); b) contours on a topographic map in the scale 1:500,000, manually generalised from larger scale topographic map (source data: photogrammetry surveying from the 1970s); c) the result of automatic generalisation of a) using our approach; d) overlaid contours (b-red and c-blue).

Testing the success of automated generalisation was done by generating contours as for old maps and visual comparison. Adjustment of algorithm parameters was carried out, since the default parameters gave more detailed lines then those manually generalised. Figure 9 shows some of the source contours, the reference manually generalised contour, and the automatically generalised contours. It can be seen that the manually generalised contours have some exaggerated features (small peaks or valleys) and a few more 'shallow' parts representing valleys and ridges. The fact that some parts of the contour lines are too close to each other was detected as the main requirement for quality improvement (Figure 10).

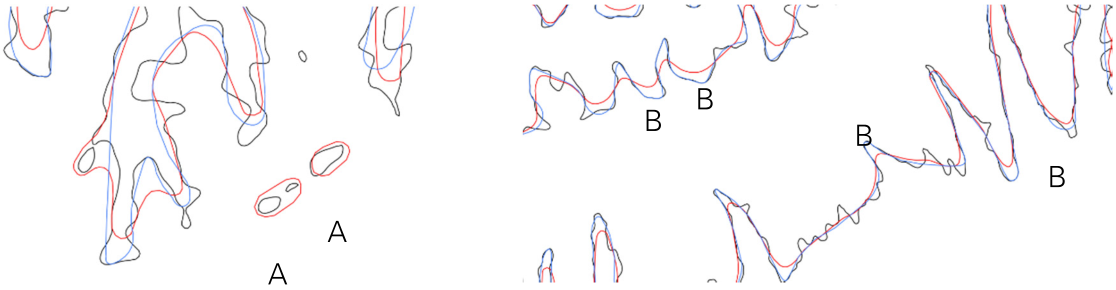
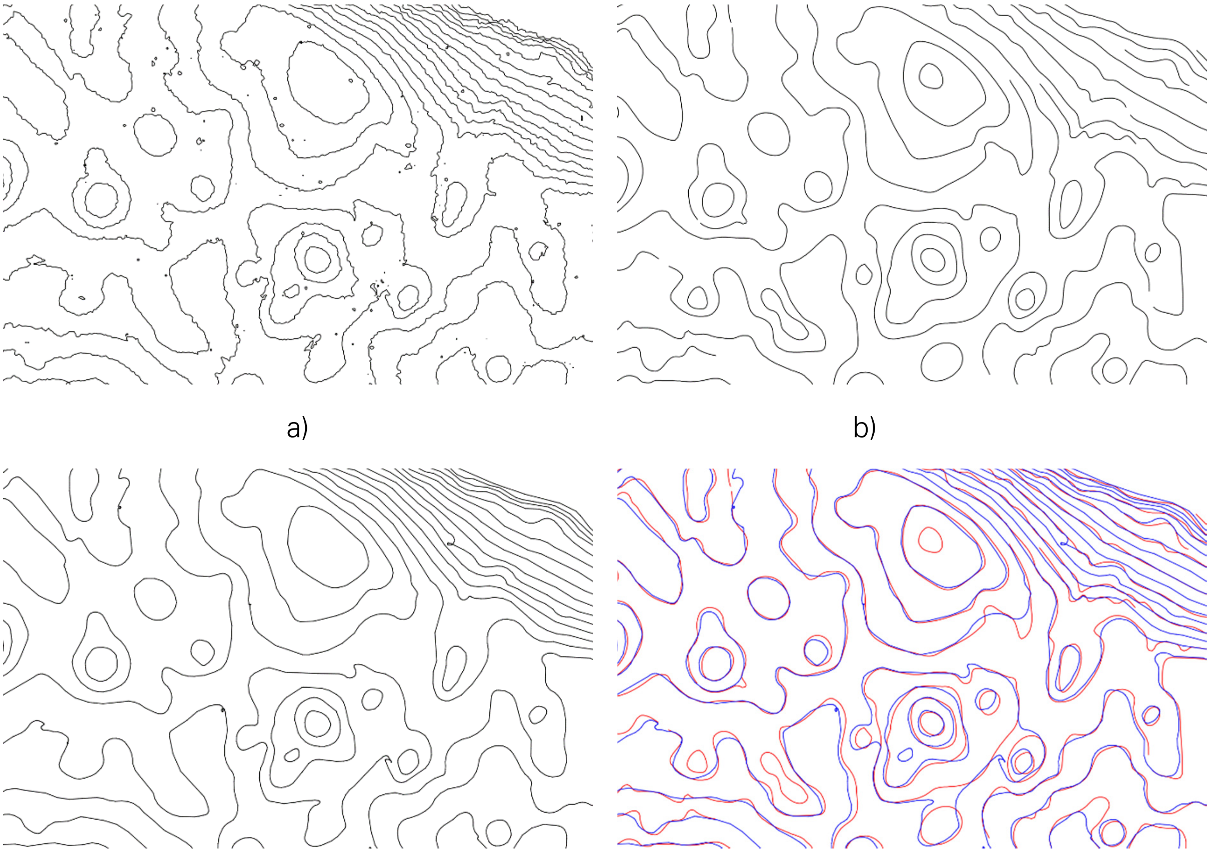


Figure 10: Comparison of manually (red) and automatically (blue) generalised contours. Better quality could be obtained if line parts could be exaggerated automatically, e. g. small contours representing pits or peaks (A), or narrow valleys and ridges (B).



a) b) c) d)

Figure 11: a) Contours generated from DTM with resolution of 1 m (source data: airborne LiDAR); b) final contours on an orienteering map at a map scale of 1:10,000, drawn by a map maker after field work using a) as background map; c) the result of automatic generalisation of a) using our approach; d) overlaid contours (b-red and c-blue).

Orienteering maps are special maps where contours are among the most important features. They are traditionally drawn by hand from several of the sources mentioned and field measurements. Lately, high density LiDAR data has become the primary source for initial contour generation, and again, quality contour generalisation is needed. A comparison of contours obtained from LiDAR data, final contours on a map, and generalised contours in Figure 11 proves that it can also be used in this demanding task, where it can reduce the costs and time required for orienteering map production.

From Figure 11 it can be seen that automatically generalised contours have good visual and geometrical properties, but for orienteering maps, the main demand is for good interpretation of terrain features while running, and for that reason, the shape and topology of contours must sometimes be quite different from those obtained by measurement, no matter how accurate the measurements are.

6 DISCUSSION

The main geometrical properties of the algorithms concerned have already been given in Tutić and Lapaine (2009), Tutić and Lapaine (2010) and Tutić et al. (2009). Here, we present a short overview of properties, advantages and disadvantages found during application.

Firstly, an algorithm preserves areas exactly. This precision is advantageous in some cases, but is not crucial to all applications. For example, when objects are filtered by a small area, this can be done before or after generalisation, with the same result. A more important consequence is that polygon objects will never collapse to lines or points, nor will areas enclosed by more than one line. When an object is maximally generalised, it will acquire a convex shape. If an attribute on a thematic map is calculated against the object area, the application of this algorithm will not entail storing the area values in the attribute table. Finally, manual generalisation tends intuitively to preserve the areas of objects (Figure 5).

Line parts that are monotonous, i.e. with no zig-zags in the segments, remain intact after generalisation. This means that circles, other convex polygons, or line parts do not change after generalisation. This improves the visual quality of lines substantially and represents a rationale of generalisation principles (Figure 12).

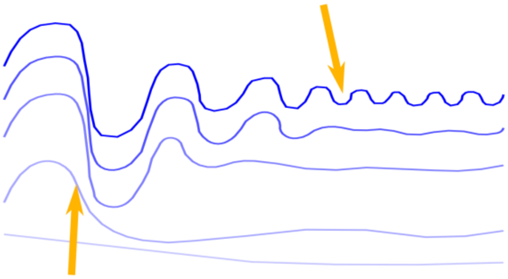
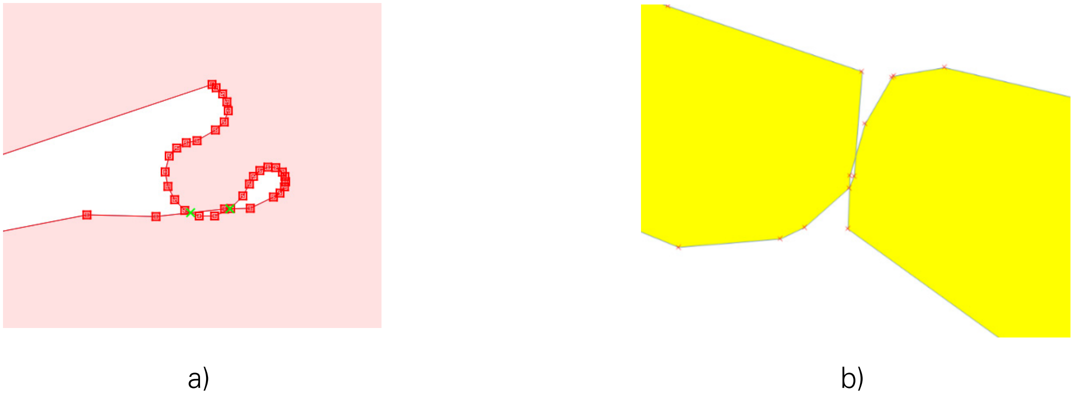


Figure 12: The parts of a curve large enough to be represented in the desired map scale remain intact.

We have already discussed some disadvantages of algorithms compared to manual generalisation. These requirements are not easy to define in algorithmic terms, since they fall within exaggeration operations. In this respect, it is not anticipated for now that automation will provide completely acceptable results.

Some other problems are common to most simplification or smoothing algorithms. For example, self-intersections may occur with lines that meander strongly, while intersections with other lines can occur when two lines are close to each other (Figure 13). Presented algorithms generate relatively small number of such problems, but they can occur in special cases of very close objects with a lot of details combined with generalisation for a much smaller scale than scale of original data. These topological issues can be resolved after generalisation using cleaning tools, nevertheless, they deserve to be considered during the generalisation process, as in some implementations in existing GIS.



a)

b)

Figure 13: a) Example of self-intersections generated by generalisation on part of Greenland's coastline; b) Example of intersection of objects generated by generalisation for a small scale map on Bosphorus.

7 CONCLUSION AND FUTURE WORK

In this paper, we have presented the application of an approach to automated cartographic generalisation of contours developed at the Institute for Cartography, Photogrammetry and Remote Sensing, Faculty of Geodesy, University of Zagreb. Two new algorithms have been developed, one for simplification and the other for smoothing, which are linked in one line generalisation operator with the property of preserving areas. The design of the algorithm and its parameters were controlled by the properties of manual generalisation.

In order to make algorithms available to the wider cartographic community, this was implemented as a Web Processing Service (WPS). Thus, any user with a WPS client in his preferred GIS software can use it. Despite the concept of WPS which offers the availability of a process to anyone interested, we assume that this is still not a widely accepted way of doing things among map makers and GIS users. For this reason, we decided to make it also available as QGIS plugin in the near future.

Despite the relatively good results obtained from our approach and proved in the applications discussed in this paper, the algorithm itself can be improved in a number of ways. First, it is desirable to establish the 'global' character of the algorithm, i.e. generalisation through intermediate map scales should give the same output as generalisation done once into the target scale (1:10,000 → 1:20,000 → 1:50,000 = 1:10,000 → 1:50,000). This is a useful property of Douglas-Peucker and Lang algorithms.

Second, the 'orthogonal' version of the algorithm, i.e. the preservation orthogonal (or other angles) while preserving areas is another way of improving it, with the simplification of buildings in mind. Third, improving the selection of positions of new points, since many solutions are possible (Tutić and Lapaine 2009), might lead to better line shapes, compared to the reference lines). And finally, bug fixing and the computational robustness of implementation could also be improved.

The current version of this cartographic line generalisation operator is available as a WPS (Tutić 2014), and the authors invite all those interested to test it and send their feedback or ideas.

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MOUNTAIN AND HIKING CARTOGRAPHY

NEW TOPO MAPPING

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ABSTRACT

The adoption of a new mapping projection and geodetic datum by New Zealand's national mapping organisation in the year 2000 provided an opportunity to improve the design of the basic topographic series, taking advantage of the technical and graphic innovations made possible since these series were designed in 1972.

In attempting to contribute to an improved topographic map design it was realised that there was potential for a privately published recreation series on an improved topographic base. NewTopo NZ Ltd was registered as a private company and the first two maps published in 2004 – Wellington Walks and Tararua Tramps. Although these maps were initially considered a success, lack of on-going sales indicated otherwise.

Some redesign and collaboration with a commercial printer using digital technologies has successfully expanded the series to the point that further financial investment is not required. The series now comprises 40 maps varying in scale from 1:30,000 to 1:130,000 on standard A1 and A3 formats each focussing on a specific track or area.

An attractive presentation enhances communication. The balance between the map elements in their diverse graphic environments is carefully controlled. An evolving and dynamic specification has encouraged innovation in the portrayal of the landscape, the development of iconic symbology, and improvements in legibility. The details of these issues are illustrated and discussed.

NewTopo's business model and its relevance to the New Zealand map market is discussed briefly.

Keywords: topographic mapping, mountain cartography, map design and publishing, New Zealand.

1 BACKGROUND

When our national mapping organisation, Land Information New Zealand, was considering a new metric series shortly after 2000, I saw the opportunity to take advantages of changes in drawing and printing technologies to further improve the design and communication potential of our basic mapping.

Experiments with the presentation of topographic information, partly influenced by some European series, let to a design that enhanced the unique character of New Zealand topographic mapping. Although design contributions were rejected, this led to the realisation that a more thematic approach would be more effective for most users than an all-of-government general-purpose approach.

In contemplating the use and purpose of topographic maps there was the opportunity to change mind-set and rethink the information people really need in the mountains and to design a communication environment that encourages user engagement with the landscape.

2 THE BIRTH OF NEWTOPO

An advertisement seen in a GIS magazine many years ago for software designed "by cartographers, for cartographers" seemed promising. A strong collaboration has since been developed with the management and staff of Lorienne in Paris which continues to this day. They are friendly people with a brilliant understanding of graphic concepts and user needs. Conversion of LINZ's LSLIFF data to Lorik graphic files is as methodical and pedantic as one wants to make it – or not. First attempts at using this cartographic software were promising. Workflows and graphic design have translated potential to solid success.

A useful exercise was the development of a business plan in 2004. A Diploma in Business Administration was useful after all…! The objectives set at that time are still relevant:

- Setting a standard for digital cartographic products.
- Increasing financial return from a diminishing investment.
- Providing a promotional vehicle for Lorienne products in New Zealand.
- Indulging in some cartographic creativity.

The fourth of these objectives seem to have become the most significant. This quote was found useful at the time, and encouraged focus: *People who constantly react to the competition are not really concentrating on their own business.*

So, the new 'business' was focussed on, and mistakes were made along the way. These will be picked up throughout this paper.

3 Thinking

The scale range that suggested itself was around 1:75,000. In New Zealand, this is small enough to cover a useful area and large enough to give a reasonable amount of detail.

The exercise of re-thinking every graphic element was interesting and worthwhile. Questions were asked: who needs **what** detail and **why**, the semiology constraints, and the relative emphasis in the visual variables needed for the best legibility. It was thought that the maps, though thematic in character, needed to look like, and be as useful as, real large scale topographic maps. However, this has not been totally achieved in the smaller scale maps.

As an enthusiastic map user for 65 years I had confidence I knew what others would want... an accurate, comprehensive, quality product on synthetic paper. After an initial enthusiastic reception by Wellingtonians; I found I was **wrong** on several content and design points. It is now realised that this group of connoisseurs is a small corner of a niche market.

When the efficiencies of HP's Indigo digital offset press were introduced and an adjustment was made to both thoughts on design and the business model, an approach was developed that was appreciated by a wider market.

The maps now focus on areas of interest at scales between 1:30,000 and 1:130,000, to encourage people to walk in these areas in both safety and comfort; while also providing a reminder for identifying their photos... and to brag about where they have been, of course. All maps are GPS compatible, are on the New Zealand Transverse Mercator projection and are supplied in a robust clear vinyl wallet.

Several of the A3 series have been exceptionally successful. This is attributed in part to the coverage and design, but more specially to identifying the best retail outlet with enthusiastic sales staff.

4 DESIGN OF THE A3 SERIES

The object of the design was to produce an attractive, uncluttered map with a high degree of legibility. Principles to achieve this had been established over many years and could now be practiced. (Aitken 1972). An A3 one-sided format presents compromises in both area and scale. Recently several have been designed that are two-sided – either with a small overlap or with details continuing over the edge of the sheet. This enables a larger scale to be used, enhancing utility and legibility.

The shape of the 'area of interest' dictates many layout features. In some cases, splitting the reference panel away from the title panel has the advantage of showing part of the map below the title panel to entice the potential buyer to open the map. Pretty title panels with postcard photos and other illusions may be attractive; but are not always honest. It is observed, however, that the NewTopo title panels are rather boring. The map name and the appearance of the face of the map should be the attractive 'grab me' points.

As a 'thematic' map it is easy to balance the recreational theme with the geographic context to provide a map with a high degree of legibility. A judicious selection of detail is made, rather than adopting everything from the topo database without judgement of its value in its context. This helps reduce visual 'noise'.

Another factor which aids the legibility and clarity of the image is the sparing use of black. It is contended that the over-use of black 'kills' other colours and reduces the available contrast range, so a minimum of black tints or text is used on the maps. Small percentages of black are, however, used in some coloured text to improve contrast.

As well as the common graphic components described by Bertin: point, line, area, and text, the maps have a detailed relief produced by Geographx in Wellington. Not only is the relief specification precise in its pixel size, and flat area and deepest shade percentages, the image is only produced and printed in cyan, magenta and yellow so that it is an integral and integrating part of the map image. Typically, a 20m pixel is used, with flat areas being 10C, 7Y, 7M (noK) and deep shadow 45C, 39M, 38Y (noK). Again: black is avoided because it lacks transparency and kills other colours.

5 COMPILATION

The internet gives access to the detailed aerial imagery of regional authorities, maps and diagrams from the Department of Conservation (DOC), and many other sources. In a few cases NewTopo has been fortunate enough to have the assistance of individuals with specific knowledge, and (occasionally) GPS traces to improve the positions of tracks. DOC field staff are asked to check proofs for accuracy and completeness, but some also try to influence the design towards former DOC specifications (!).

Selected detail is culled from the base data, particularly spurious spot heights that add more clutter than information. Some names are added from other publications. Māori dialect variations also present a challenge which can be resolved using the United Nations' 'donor-name' principle. Many tribes have had a number of place and feature names embedded in their treaty settlements. These need to be preserved correctly. Local iwi have been approached where there seemed to be an unnatural lack of names, but this hasn't been successful.

6 DRAWING

For a '60s' cartographer this is the most rewarding activity – fun really. Several days' work is required re-positioning text to avoid conflict, the curving of river and range names etc. This is easy: a pleasure, and very rewarding. The title and reference panels, and the labelling of grid and graticule values, are simple and routine. The symbol and text variations between the publication scales are effected by importing style sheets which have been developed earlier.

7 SYMBOL DEVELOPMENT

In the topographic map symbol design of today there is evidence of map reproduction technologies that are 300-year-old. Some of these symbols are considered classic, and shouldn't be touched or improved. **This attitude is thoughtless and lazy!** Every generation has to learn what these symbols stand for because the symbol image does not always lend itself to intuitive recognition or decoding. Everything in communication can be improved using contemporary technologies for the current social environment.

Cartography has always adopted and adapted relevant technologies (Aitken 2006). We should reconsider 'classic' symbology in the light of the graphic freedoms now available, with some regard for the map users of tomorrow. We **can** and *should* do better – or be left behind as historical artefacts.

Recognition of new needs and technical graphic solutions are very important. Emulations of old technologies' limitations need to be recognised and eliminated.

A case in point is the firmly embedded use in medium scale mapping of the 'shark's tooth' symbol for a cliff, river terrace or escarpment. Not only is it necessary to explain to new users what the symbol means, but also why it looks as it does. The symbol, being usually in black, is more prominent than the feature deserves and does not integrate with the physical relief image.

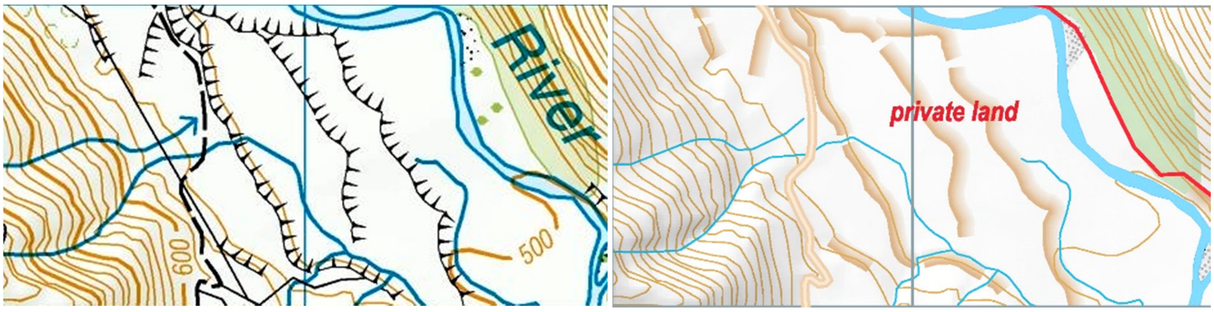

Figure 1: River terraces – left: traditional symbol (Topo50 sheet BU23 enlarged 185%), right: an alternative presentation (NewTopo Lake Sumner enlarged 140%).

A 'belief', perhaps rediscovered, is that *continuous* lineal features should be represented by *continuous* lines. The use of pecked or broken lines to represent foot tracks and vehicle tracks does these features a disservice as they are continuous features on the ground. The limitations of previous technologies used the pecked or broken line symbol to extend the available range of symbols, but this device is no longer necessary.

As a firm believer in **evolution rather than revolution** when it comes to communication development of any sort, it is satisfying to see several small symbols introduced into the new Topo50 series that are simple, subtle and intuitive.

8 Fonts

NewTopo text fonts are basically the Arial family with two others used for emphasis or de-emphasis. A year ago, I became dissatisfied with Arial and explored some of the wealth of digital alternatives now available. This led around in a circle, which validated the original choice, with the exception that variants of Segoe have been adopted for hydrographic features.

During this exploration, I came across a paper by Raposo and Brewer (2013) describing the use of double halos for road names in variable graphic contexts. This works really well for hydrographic names where the background can be dark or light from the relief shading, confused by contours, variable with ground cover, or flat as with lakes and oceans.

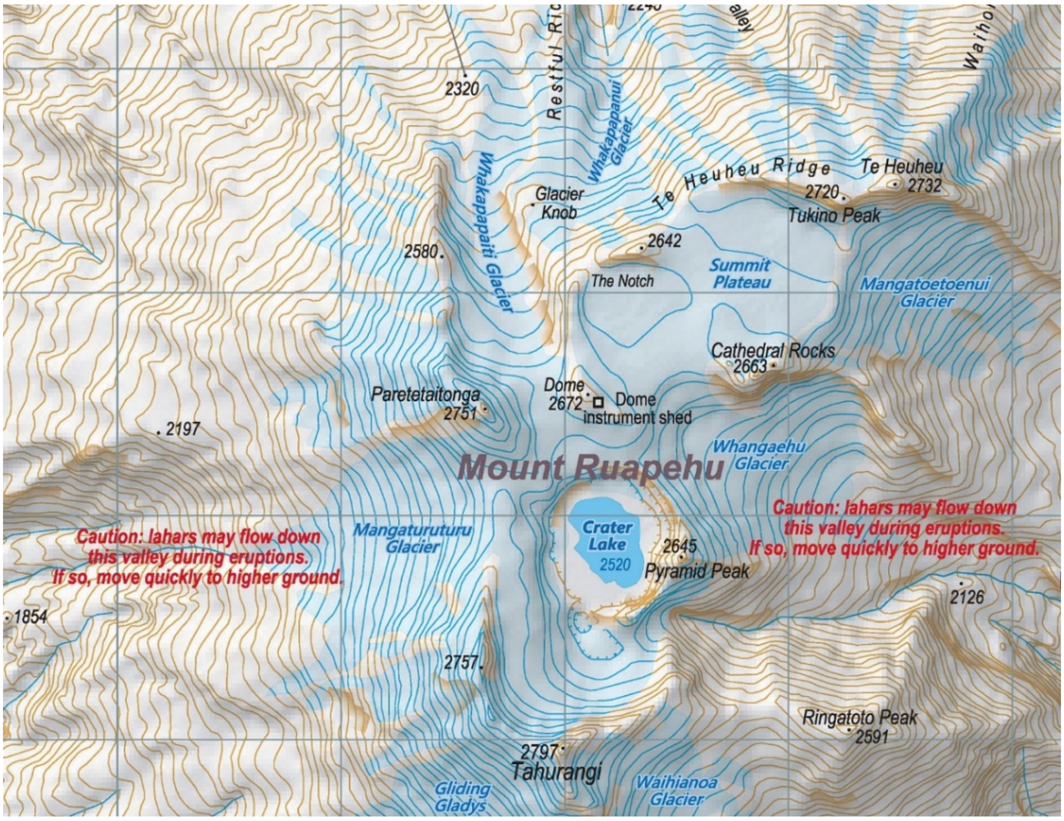

Figure 2: Text with a small halo illustrating the effect of different shaded backgrounds.

9 PRINTING TECHNOLOGIES

No map can be successfully designed without knowing the reproduction technology to be used in publication or promulgation.

The HP Indigo digital offset printer mentioned earlier is a high-speed printer which revolutionises the small format printing technology and is the forerunner of similar larger machines. The Indigo prints a complete map in one pass and the colour sequence and many other variables are all computer controlled, variable, and easily repeatable. Four-colour printing and an infinite colour palette present temptations that have to be managed if legibility is to be optimised. Pre-press is simple. Digital all the way…

Large format maps are produced similarly, but offset printing plates are made digitally in an automated plate maker and again, all printing variables are computer controlled. The process is very smooth. Unfortunately, it is hardly worth going to pass the print run on either machine. But the temptation is still there...

The results of offset printing are far superior to any proofing system.

10 PRINT MEDIA

The A3 maps are printed on 113gsm Sumo K Matt paper or 124gsm Polyart, and the large format maps are either printed on 90gsm Polyart synthetic paper or on 94gsm high wet strength paper. All inks are fade resistant. The characteristics of the paper, both for printing a fine dot and folding without tearing, are important.

The finished maps are trimmed and folded to 120 x 210 mm, and offered for sale in clear vinyl wallets. Short print runs ensure that reprint or revision options are considered regularly, but increase the unit cost.

11 PROMOTION

Several ways of promoting new publications have been tried unsuccessfully, including: outdoor magazines, the FMC Bulletin, letterbox drops, leaflets on windscreens, and free samples to tramping clubs, transport operators etc. None of these have been noticeably effective. The website draws interesting comment from far-away places – but only a small number of individual sales.

The most effective influences on purchase seem to be the enthusiasm of the sales person and to a lesser extent point-of-sale displays. In an effort to stimulate repeat sales a small card with a map index and selected sales outlets is inserted with the map in every vinyl wallet (Figure 3).

In recent years, the sales of some DOC Visitor Centres have eclipsed those of specialist map shops several times over.

NewTopo supplies maps to about 50 retail outlets in New Zealand, one in England, one in Australia and one in the USA.

12 THE WEB

Having a website has been a learning curve too…www.newtopo.co.nz.

Although the website has now been developed professionally, its effectiveness isn't helped by the variance of display and function between browsers and devices. The website includes a graphic index, comprehensive details of each map on separate pages, known errors, and a list of retailers. Purchase of maps from the website using PayPal is growing and has added an interesting international dimension. Internet sales are around 300 maps per year – about 5% of total sales.

13 ALTERNATIVE PRODUCTS

When the Wellington Walks and Tararua Tramps maps were published in 2005 a mini-CD was offered at cost so that the map images could be loaded onto computer and small sections enlarged and printed for personal use. This did not meet a market need and was discontinued.

From time to time requests are received for images for use with GPS programmes. Not long ago there was a request from Dart River Jet Safaris in Glenorchy, near Queenstown, for a composite image from three maps. This was surprisingly successful.

The introduction of the iPad and other similar devices suggests that these may be an innovative reading device for digital cartographic artefacts in map libraries and research. (Aitken GD, GV O'Malley, HE Macfarlane 1993). However their field applications may be restricted to fine days.

Experience suggests that it is important not to become obsessed with a single production technology (as the author may have) or a single output media or market segment, so consideration of alternative products is an on-going area of interest.

Figure 3: Overview of topographic maps published by NewTopo.

14 THE MARKET

Contrary to some people's expectations, GPS and other technologies have not superseded the need for a paper map in the field. Maybe it never will. Last year a mountaineer visiting New Zealand from Europe found himself in a difficult situation after transferring a map to a handheld device and using it so much his batteries went flat. Local Search and Rescue personnel were not impressed.

This incident highlights the need for paper copies of maps in spite of technological advances in other communication fields. This view is confirmed by research indicating that reliance on GPS technology may negatively affect how our brains function. Reported by Joan Raymond of msnbc.com.

The map market has changed considerably since the 80s (Aitken et al. 1985); as has the number of players. The split of the cartographic centre-of-excellence which was a core part of the Department of Survey and Land Information, and subsequently became parts of Terralink International and Land Information New Zealand, and subsequent events, has left opportunities for client mapping services and commercial publication that have rarely been taken up.

In 2004 an opportunity was foreseen for well-focussed user-oriented up-to-date and attractive mapping, between the full public take-up of the future Topo50 series, the aging of the old Terralink series (on NZMG), and the demise of DOC's perception of its responsibility for National Park mapping. The adoption by Government of the NZ Transverse Mercator projection was a factor, too. This opportunity has become concrete although it has taken several years for the market and NewTopo to converge.

The best advice on which areas to map and publish has been received from visitor centre sales staff who are in direct contact with the public: market intelligence. A perceived need does not always translate into sales.

Pricing is a vital part of the business model. As with most fledgling businesses NewTopo lost money at the beginning, probably through having products that were seen as too sophisticated and too expensive – including making maps available on mini-CD. The stage has now been reached where income from sales can be recycled, and a 'breakeven' point achieved. The business model is not a commercially viable one but it achieves the original objectives.

Figure 4 illustrates the growth of sales since the first two maps were published in 2005. Sales appear to have reached their peak.

It can be seen that even though the number of maps has increased, the sales per map has remained static. Some maps which have not sold well will be withdrawn from sale as the edition becomes old and changes are reported by users.

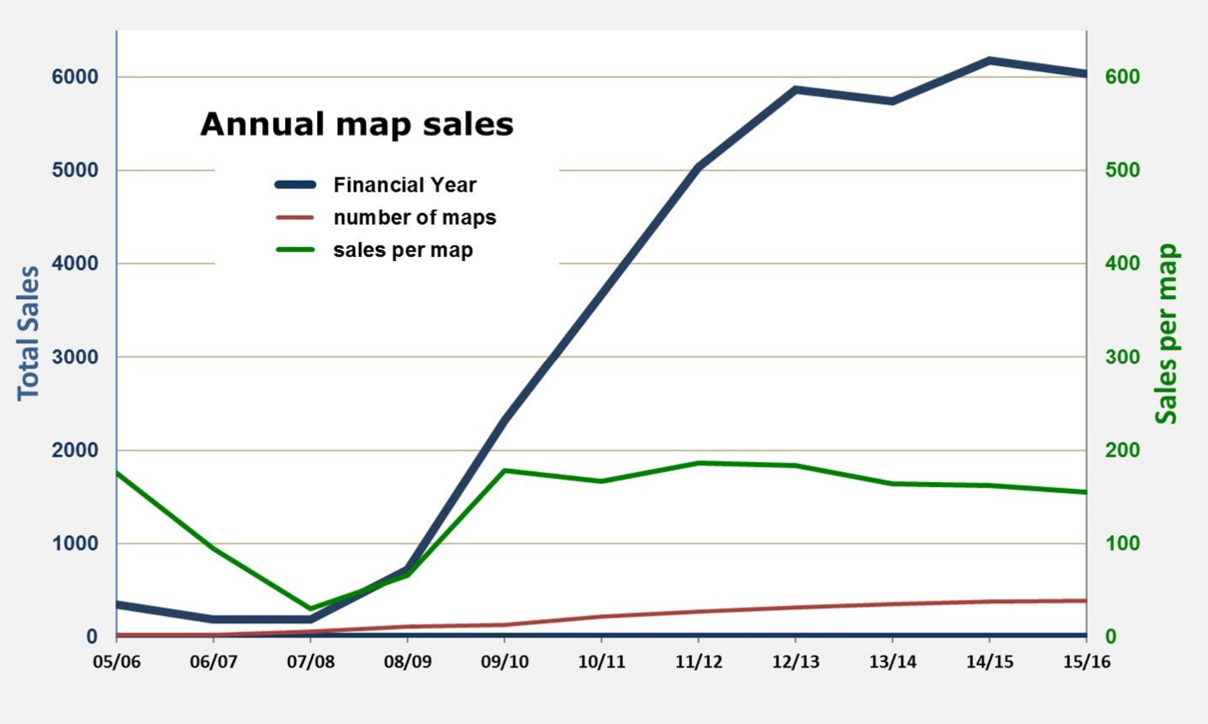

Figure 4: Annual map sales.

Sales are seasonal, retailers stocking up before the Christmas holidays and through summer but more cautious through the winter months. This can be seen on the following graph below (Figure 5).

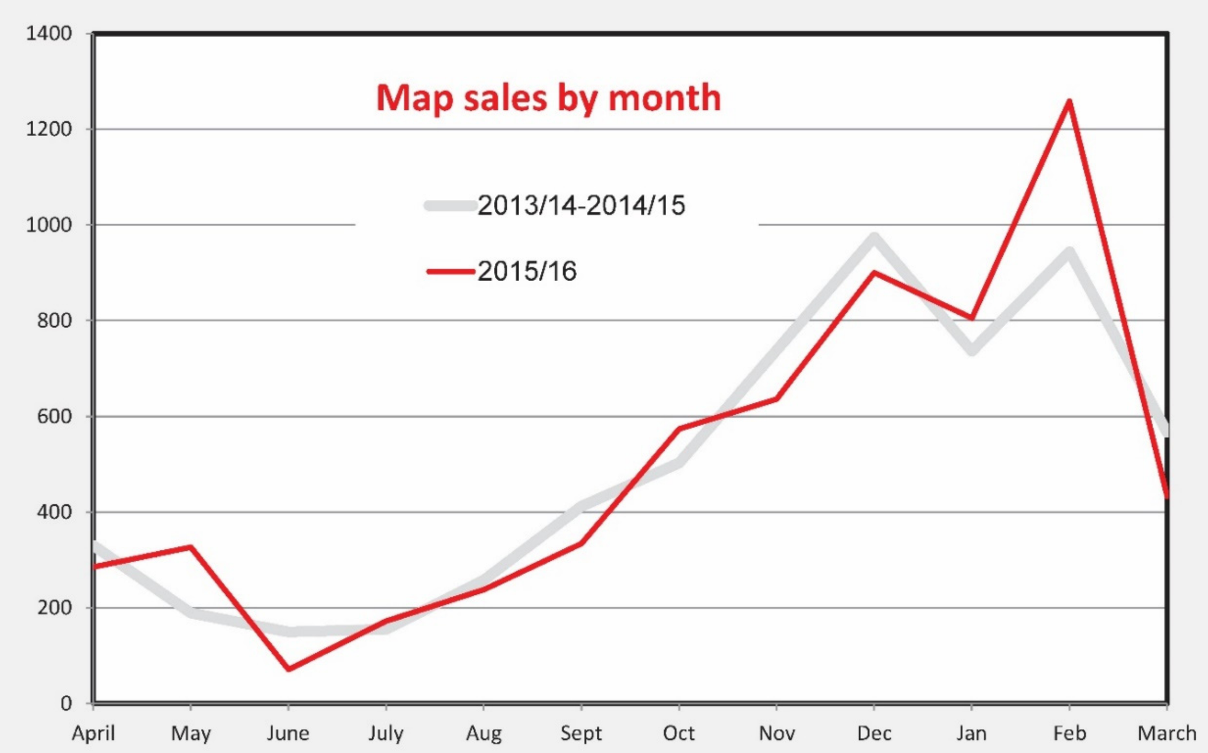

Figure 5: Map sales by month.

It is difficult to get…

the **right product** in

the **right place** at

the **right time** at

the **right price**.

About half of the 40 NewTopo maps could be considered to be commercial failures.

15 THE FUTURE OF PRIVATE TOPOGRAPHIC MAP PUBLISHING

In a time of change, as we have now, there are opportunities for success as well as failure. Previously, a comprehensive recreational map series was published by the Department of Survey and Land Information, with considerable input from the Department of Conservation (DOC). The separation of the 'information' and 'commercial' activities of DOC, as it currently functions, provides commercial opportunities for a variety of narrow focus map products. Certainly, the changes in national mapping – particularly the changes to datum and projection – have helped the situation by reducing the usefulness of older maps.

Other opportunities may be developed as they present themselves. Many will require sponsorship or some other business model to be commercially viable. The growth of both recreational and competitive mountain biking presents some graphic, production, and distribution challenges to replace the sketch maps that are currently used.

Historic 'rail trails', the Te Araroa trail, and the national cycle trail also merit focus. The introduction of the smaller-coverage Topo50 sheets in 2009 has increased the number of intersections of four sheets, and if these intersections cover areas of interest or major use there may be opportunities for montages of the four Topo50s at the same scale.

16 SUMMARY

This paper has described the development of NewTopo (NZ) Ltd over the last twelve years. Mistakes in concept and execution are revealed as well as the attention to detail that ensures an integrated and successful map image. It is clear there will be opportunities for future topographic publications by the private sector in New Zealand, but their commercial viability is uncertain.

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MOUNTAIN AND HIKING CARTOGRAPHY

THE CANADIAN NATIONAL TOPOGRAPHIC DATABASE AND MOUNTAIN CARTOGRAPHY

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ABSTRACT

The mapping of Canada at 1:50,000 scale was completed in 2012, with the last map sheet located in the Arctic Cordillera. All 13,377 map sheets comprise the National Topographic DataBase (NTDB), and are freely downloadable as scanned raster maps and vector layers. The map sheets display standard topographic cartography with contour lines and forested vegetation, leaving scope for cartographic enhancements in mountain areas in western and northern Canada. These include the incorporation of shaded relief with other layers such as glaciers and forest cover, hypsometric tints, alternate contour design and non-forested layers especially ground cover in alpine and arctic environments. This process is illustrated for three map sheets in western and northern Canada representing portions of the three primary mountain chains - the Coast Mountains, Rocky Mountains, and Arctic Cordillera.

The first area is on Axel Heiberg Island, in the Arctic Cordillera. This area is heavily glacierised with limited glacier retreat, and only small patches of tundra vegetation. The second area includes two outlet glaciers of the Andrei Icefield in the Coast Mountains of British Columbia. Historic glacier extents date back to 1965, inviting techniques to depict multiple date extents. The third area is centred on Mount Robson, the highest point in the Canadian Rocky Mountains. In all cases, satellite images can be used for geovisualisation and to create non-forest vegetation cover which can be important both for wildlife and outdoor enthusiasts.

Cartographers and educators are encouraged to utilise this extensive database for map production and cartographic exercises.

Keywords: hillshading, topographic database, glaciers, GIS, alpine, remote sensing

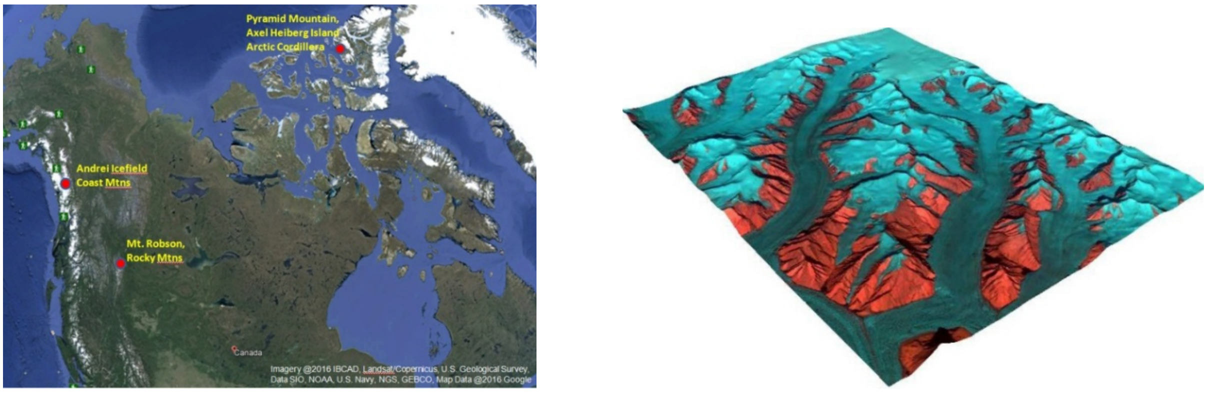
1 INTRODUCTION

Prior to 1945, much of Canada's topographic mapping in mountainous areas was based on oblique aerial photography captured from mountain peaks and employing the photo-topographical method described in another paper in these workshop proceedings (*Michael J. Fisher: Deville and Laussedat: France's contribution to photographic surveying in the Canadian Rocky Mountains, 1885-1924*). Following the Second World War, Canada endeavoured to complete the country's National Topographic System (NTS) at scales of 1:50,000 and 1:250,000, a substantial task for the world's second largest country, but enabled by the postwar return of airplanes and personnel. The 1:250,000 series was completed in 1970 (Nicholson and Sebert 1981), and the 1:50,000 series for the provinces by 1995. The remaining parts of the Arctic Islands, were completed in 2012 through the Northern Mapping project incorporating RADARSAT, SPOT and Landsat imagery (Clavet 2011).

The Canadian National Topographic DataBase (NTDB) contains digital versions of all 13,377 1:50,000 map sheets. These include vector layers: e.g. roads, hydrography, contours, forests etc., along with georeferenced raster map scans, DEM/DTM and Landsat ETM+ satellite images for each map sheet. These data are freely downloadable from the Geogratis website *(http://geogratis.cgdi.gc.ca)*. Geogratis also offers a more recent DEM (2000) option from the Shuttle Radar Topographic Mission (SRTM).

Conventional printed map output for the 1:50,000 NTS map series present standard topographic map design without the use of shaded relief, nor even colour in the case of some northern map sheets produced in the first decades after the Second World War. Prior to the digital era, the production of manual shading was overwhelmingly time consuming and expensive for such a large country, although it was applied along with representation of alpine vegetation in special projects such as those associated with glacier mapping in the International Hydrological Decade 1965-75 (Henoch and Croizet 1976).

This paper will show some simple examples how these data can be used to enhance cartographic depiction in Canada's mountain landscapes, incorporating the documented visual and perceptual advantages offered by the use of shaded relief (Castner and Wheate 1979). Locations and topography for the selected map sample areas are illustrated below in Figure 1.



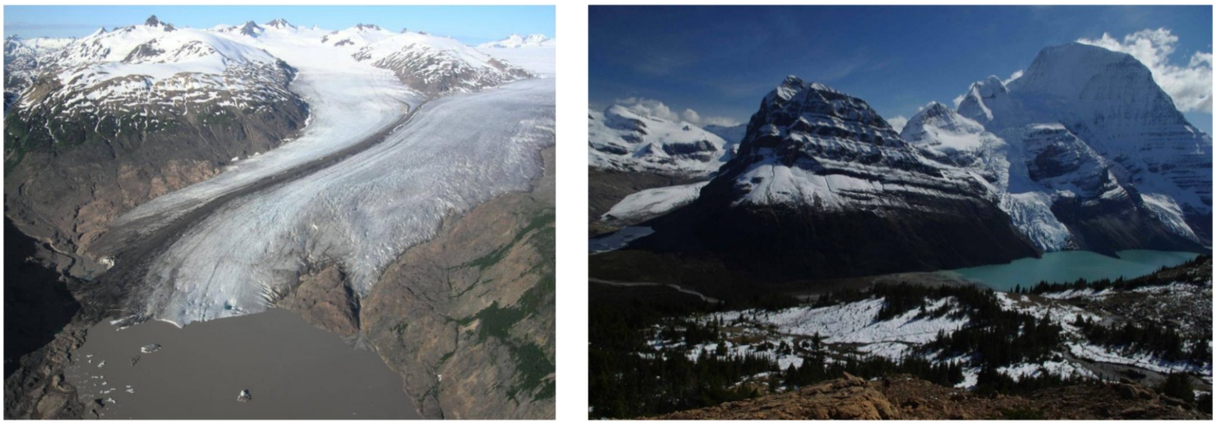


Figure 1: (top left) Google maps location for the three map areas; (top right) 3D perspective view of Pyramid Peak map area, Axel Heiberg Island with Landsat image overlain on DTM, viewed from southwest; (bottom left) Andrei Glacier, Coast Mountains, photo Laura Thomson; and (lower right) Berg Lake - Mt. Robson, Rocky Mountains, photo Roger Wheate.

2 ARCTIC CORDILLERA: PYRAMID PEAK, AXEL HEIBERG ISLAND (79.9ºN, 93.2ºW)

This area is extracted from the designated last topographic map sheet (059H12) to complete the NTS maps, incorporating Pyramid Peak. Mostly ice covered, it includes some lakes and small patches of tundra vegetation, or tussock grass (Figure 2). The map and image are supplied in the local UTM zone system, while vectors and DEM are geographic and need to be reprojected. It is sometimes easier to reproject the contours and generate the DEM from these to avoid raster artefacts. The following steps are then taken, using GIS software tools:

- Generate shaded relief (hillshade) from the DEM.
- Intersect the map extent with the ice layer to create non-ice areas as polygons.
- Intersect contours and ice (or non-ice) to create two contour layers for ice and non-ice.
- Separate index and non-index contours to apply different line thickness.
- Include vegetation by creating a vegetation index threshold from the Landsat image.
- Apply contour labels using 'minimum length' criteria to avoid too many labels.
- Combine these layers for map output and enhance cartographic labelling (not shown) as required, along with secondary map embellishments.

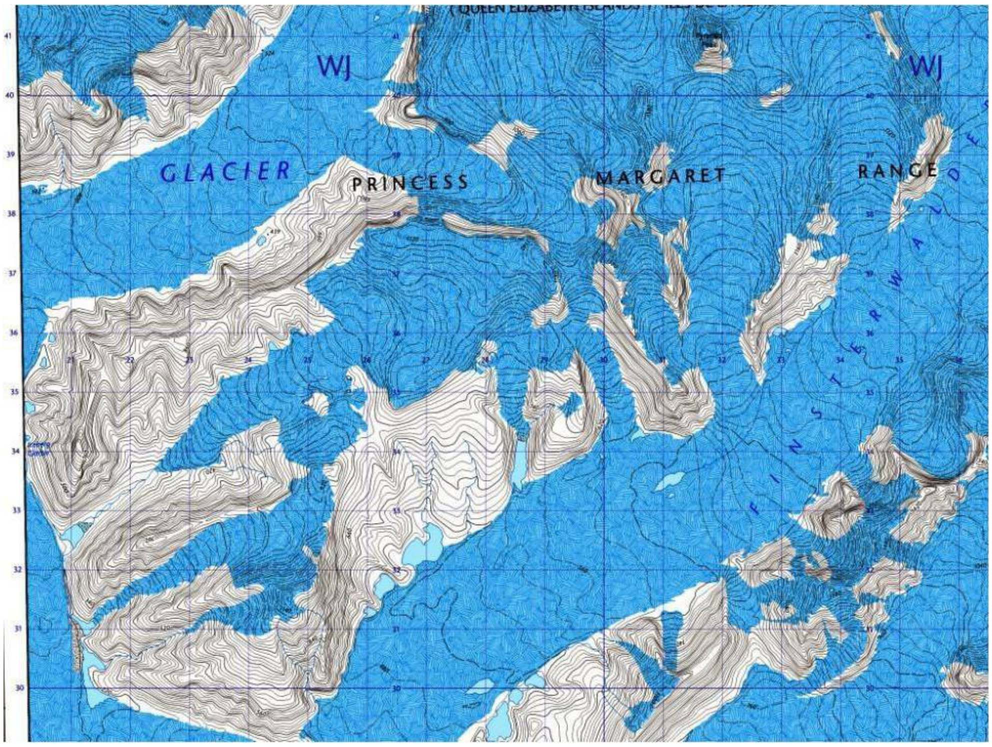


Figure 2a: Portion of scanned map sheet, Pyramid Mountain (2012); the UTM grid shows 1 km squares for scale, also in Figures 3-4.

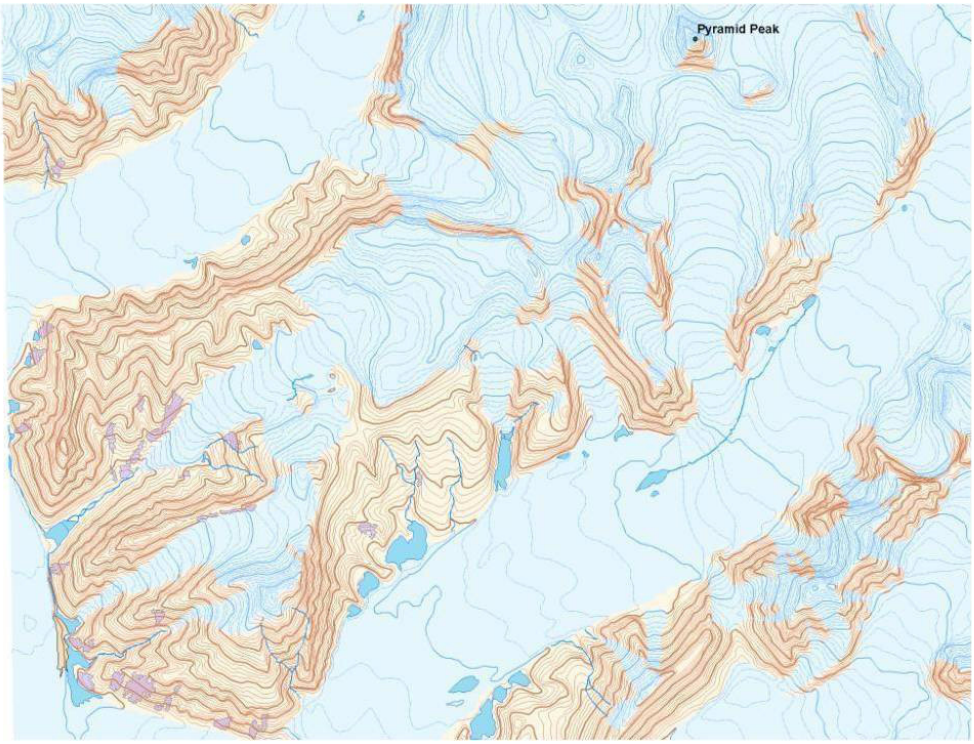


Figure 2b: Separation of ice-free land and contours in brown from ice and contours in blue, with vegetated areas shown in purple.

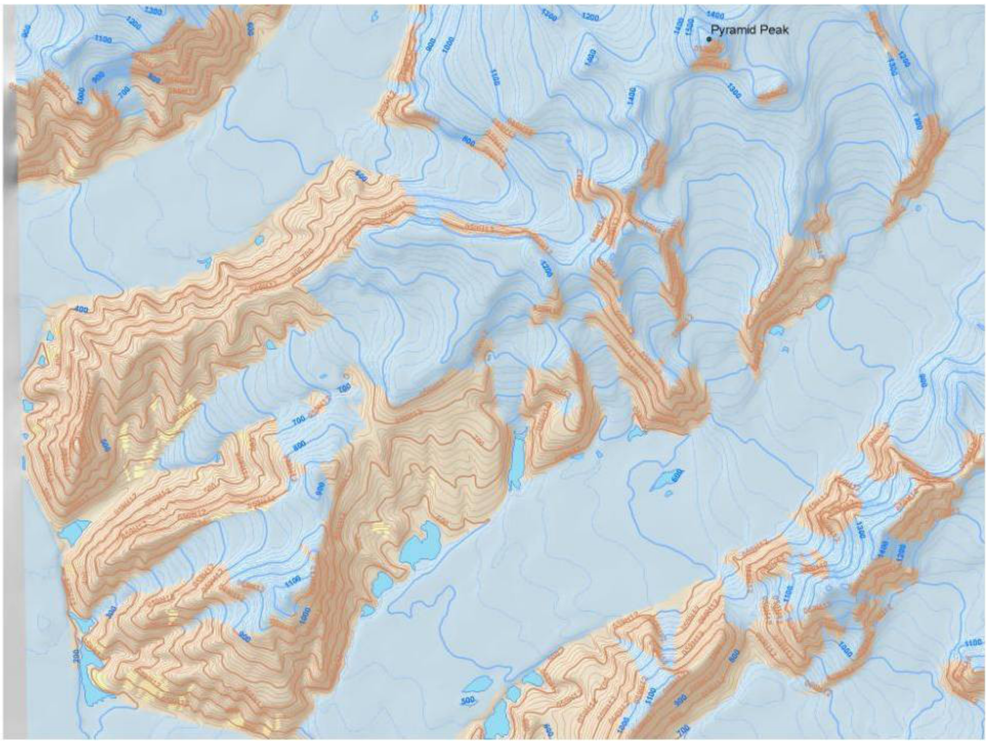


Figure 2c: Addition of shaded relief and index contour labels, with vegetated areas in yellow.

3 COAST MOUNTAINS: ANDREI ICEFIELD (56.9ºN, 139.9ºW)

This map sheet (104B15) includes the Andrei and Forrest Kerr, two outlet glaciers from the Andrei Icefield to the west; this remote location is visited annually by only a few scientists and travellers. The monochrome topographic map was printed in 1975, but the data were produced from 1965 aerial photography. This is not unusual in Canada with our large geographic area and limited mapping resources. Deciduous alpine shrubs and herbs, not shown on topographic maps are significant as added features for wildlife, while the supplied map vector layers cover only forested areas. The process followed is similar to that in section 2, although in this case, contours are not shown; deciduous areas are more substantial than in the arctic and can be seen at altitudes above forested areas and adjacent to glaciers indicating plant regrowth following glacier retreat since the Little Ice Age (LIA) ~ 1850 (Figure 3).

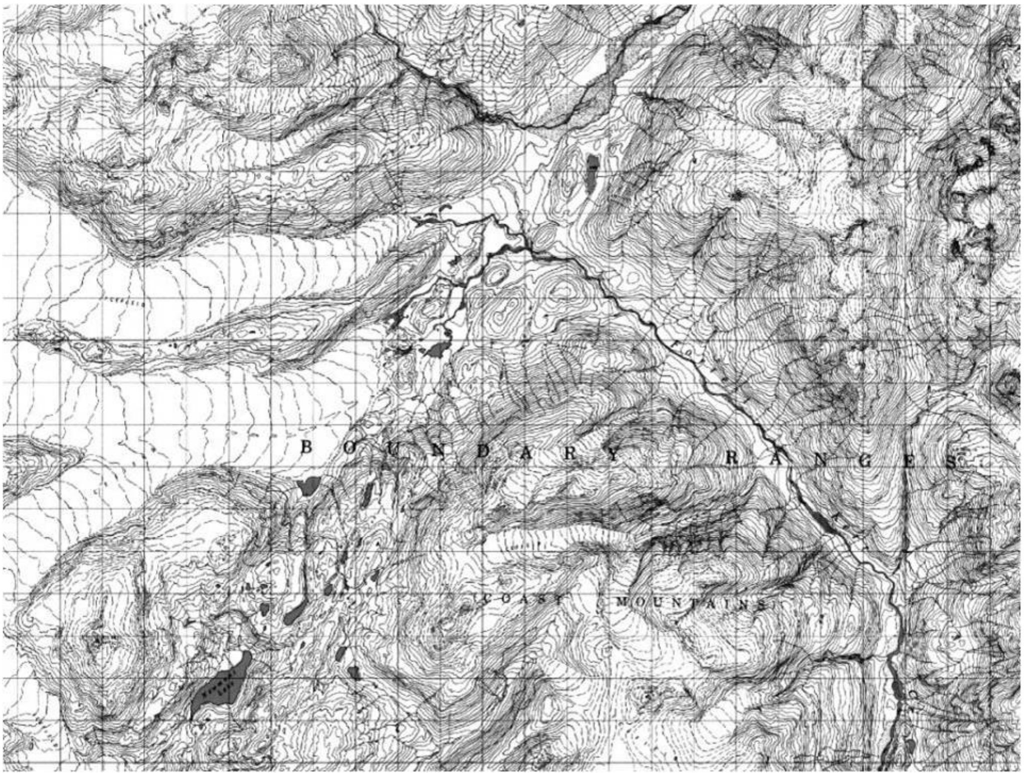


Figure 3a: Portion of scanned map sheet, 104B15 (1965)- UTM grid represents 1 km divisions.

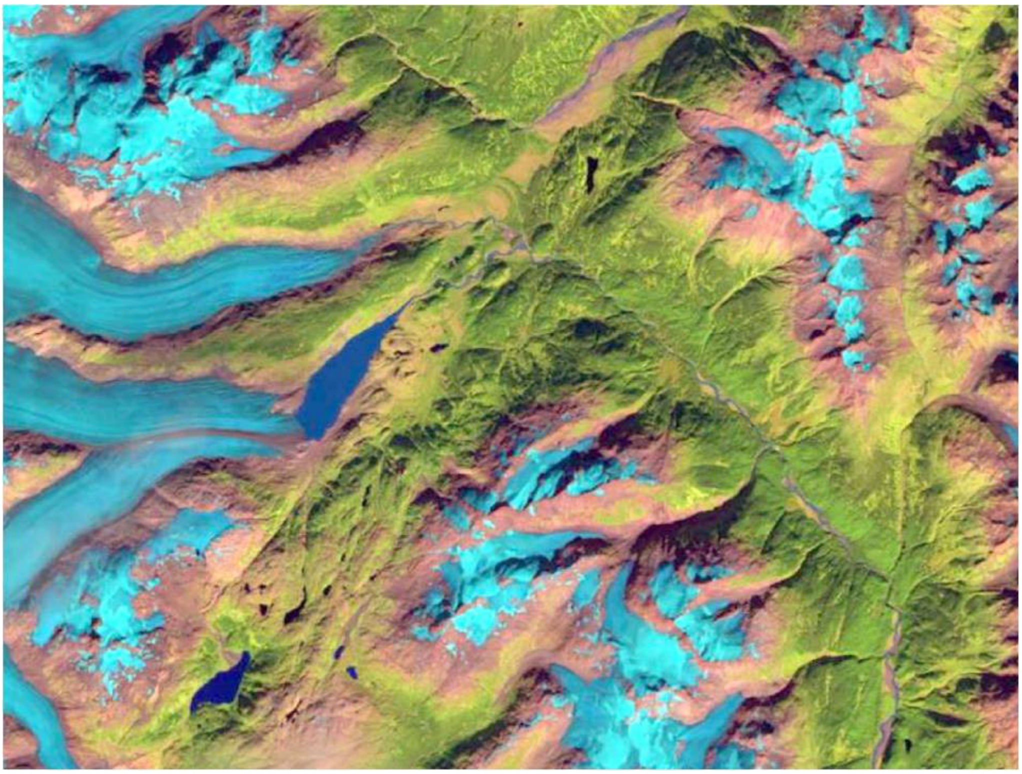


Figure 3b: Landsat 2005 image used to create alpine vegetation.

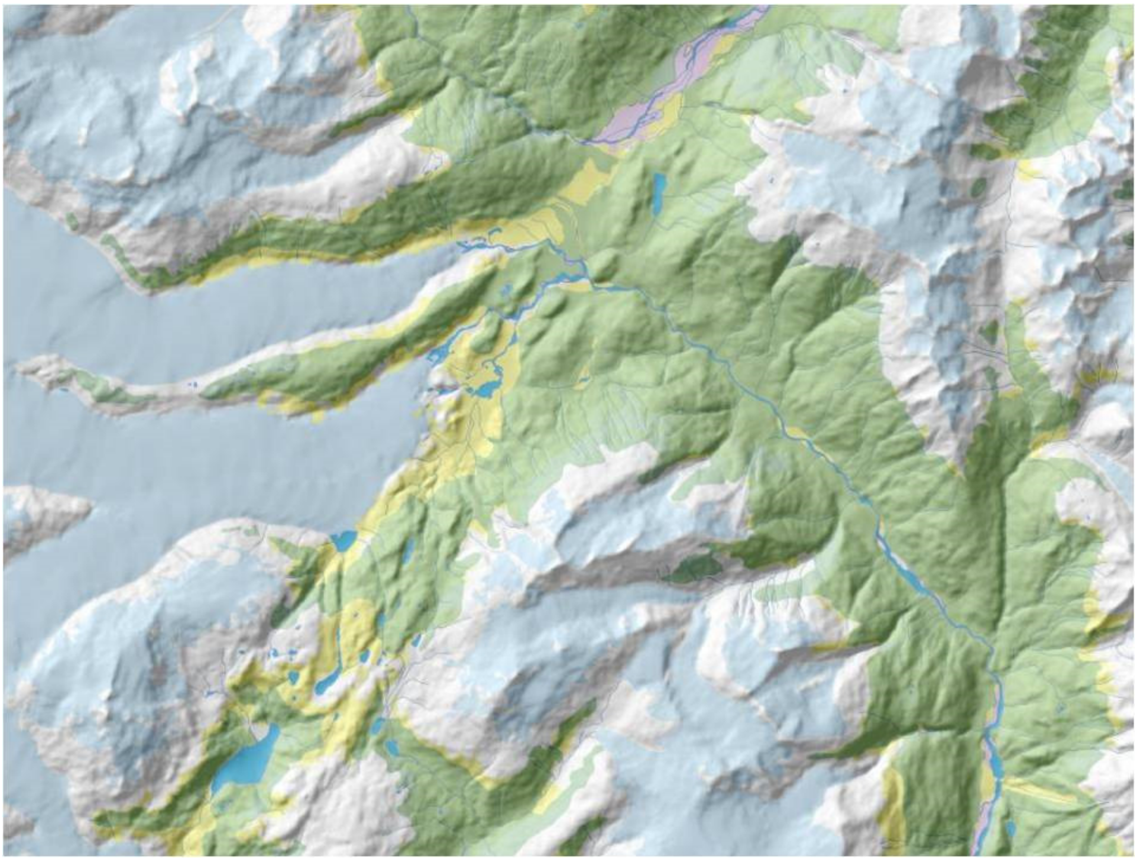


Figure 3c: Addition of forest (green) and deciduous alpine meadows (yellow).

4 ROCKY MOUNTAINS: MT. ROBSON (53.1°N, 113.1°W)

Mt. Robson (3954 m) is the highest peak in the Canadian Rocky Mountains. The map sheet (83E03) also contains Robson Glacier, Berg Glacier and Berg Lake; the trail passing these features is the most popular multi-day hike in the Rocky Mountains, but like the two previous examples, the map sheet houses no permanent residents. The earliest topographic mapping dates back to 1923, enabling the inclusion of historic glacier extents, as well as clear LIA extents (Figure 4). The addition of alpine meadows from satellite imagery help to indicate where hiking trails enable extra vistas and photographic opportunities. While the map was printed in 1995, only roads have been updated since the first modern mapping, so hydrography and glacier extents date from 1975; these can be updated using satellite imagery. Like the previous examples, the addition of shaded relief, bi-coloured contours, semi-transparent overlay of glaciers and satellite image derived non-forest vegetation cover enhance cartographic depiction and geovisualisation.

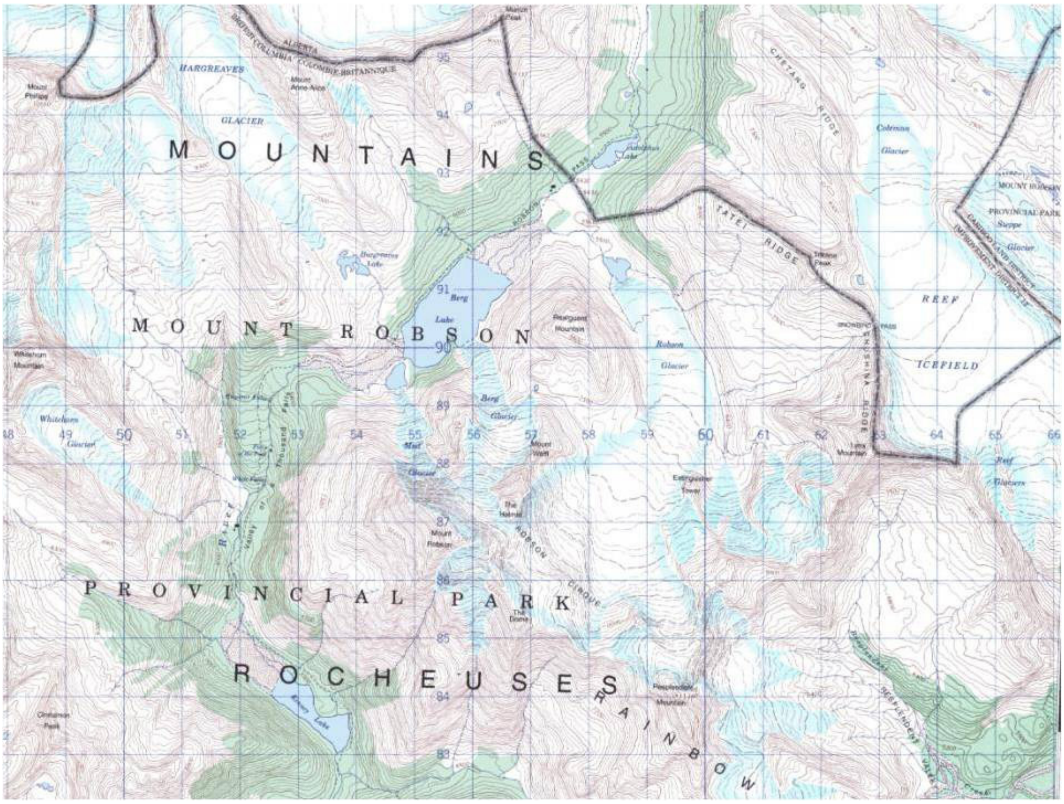


Figure 4a: Portion of scanned topographic map 83E03 (1995)- UTM grid represents 1 km divisions.

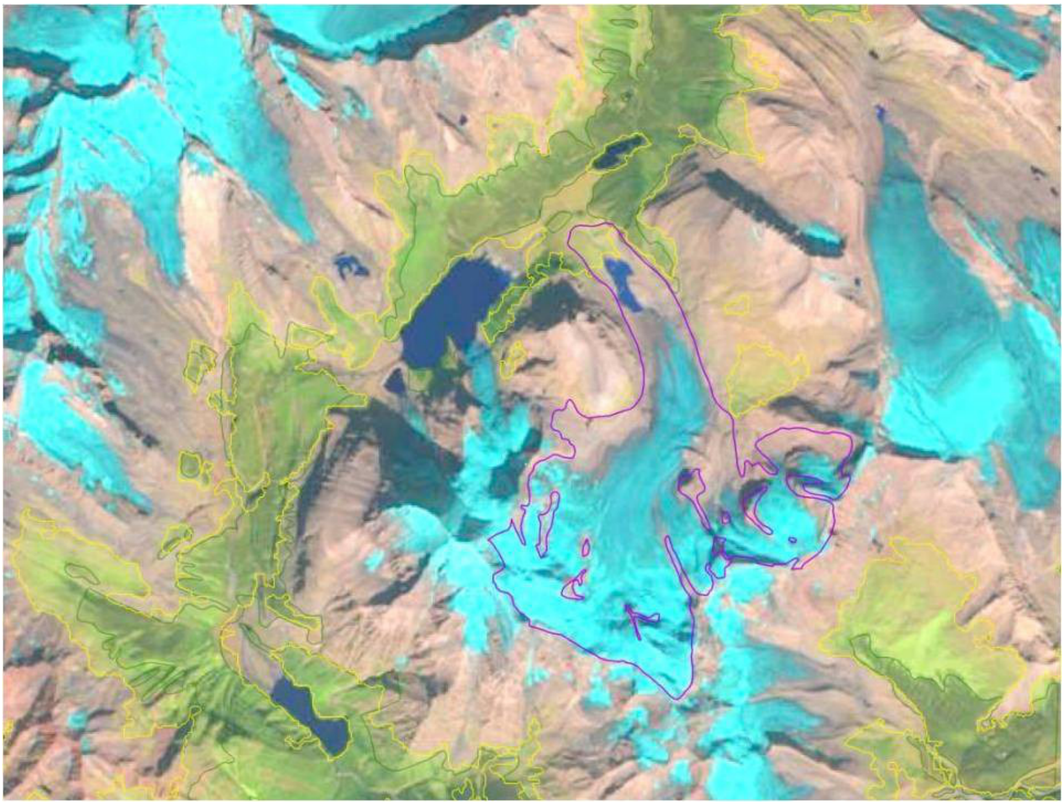


Figure 4b: Landsat image (2013) with added vectors for deciduous vegetation (yellow) and 1923 glacier extents (purple).

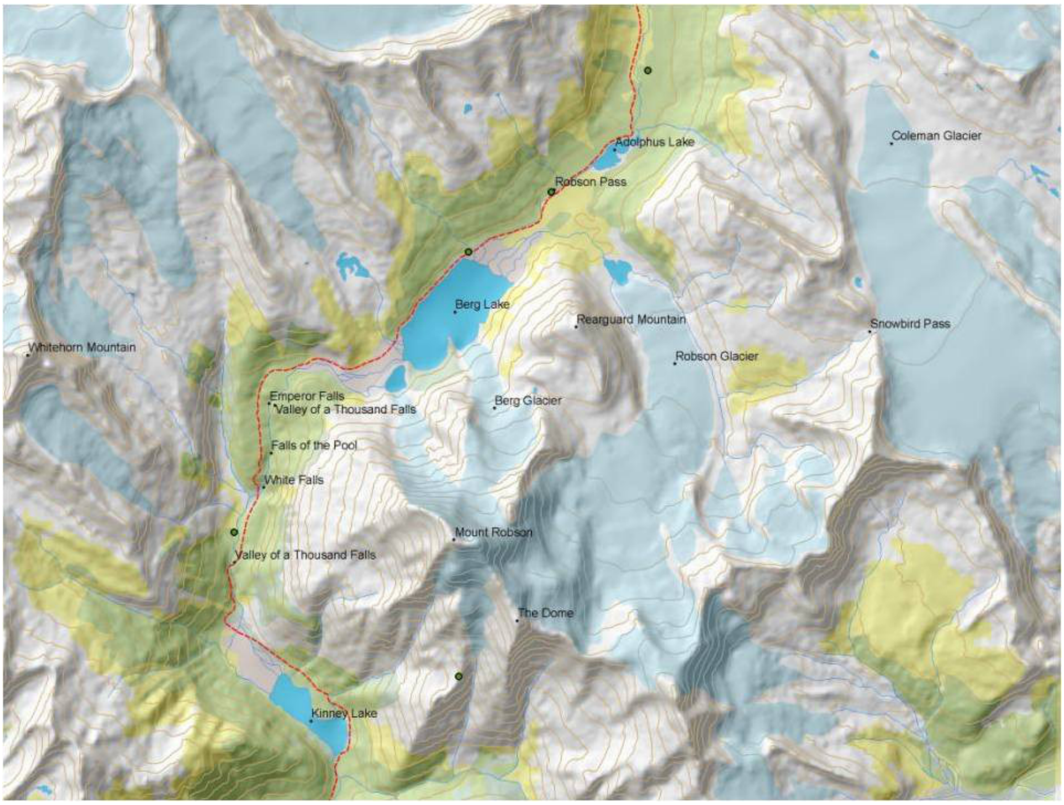


Figure 4c: Addition of forest cover(green), alpine meadows (yellow), Berg Lake trail and toponymy (non-selectively positioned).

5 SUMMARY

The NTDB offers an extensive collection of vector and raster data, which can be used for topographic representation and cartographic exercises. While map sheets can be outdated by several decades, changes have often been relatively minor and in any case can be updated using available (Landsat) satellite imagery. Three examples have been illustrated here for sample areas in remote portions of the Canadian Arctic and Alpine Cordillera, where the main changes have resulted from glacier retreat and downwasting since the Little Ice Age.

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MOUNTAIN AND HIKING CARTOGRAPHY

NEW GENERATION OF SLOVENIAN ALPINE ASSOCIATION'S MOUNTAIN MAPS AND MOUNTAIN TRACK DATABASE

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ABSTRACT

Mountain maps have always been essential data source for all professional and leisure activities in mountain areas. Technological changes, new design principles and advanced user needs resulted in renewal of mountain map systems. Slovenian Alpine Association is launching the new series of maps, based on newly established mountain track database and other available source data, such as LiDAR.

Keywords: mountain maps, mountain track database, Alps, Slovenia

1 INTRODUCTION

Mountains have always played an important role for the human communities lived in foothills of the mountain peaks and ridges. Most of nowadays Slovenian territory has hilly or mountainous character; the relief rises from Pannonia plateau in the north-east to Dinaric mountain ridge in the south and Alpine peaks in the north-west. In the early eras mountains represented mostly obstacle for migrations or daily movements, while later people started using them for protection and for economic reasons, such as woodwork, mining, hunting or pasturing. Detailed mapping of mountain areas in today Slovenian territory started in 17th and 18th century with intention describing geography of the area, often based on personal terrain field check and measurements. Scales of those maps were quite small, mountains, depicted as perspective hills were vertically enlarged. Figures 1 represent inserts of two geographical maps of area of Julian Alps, the highest mountain area in today Slovenia, both from 18th century.

Figure 1: Julijske Alps and western Karavanke on Janez Dizma Florjančič map from 1744 (left), Slovenian Alps on Baltazar Hacquet map from 1782 (right).

The official military maps of the first survey, presented on Figure 2, produced in the same period, presented mountain areas differently, using Lehman's hatches.

Figure 2: Triglav surroundings on Military Joseph's survey, late 18th century.

Mountaineering as a leisure activity developed in Slovenia during the second half of the 18th century, coinciding with the development of mountaineering in other Alpine areas. Among the first people to undertake ascents were botanists, geologists and other scientists. Slovene Valentin Stanič, often recognised as the first sports mountaineer in the Alps in beginning of 19th century carried out geodetic measurements throughout the Alpine region of Europe. He was the first person to ascend several significant Alpine peaks, including Mt. Watzmann in Bavarian Alps. In the 19th century, mountaineering in Slovenia became increasingly popular, which resulted in the founding of the National Mountaineering Association - Alpine Association of Slovenia (AAS) in 1893. Although local people, usually hunters, served as mountain guides for foreign tourists and explorers coming from cities, like famous Austro-Italian writer Julius Kugy, more individuals or members of some Alpine clubs' like "Piparji" (Figure 3) visited mountains by themselves.

Figure 3: Members of Slovenian Alpine club "Piparji" in the beginning of 20th century.

Therefore soon in the beginning of 20th century, need for maps presenting mountains areas became evident and resulted in several hand-drawn ridge lines to depict the mountainous topography (Figure 4 left). After the end of World War II, the development of civil cartography was partly restricted in the former Yugoslavia. The official state and military topographic map system was produced and maintained by the Military Geographic Institute of Belgrade, while there were restrictions for civilian map production, including mountain maps. Facing such limitations, civilian cartography in Slovenia developed slowly during the 1960s, when the first modern maps were produced. One of them was mountain map of the Julian Alps at 1:50,000 scale, produced by the Institute of Geodesy and Photogrammetry of Ljubljana (IGP) and published by Alpine Association of Slovenia (Figure 4 right). The aforementioned government-imposed restrictions in regard to data presentation resulted in relief presentation with 100 meter contours and generalized pictograms for rocky areas. The map is most noteworthy for its detailed and distinct presentation of mountain tracks, a needed quality that was appreciated by Slovenian mountaineers.

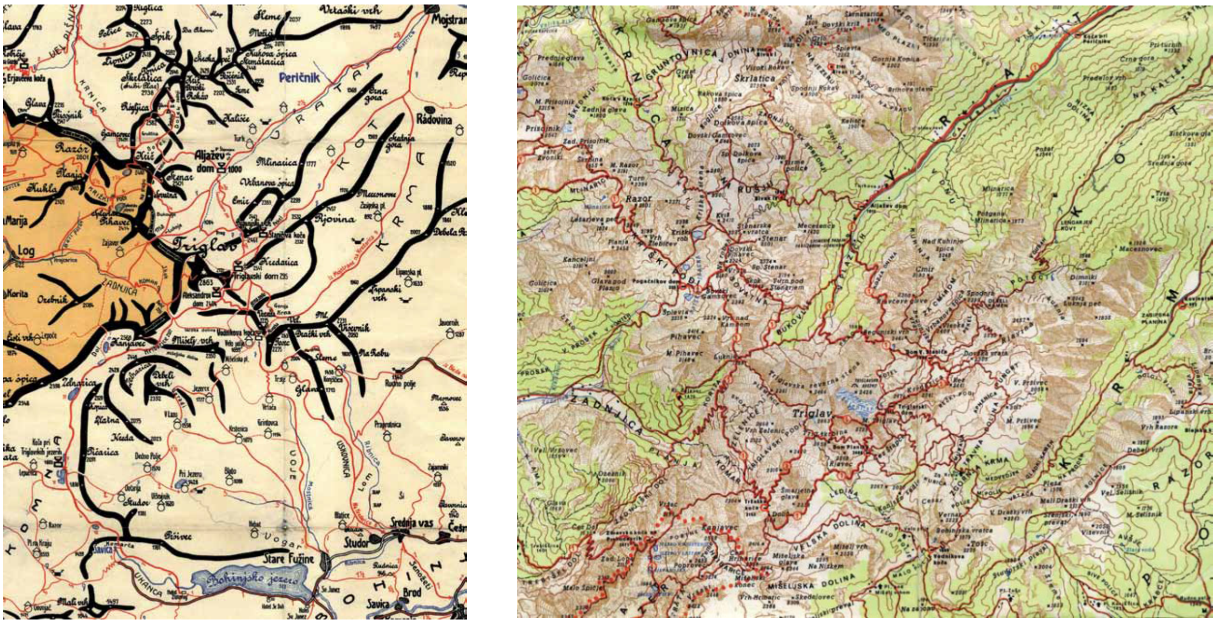


Figure 4: Triglav surroundings on ridge map from 1923 and on the first modern Slovenian mountain map from 1969.

2 PAPER MOUNTAIN MAPS OF ALPINE ASSOCIATION OF SLOVENIA (AAS)

In the following years mountain maps at 1: 50,000 scale of Alpine Association of Slovenia became the well-recognised and commonly used large scale maps, not only for mountain tourism purposes. The maps covered all mountain and hilly areas of major importance. Over the decades the design and content of this map series changed as a result of the abolition of the former restrictions and new findings on map design theory (Figure 5). The contour interval has been improved to 20 meters and mountain tracks were divided into categories.

Figure 5: Different front covers and portion of 1: 25,000 scale mountain map, all published by Alpine Association of Slovenia.

The need for even more accurate and detailed mountain maps resulted in a new 1: 25,000 scale map series in the late 1980s. These maps show some of the most attractive and most rugged mountain areas. Mountain tracks are divided into three categories according to difficulty of access, and mountain touring ski routes are depicted.

All official mountain maps of Slovenia territory from 1969 to 2005 have been produced by the two cartographic institutions in Slovenia: the Geodetic Institute of Slovenia (GIS, the former IGP), and the private company Geodetski zavod Slovenije (GZS). The mountain maps produced by these institutions were exclusively published by the Alpine Association of Slovenia and became one of the most recognised and proudly products of all involved institutions. In addition to cartographic content, textual information about mountain huts and natural and historic points of interest, block diagram, and other attractive presentations were printed on the verso of the maps.

After Geodetski zavod Slovenije (GZS) as the largest map producer in Slovenia collapsed, a lot of new cartographic firms were established and some of them created and published their own mountain maps series. Therefore Slovenian Alpine Association as a long time exclusive mountain map provider was faced with other map publishers. This competition on small mountain map's market forced publishers and map producers to increase map quality, optimize the procedures and offer new products.

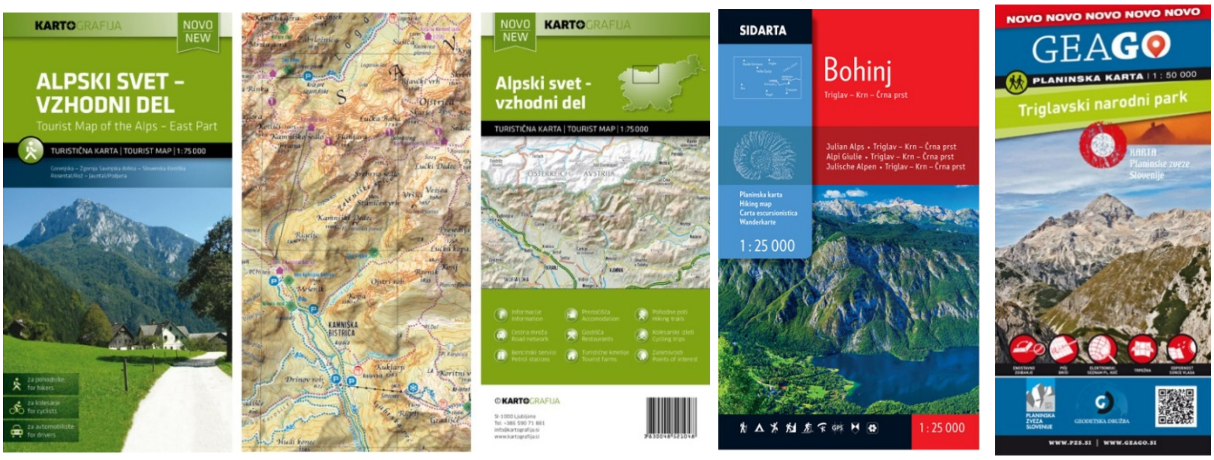


Figure 6: Mountain maps produced by AAS's competitive publishers.

Some of them were innovative and also successful. Company "Kartografija" decided for different scale, 1: 75,000 and larger covered areas (Figure 6, left three items). A publisher Sidarta started their mountain map series as support to already well accepted and recognised attractive Mountain guide books. Their map of Bohinj (Figure 6, second from the right) was even awarded at International Cartographic Conference in Paris 2011 in the category of Topographic maps. "Geodetska družba" launched maps with plasticised paper with innovative folding solution under the name GeaGo (Figure 6 right). Besides those commercial providers Ministry of Defence presented their Military Mountain Topographic map series at a scale 1: 25,000 (Figure 7), mostly used for army troupes practices in mountain areas.

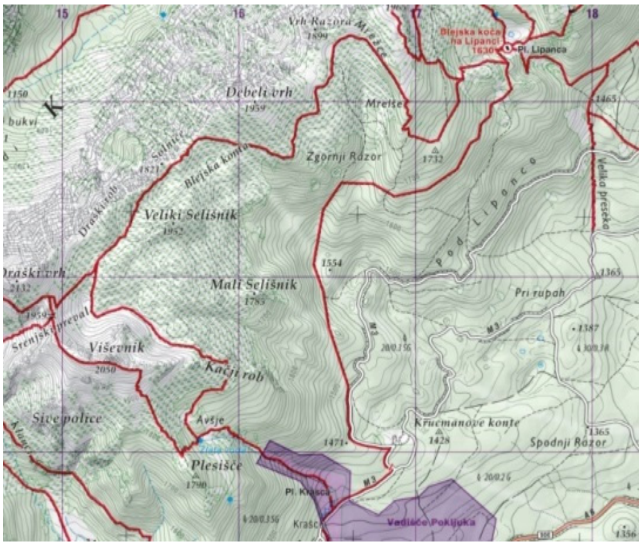


Figure 7: Military Mountain Topographic map of Julijske Alps (Ministry of Defence).

3 MOUNTAIN TRACK DATABASE AND NEW MAP SERIES

The popularity and also market inquiry for AAS's mountain maps decreased. To compete to the other publishers AAS realized that their maps should have a recognised advantage according to other publisher's mountain maps. From year 2000 all mountain maps from all publishers were made in computer vector form, based on national topographic databases, but mountain tracks weren't part of them. AAS as a responsible body for building, maintaining and marking all mountain tracks in the territory of Slovenia found out, that quality of mountain track's presentation should be an important fact, hopefully recognised among the consumers.

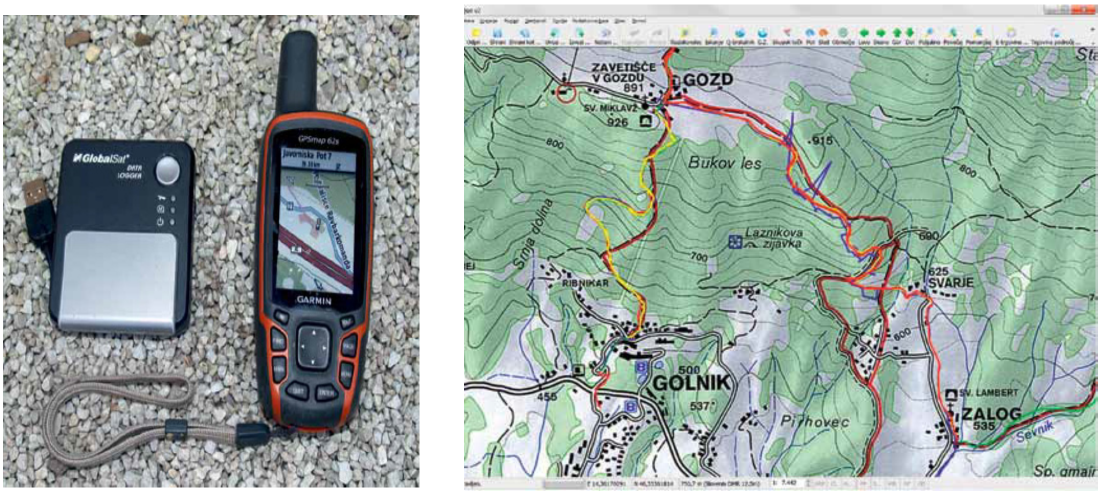
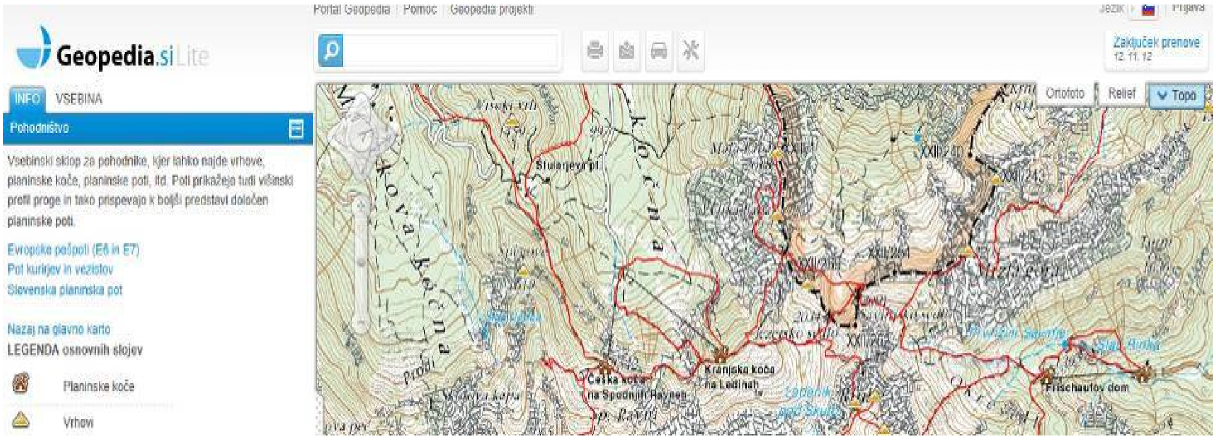


Figure 8: GPS devices and corrected mountain tracks.

AAS equipped all their terrain teams and volunteers with GPS receivers to improve the horizontal accuracy of mountain tracks (Figure 8). In period of few years all mountain tracks in entire territory of Slovenia were captured and collected. As the next step the Alpine Association of Slovenia established mountain tracks databases. To allow 14 regional editors cooperatively create and maintain the database the common used web portal geopedia.si has been used as an interface (Figure 9).



Vsebinski sklop za pohodnike, kjer lahko najde vrhove, planinske koče, planinske poti, itd. Poti prikažejo tudi višinski profil proge in tako prispevajo k boljši predstavi določen planinske poti.

Figure 9: Web-portal geopedia.si has been used as an interface for database maintaining.

The work with the database creation and maintaining has to be intuitive and logical, since most of regional editors are volunteers, familiar with tracks on the terrain, but with minor or no GIS experience. Editors could select among different background image data: existing mountain maps, official topographic maps, or orthophoto images (Figure 10).

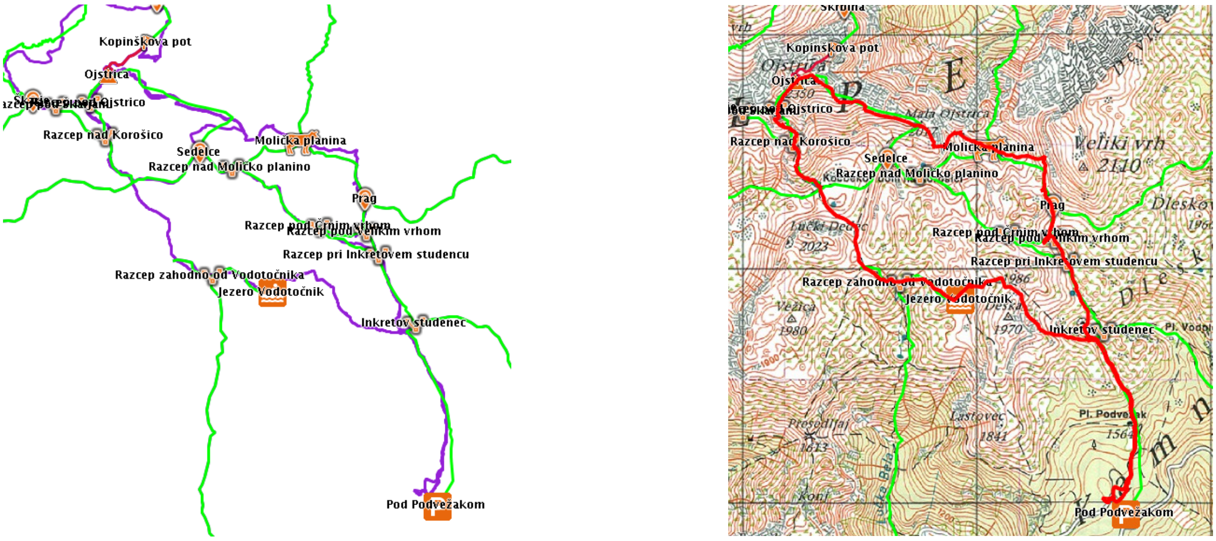


Figure 10: Insert of mountain tracks database, official topographic map as a background.

Database is organised in three different data types, points (start and end point of the tracks, junction, mountain hut, prominent peak, other points of interest), segments (part of the track with the same attributes) and trails (mountain track from the start point to the final destination). Initial set of vector data, derived from terrain GPS survey consisted of 5,000 track segments with overall length 9,500 km, which were prepared to be regularly updated by 14 editors, each of them covering one area. The main issues for editors are correct the horizontal accuracy according to orthophoto and other available sources, set the correct attributes, compose the tracks from segment and establish the correct topology. In the beginning of 2016 all 1,500 tracks were composed and most of them have already been edited, primarily in high alpine parts, which are most attractive for users (Figure 11).

Figure 11: Tracks in mountain tracks database, purple and red coloured are edited, green not yet.

With this database Alpine Association got the advantage in accuracy, completeness and up-to-datedness of mountain tracks from other map publishers. Following improved content Alpine Association also introduced new map design, both for map itself and for covers (Figures 12).

Figure 12: Design of new series of AAS's mountain maps.

The new series of mountain maps was launched in 2015, 5 maps are already available on the market; few more are in works or in order with map producers (Figure 13). In next few years all mountain attractive areas are planned to be mapped.

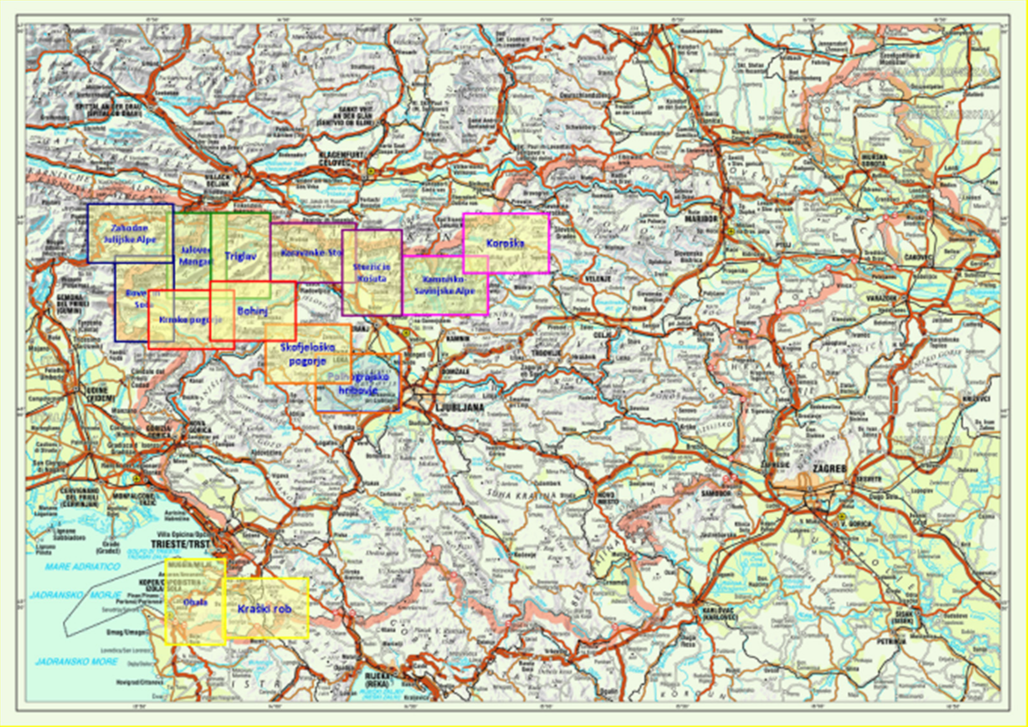


Figure 13: Maps of the new series, already available and those in works.

Improved quality of mountain tracks data can be reached using aerial laser scanning (LiDAR) data, which is freely available for the entire territory of Slovenia from 2015 (Figure 14).

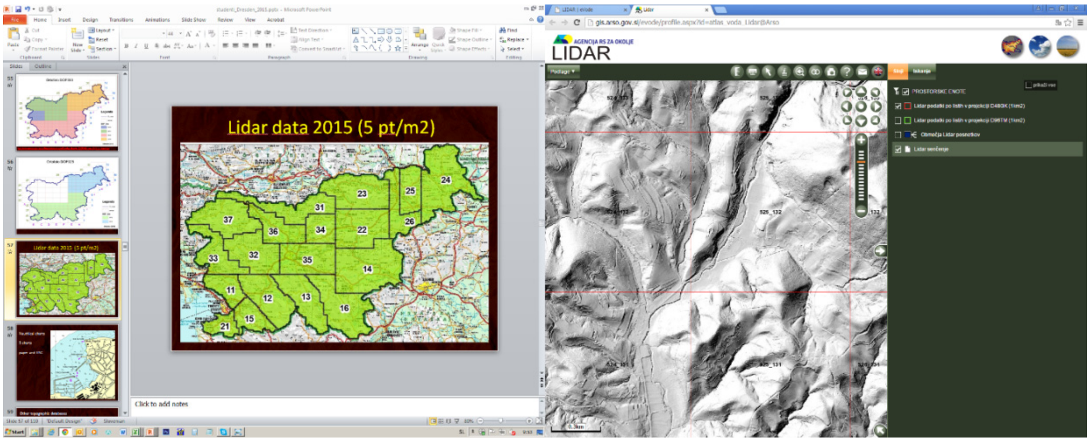


Figure 14: LiDAR data for Slovenia, sectors and web-portal with hillshading.

The airborne laser scanning data are very useful source data for mapping different objects and phenomena, like vegetation type and density or hardly distinctive paths and terrain features in forest or other vegetation covered areas. Currently manual visual recognition of objects on different LiDAR points' derived images (eg. hillshading, slope map, vegetation height map) is probably still the most efficient method. Such images can be prepared either directly from point cloud, either from pre-generated DTM and DSM in different nowadays software. But, as a result of additional research some algorithms enabling automated or semi-automated deriving object with minimum local height values (waterbeds, gullies) or other common similar values (ridges, paths) can be introduced.

5 CONCLUSION

Mountaineering has been very popular in Slovenia for at least last two centuries. Although mountain tracks have been marked with unique circle two colours signs (Figure 15) people, climbing and walking in hilly and mountain areas have always been interested in cartographic and other presentations that helped them navigating on the terrain.

Figure 15: Unique circle two colours sign on Slovenian marked mountain tracks.

Therefore mountain mapping has been developing parallel to mountaineering, triggered by technological changes, available data source, improved user need, political or market changes. Improvements in map design, data quality, used media therefore resulted in new mountain map series that intend to be recognised and well accepted among the users.

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MOUNTAIN AND HIKING CARTOGRAPHY

COMPARATIVE GEOGRAPHICAL REPRESENTATION OF HIGH MOUNTAIN REGIONS BY MEANS OF REMOTE SENSING

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ABSTRACT

This paper deals with a comparative analysis of various high mountain regions by means of remote sensing and their cartographic representation. At the core of this paper are thus not only purely physical geographical priorities, but also methods and techniques of remote sensing and related classification and analysis techniques. One of the main points of this study is to enhance the comparative high mountain geography, within a variety of tie points in climatic, geomorphic or human geographical aspects, with the aid of remote sensing data (e.g. ASTER satellite).

Keywords: comparative high mountain geography, remote sensing, landuse/ landcover maps

1 INTRODUCTION

Carl Troll (1962) emphasized "comparative high mountain geography" and a "three dimensional classification of a mountain region." This conventional approach can be improved with remote sensing classification and change detection techniques. Especially with the availability of remote sensing data and worldwide digital terrain models, new spatial information can be used to add new data and information to this comparative high mountain geography (cf. Sulzer and Gspurning 2009). Remote sensing technologies provide powerful tools for observing the mountain environment. Remote sensing is often the only way for investigating large sections of the earth's surface and especially remote alpine regions. With the integration of remote sensing data the actual extent of land use/land cover (LU/LC) features of the observed mountain regions can be mapped and the simple additional output of this study is to compare altitudinal belts and vegetation structures in representative high mountain environments of different latitudes, contributing to the studies by Walter (1970), Zsilincsar and Sulzer (2002), Tappeiner et al. (2006), Sulzer (2009) and Sulzer (2012).

It was important for this work that the high mountain regions differed fundamentally from each other. The selection of different regions was mainly influenced by the location and the availability of data. The following regions were selected: Aconcagua in South America (Sulzer and Kostka 2006), Mount Meru in Africa, Grossglockner in Europe, Ararat in Near East and Ama Dablam (Kostka 1998) in Asia, as well as Aoraki in the New Zealand Alps. The classification refers to a study area with an extent of 900 km^2 (30 km x 30 km) for each region. This is not only for comparative purposes, but above all, for visual cartographic expressiveness. For example, it is clear that the two volcanoes, Ararat and Meru, exert incredible dominance in their region, and that powerful and impressive glaciers still dominate the landscapes of the Ama Dablam and Aoraki regions, despite noticeable glacial retreat.

High mountains contain sensitive indicators of global climate change. Many of these physical indicators and their alteration can be detected by remote sensing monitoring programs (cf. Leber et al. 1995). Therefore, LU/LC changes are a second centre of interest for this paper. The focus on the LU/LC status quo of high mountain regions plays a significant role. A historical comparison of the LU/LC development in two regions was added exemplarily for the High Tatras (Slovakia) and Hohe Tauern Mts. (Austria).

This work is an attempt to capture and map these regions in their uniqueness by means of remote sensing. Although there is at the first glimpse no visible connection between these regions, a comparative geographical approach and comparative analyses in these regions are possible.

2 CASE STUDY 1: COMPARATIVE ANALYSIS OF SIX HIGH MOUNTAIN REGIONS BY MEANS OF REMOTE SENSING

This study deals with the comparative analysis of six different high mountain regions by using remote sensing and shows the main outcomes of Pink (2010). The main focus is not limited to physical geography analysis itself. Other methods and techniques of classifications and their cartographic representation are part of this study to present the actual state of these high mountain regions. For that purpose the areas of investigation are situated on different continents to get a global content. However, it is not easy to find the right regions, due to the availability of suitable ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) scenes. In the end, the regions around Aconcagua, Ama Dablam, Aoraki, Großglockner, Ararat and Meru were chosen (Figure 1).

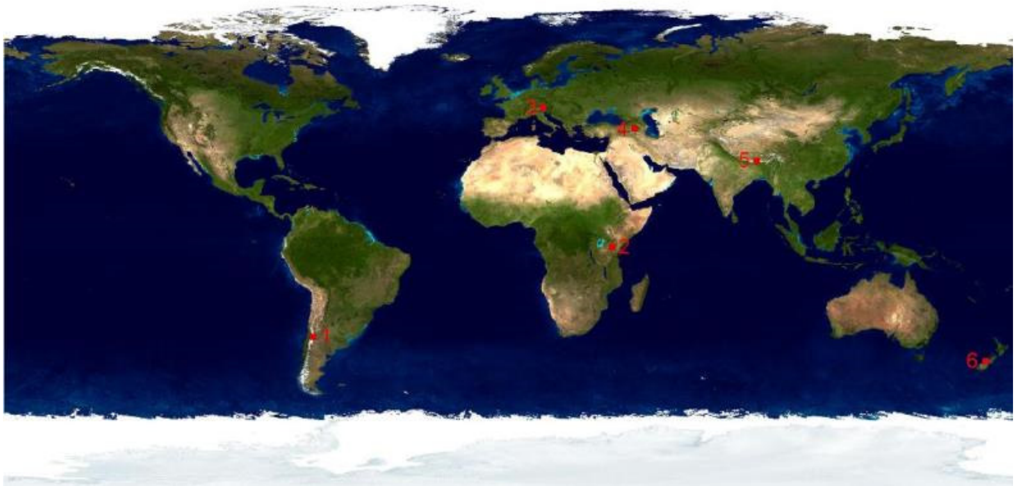


Figure 1: Investigation area: Aconcagua (1), Meru (2), Großglockner (3), Ararat (4), Ama Dablam (5), Aoraki (6).

This study intends to prove if it is possible to classify and compare six completely different high mountain regions around the world with the same remote sensing methods. This juxtaposition involves a wide range of physio-geographical and human geographical aspects, and also geomorphological, glaciological, climatic and anthropogenic comparisons. The basis of this work is a self-developed classification based on Landsat and ASTER data. As already mentioned it is not easy to find suitable data sets, especially in high mountain regions with many confounding factors, therefore some reasonable compromises had to be accepted. The selection of the six study areas was carried out in several aspects: relatively currency of data, recording time between 2006 to 2008, and suitability for the purpose of classifications and analysis. Obviously the percentage of cloud cover is always a relevant problem in those regions.

The different study areas are defined by a dominant mountain, which is representative for a certain region. In each case areas of nine hundred square kilometres, respectively thirty multiplied by thirty kilometres, are analysed. The identical size of each area is an important instrument to compare the areas with each other. The different genesis between those mountains is only one fact to pose a challenge for this study.

The land cover classification should be a snapshot, so the actual condition can be analysed of these areas and is not suitable for a time series analysis. The study should show that even extremely different regions can be analysed and compared with the same classification methods and algorithms. However, with the help of previous data classification results reveal serious changes in the natural landscape.

2.1 METHODOLOGY

Figure 2 gives an overview about the workflow of the data processing:

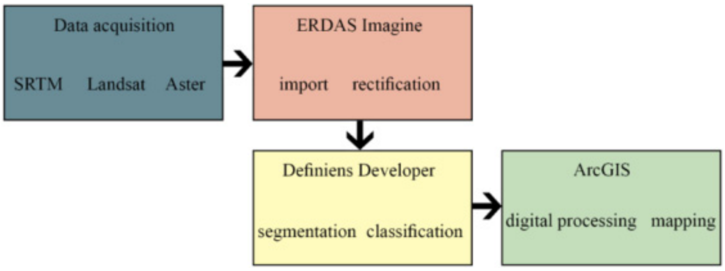


Figure 2: Working stages and main methods of this study.

As already mentioned it was not easy to acquire the right data sets for those high mountain regions within a certain timeframe. Therefore different data types were used like open source data (Landsat, SRTM) on the one hand and ASTER scenes on the other (Table 1). However, the availability of useful ASTER scenes for all six study areas was more than disappointing. Some of the regions are only partially covered by the ASTER sensor or completely useless due to cloud cover.

Table 1: Data acquisition dates and spatial resolution of the used remote sensing sensors.

Investigation Area	**Sensor**	**Date**	**Spatial Resolution (m)**
Ama Dablam	Landsat 7	05/01/2002	30
Aoraki	Landsat 7	01/02/2003	30
Ararat	Landsat 7	13/08/2000	30
Aconcagua	Landsat 7	24/03/2003	30
Meru	Landsat 7	21/02/2000	30
Großglockner	Landsat 7	14/09/2002	30
Investigation Area	**Sensor**	**Date**	**Spatial Resolution (m)**
Ama Dablam	ASTER	01/06/2008	15
Aoraki	ASTER	24/01/2006	15
Ararat	ASTER	23/03/2006	15
Aconcagua	ASTER	05/02/2006	15
Meru	ASTER	02/05/2006	15
Großglockner	ASTER	29/07/2005	15

Before the data could be classified the ASTER scenes had to be imported and rectified with the help of the Leica Photogrammetry Suite (LPS) in ERDAS Imagine. Landsat images acted as horizontal reference, SRTM data with the spatial resolution of ninety meters as vertical reference. In natural landscapes, high mountain regions in particular, it is difficult to find trustworthy ground control points (GCPs) therefore it is very important to check the Root Mean Square Error (RMSE) after the triangulation. After finishing the rectification and ortho-resampling (nearest neighbour method), layer stacks and digital elevation models were built (Figure 3).

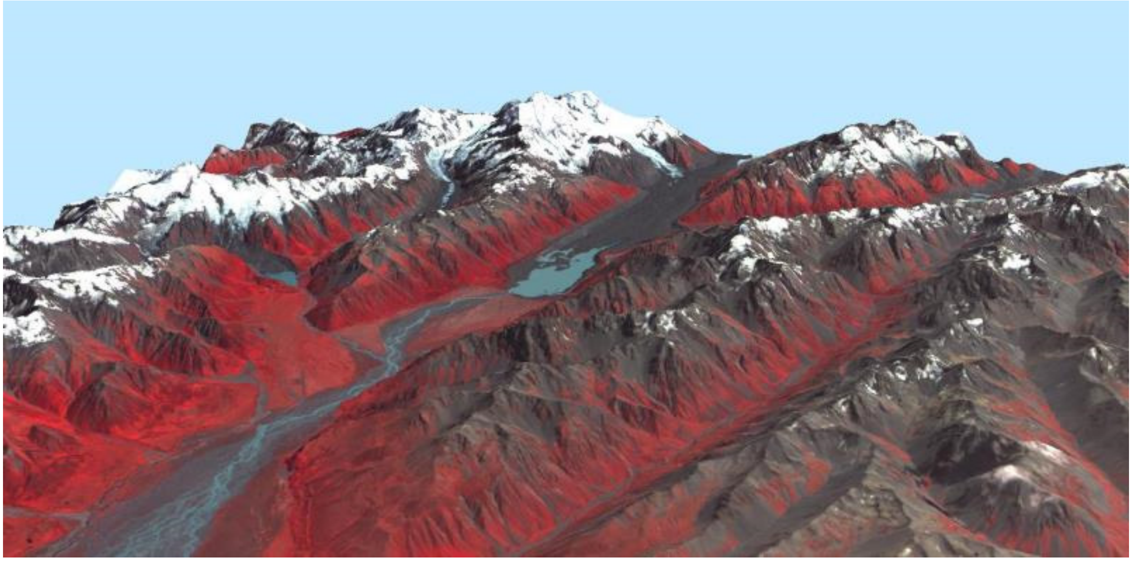


Figure 3: Perspective view of the Aoraki region based on the ASTER data set.

The segmentation process and the object based classification itself was produced by a knowledge based (top-down) method in the software program Definiens Developer 7.0. The analysis of those objects takes place within a hierarchical construct therefore a segmentation process is also needed. Thus there are always two dependent processes, the segmentation and the classification. The segmentation processes extends over several levels based on the Fuzzy logic, which is a concept to delineate realistic object classes.

2.2 CLASSIFICATION RESULTS

Because these analyses and comparisons of the investigation areas are based on a land cover classification, the classes depend on the spectral information of ASTER data and the knowledge-based integration of the height model. It was a challenge to find the right classes to create an exact, but nevertheless generalized, image of the earth's surface of those regions. The nomenclature has to be practical for local classifications and global analyses.

Nevertheless with the help of the elevation model, Normalized Differenced Vegetation Index (NDVI) and other indices the classification results are better than expected (Figure 4).

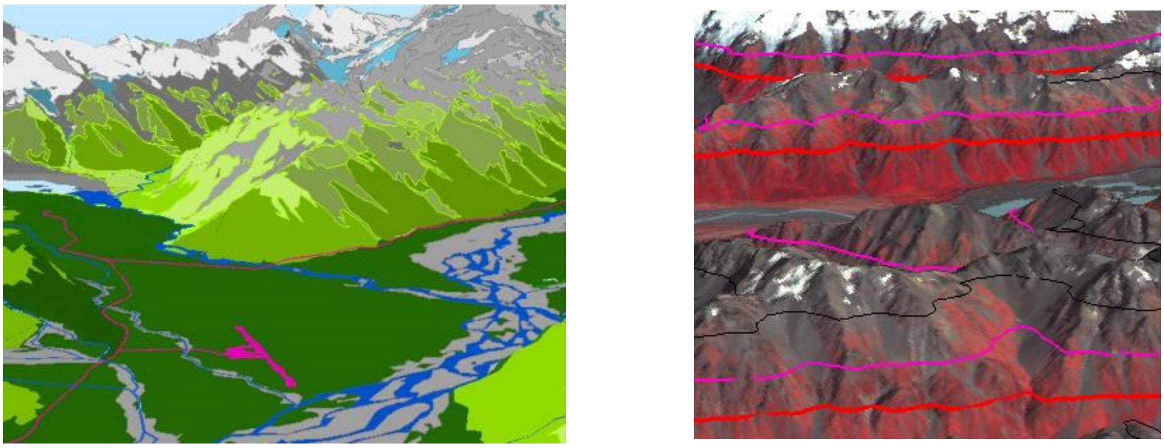
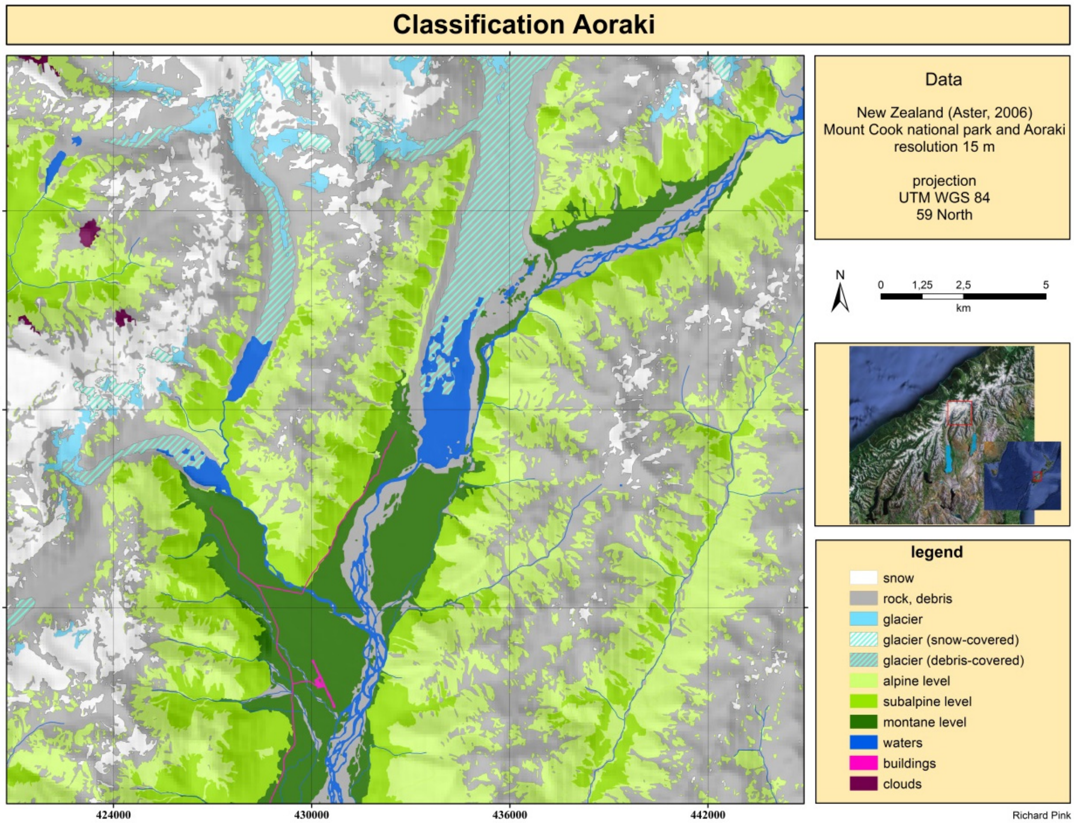


Figure 4: Classification result (left) and analysis of the alpine and subalpine zone (right).



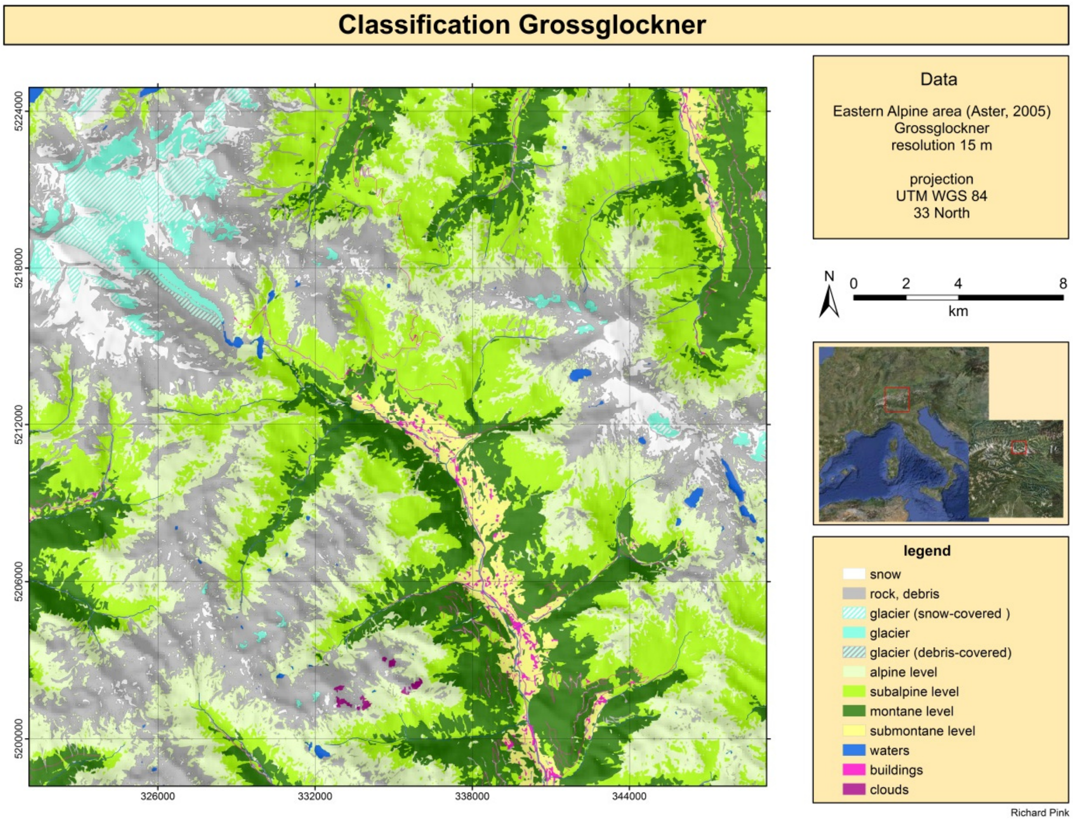


Figure 5: Classification results of Aroaki (top) and Großglockner (bottom).

Apart from Figure 5, a good overview about the classification results is also the comparison of all zonal steps in the investigation areas (Figure 6). Indirectly it shows natural and anthropogenic influences. However as mentioned before we have to take into account that these results are based on snapshots. Therefore this representation serves as an overview and shows differences but possibly diverges with average values especially in the nival, alpine and subalpine zone.

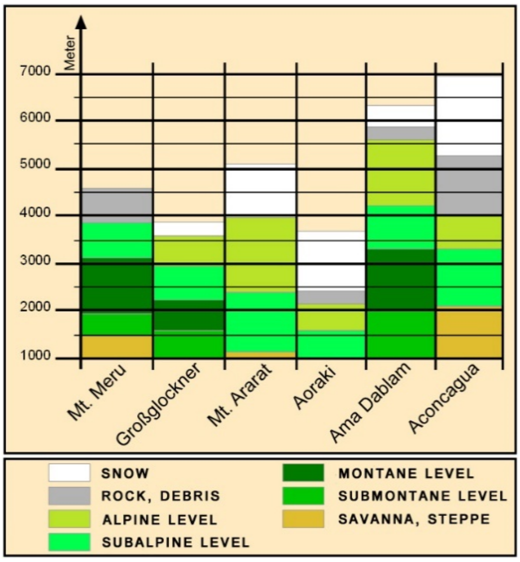


Figure 6: Comparison of all zonal steps in the investigation areas.

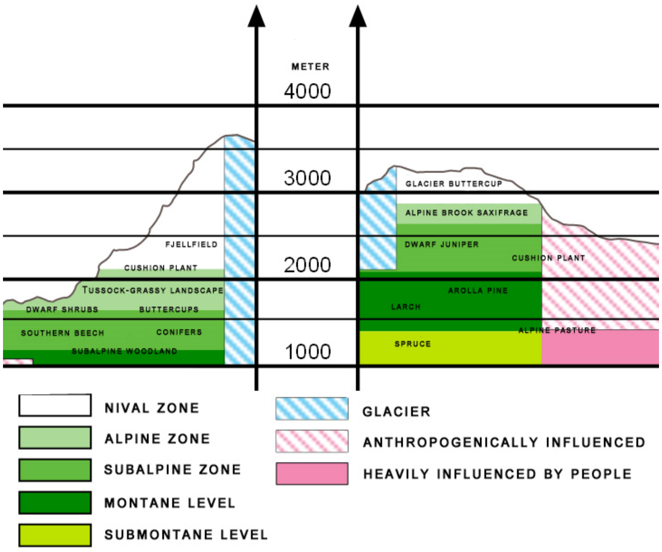


Figure. 7: Comparison between Aoraki (left) and Großglockner (right).

Even stronger is the difference between the two "Alps" in Europe and New Zealand. Because of their name and similar heights often compared they show only few common characteristics. There are amazing convergences with the flora, for example with the New Zealand edelweiss, the northern Linnea borealis and the New Zealand Lobelia linnaeoides. The anthropogenic influence in the respective areas is quite different of course. In the region around the Großglockner it is very difficult to find natural landscapes (Figure 7).

3 CASE STUDY 2: CHANGE OF ALPINE CULTURAL LANDSCAPE IN SUBAREAS OF THE HOHE TAUERN AND HIGH TATRA MOUNTAINS – ILLUSTRATED BY MEANS OF REMOTE SENSING

Apart from case study 1, which resembles a cross-sectional study, in case study 2 mainly a longitudinal study was carried out, which shows the main outcomes of Seier (2009). Within this study two separate high mountain areas are studied, one located in the Hohe Tauern Mts. as part of the Austrian Alps in the vicinity of Großglockner peak, the other one located in the Slovakian part of the High Tatra Mts. in the Carpathians (Figure 8).

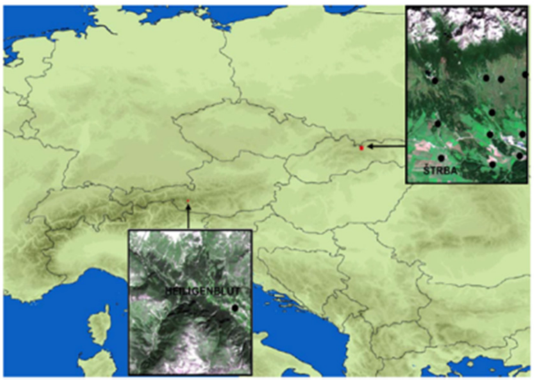


Figure 8: Location of the investigation areas of case study 2.

Although both investigation areas are located in high mountain areas, the Alpine area is characterized by its surrounding mountains and thus inner alpine climatic conditions, whereas the Carpathian area is located at the margin of the mountain range.

This study intends to use remote sensing techniques to better understand the historic development of the cultural landscape since the 1960s. Therefore the selected areas seemed to be well suited. The Austrian study area, about 37 km² in size, equals the Slovakian due to its touristic significance. The latter, nearly five times as large (about 176 km²), differs from the other especially due to the circumstance that the land use more and more developed according to upcoming tourism. The Austrian, on the other hand, has a longer touristic history.

This study is an attempt to characterize the change of the cultural landscape since the 1960s based on satellite and aerial images captured on five dates during that period of time. Due to the technical development of satellite technology the images were captured based on several sensors mounted on different platforms. According to this, one main question was, whether, by doing so, the sensor caused differences within the results that preclude a meaningful statement. Accordingly, a LU/LC classification was carried out for every data base. A methodological question was, whether the object-based or pixel-based classification approach delivers more accurate results also considering the different data used. Another question was whether the landscape developments of both areas resemble each other or in any case, whether the overall conditions, e.g. economic or political conditions, were different or not. Furthermore it was not clear how to visualize the classification results in terms of the detected change. That is, the visualization contains the changes from five dates, which makes a graphical representation or map much more complex.

3.1 METHODOLOGY

As noted in the previous section a work procedure was carried out and realized step by step (Figure 9).

When acquiring remote sensing data, several data sources, both open source and commercial were considered. Furthermore not only straightforward available data sources were used but also data archives were taken into account. This means, that a certain lead-time was needed to establish a data base for the following preparation stage. The images' acquisition dates and some sensor specifics are listed in Table 2. It is obvious that each data set has its advantages in terms of spectral and spatial resolution. For every study area the image postdating to the 60s is the oldest and only contains single band panchromatic information. On the other hand, the spatial resolution is the highest within these data and therefore these images were

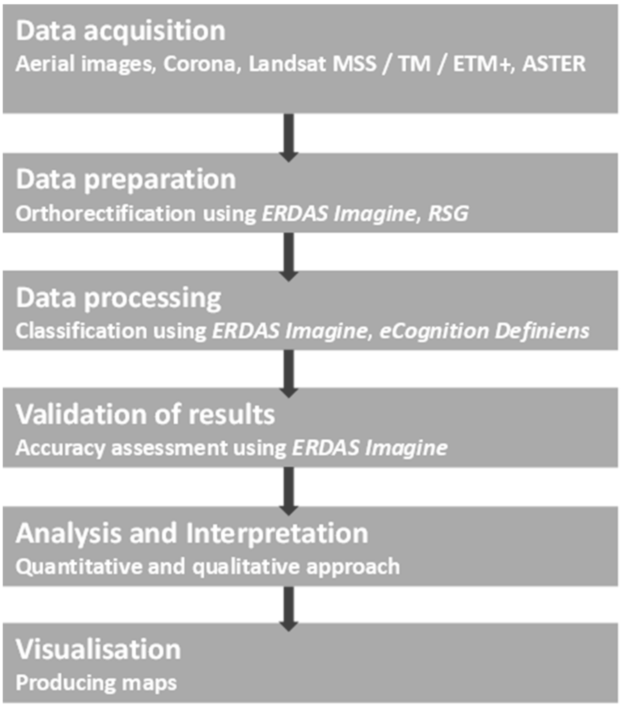


Figure 9: The outlined workflow comprising the main methods and working stages.

classified by visual interpretation. Consequently, they were not part of the main classificationprocedure that was only possible by using multispectral images captured by Landsat (MSS, TM and ETM+ sensors) and Terra (ASTER sensor) satellite. In concrete terms, for the Austrian area the Federal Office of Metrology and Surveying had archived aerial images. For the Slovakian area we fell back on the images captured by the US spy satellite CORONA, keyhole 3. In addition, some orthophotomaps (in the table mentioned as add.) were used.

Table 2: The geometric resolution and acquisition dates of the used remote sensing data.

Investigation Area	Aerial Image / Keyhole 3	MSS	TM	ETM+	ASTER
Hohe Tauern	12.10.1969 (add. 1983)	08.09.1979	09.08.1992	20.06.2000	29.07.2005
High Tatra	30.08.1961 (add. 2004)	03.09.1979	16.10.1986	26.05.2001	02.09.2008
Resolution	**aerial image / keyhole 3**	**MSS**	**TM**	**ETM+**	**ASTER**
spatial [m]	1 / 3.66-7.62	60	30	30	15
spectral [m]	1	4	7	8	14

Substantial data preparation steps concluded ortho-rectification, image registration and layer stacking of images and its spectral bands, if existing. In particular the correction of the panoramic distortion of the CORONA satellite data was very challenging. To deal with this problem not only the common software package ERDAS Imagine but also a software called RSG (Remote Sensing Graz) was used that is better suited for such cases. Satellite imagery from other whiskbroom sensors (all Landsat sensors) were obtained already ortho-corrected.

Data processing involved mainly the classification of the images. Before classifying imagery a definition of classes had to be drawn up. The LU/LC classes used are as follows for the Austrian study area: alpine meadow, built-up area, grassland, non-vegetation rock areas, vegetation rock areas, forest, and shrub; and for the Slovakian area in addition without meadows: fallow land, water areas, young forest, cropland, and snow covered areas.

The common pixel-based classification was done using ERDAS Imagine by describing a LU/LC class based on its spectral characteristics, e.g. the class meadow has its certain digital numbers in every single band of a sensor's imagery that could be noted as a spectral signature differing from signatures of other classes. These signatures are then judged according to their separability by different approaches, e.g. mean values and scatter plots, histograms, and contingency matrix. Some further separability values are based on spectral distances between classes or its training stage representatives, e.g. Divergence or Transformed divergence. These are the main parts when doing such a classification: gaining spectral signatures by training or sample areas and assessing those as well as adapting if needed. After this iterative process the actual classification - that can be seen as the assignment of pixels to classes - can be done based on different decision rules. In our case the Maximum Likelihood rule, which allows classes to be weighted, delivered best fitting results.

The more recent approach of classification is the so called object-based method, which uses amongst others in addition to multispectral information also geometrical and neighborhood information of the objects themselves, e.g. size of objects, if-else-conditional membership functions and ratios. Due to those specifics this approach is well suited for imagery with high spatial resolution. In our case using imagery with lower, mainly medium spatial resolution, the procedure used was delivering comparable classification results as attained by the pixel-based approach.

3.2 CLASSIFICATION RESULTS

In general, the classification results do not show a significant change of the classes over time, with one exception in the Slovakian site concerning classification of 2008 (Figure 11). This overall trend is also obvious in the relating cumulative area charts (Figure 12 and Figure 13). But in particular, when focusing on the Austrian site belonging results (Figure 10) a noteworthy change cannot be documented. Maybe there are differences when having a look on some details. But these are mainly related to the ground sampling distance. The differences arising from the methodological approaches (object-based, pixel-based, visual interpretation) are for some spots noticeable, but do not cover large areas. These latter mentioned differences are also related to the post processing procedures that were mainly necessary for the pixel-based classification results.

The classification results of the Slovakian site indicate mainly two effects. Apart from the already mentioned massive forest decrease, which was forced by a storm event on 19.11.2004, it is obvious that in the object-based classification results the class "cropland" seems to be overrepresented, e.g. some areas in higher altitude (see contour lines in Figure 15). In addition some detailed structures being prone to change are delineated in change detection maps (Figure 14 and Figure 15).

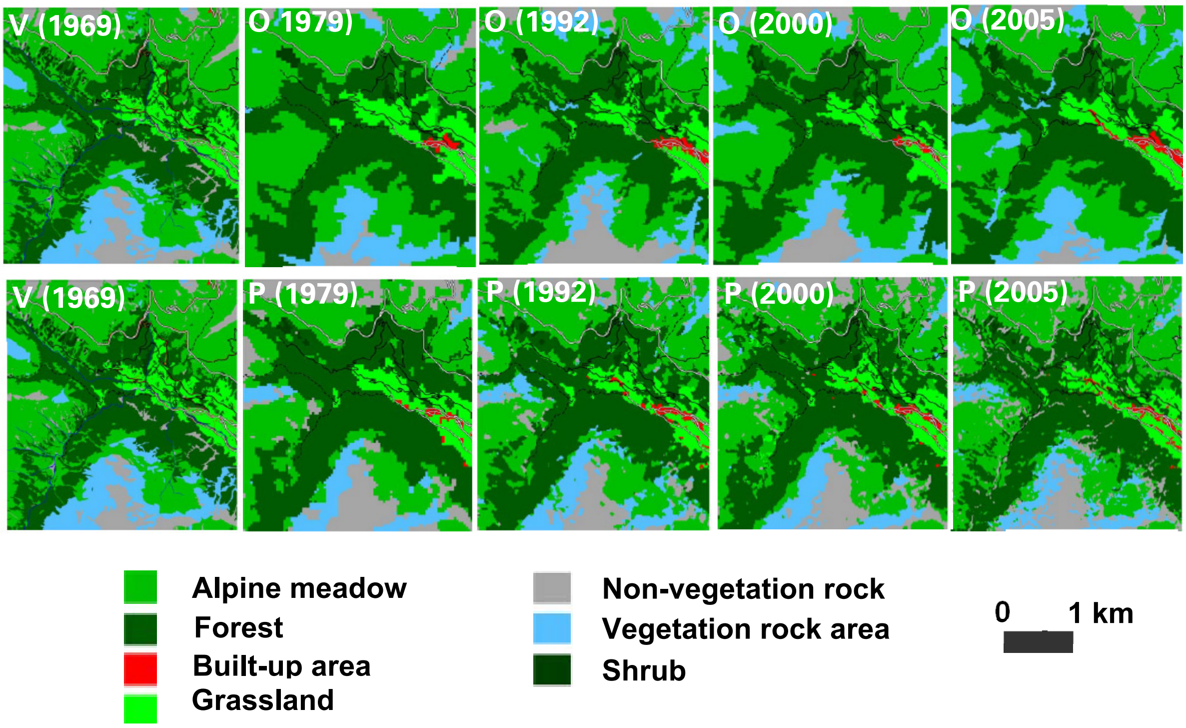


Figure 10: The classification result for the Austrian study area. Results based on object-based (O) or pixel-based classification (P) or based on visual interpretation (V). As data base aerial and satellite imagery from 5 dates, starting in 1969, were used.

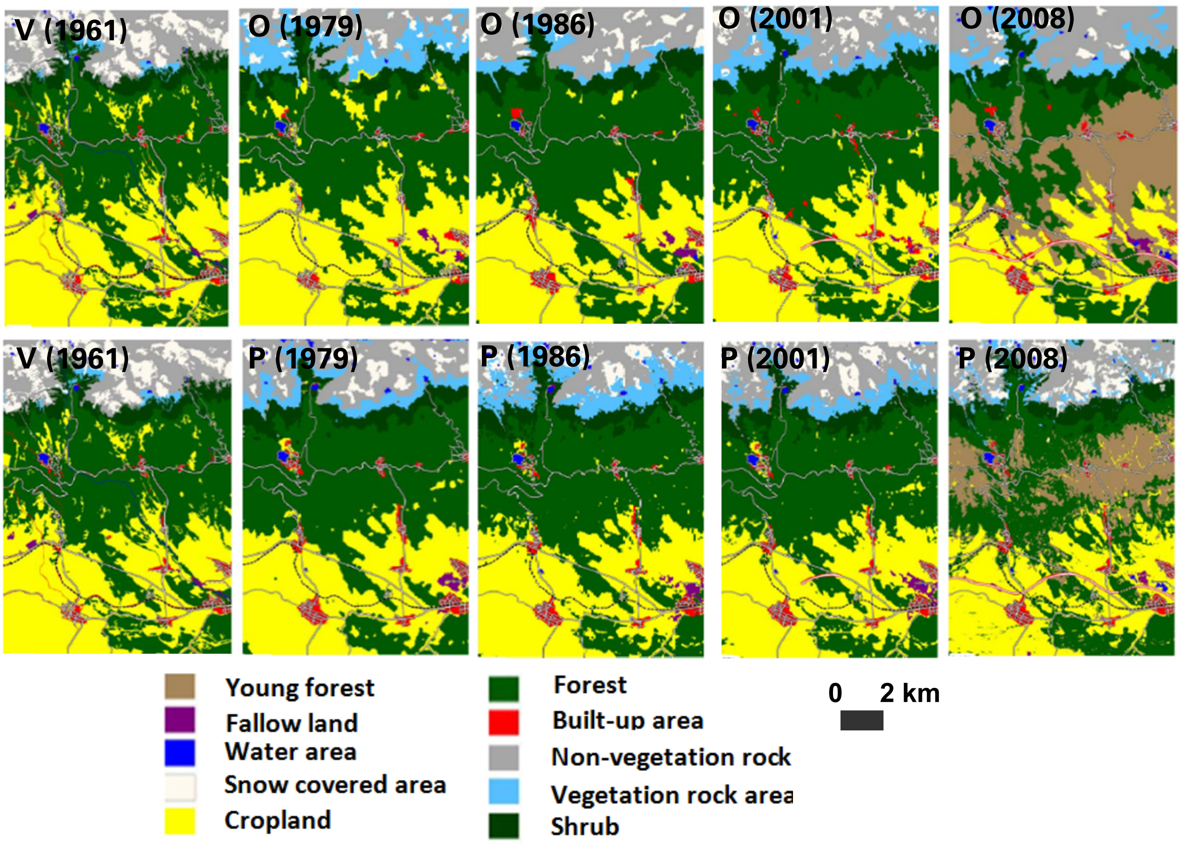


Figure 11: The classification result for the Slovakian study area. Results based on object-based (O) or pixel-based classification (P) or based on visual interpretation (V). As data base satellite imagery from 5 dates, starting in 1961, was used.

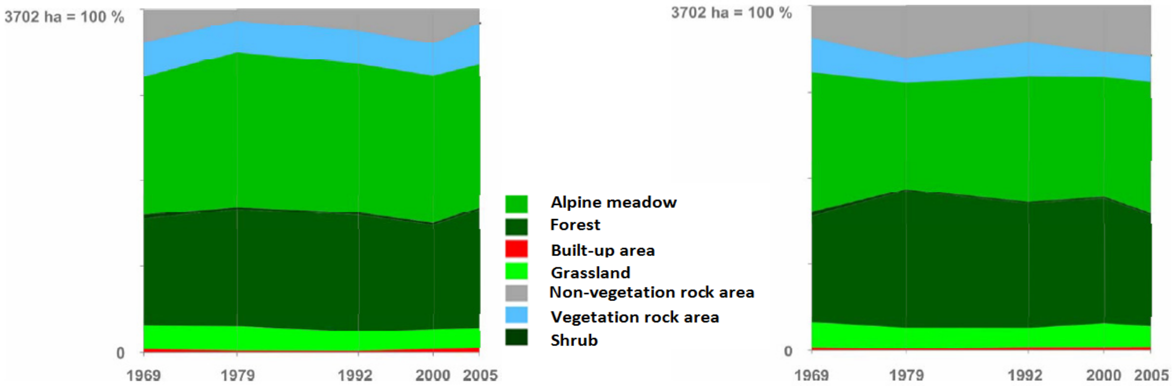


Figure 12: Cumulative area chart for the Austrian site (object-based (left) and pixel-based (right)).

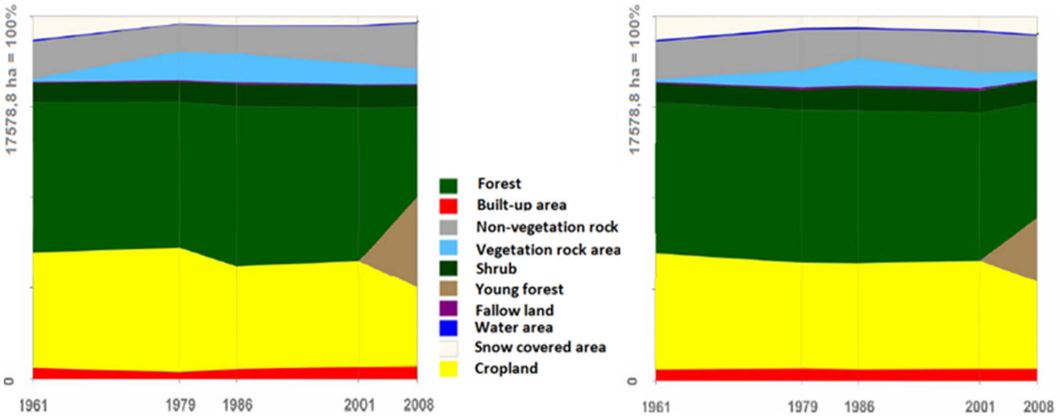


Figure 13: Cumulative area chart for the Slovakian site (object-based (left) and pixel-based (right)).

The final and post-processed classification results have been assessed in terms of their accuracy by a sample of 320 randomly acquired points. The overall classification accuracies (Table 3) are listed concerning the classification approaches and the different sensors, respectively. The accuracies are therefore at a more or less comparable level of around 90%, regardless of sensor, classification approach or study area. The errors of commission and omission did not indicate significant differences and are thus not further discussed, but are considered within the Kappa statistics.

Table 3: Accuracy assessment for the Austrian and Slovakian site, differing between sensor and classification approach.

Austria	**MSS**		**TM**		**ETM+**		**ASTER**	
Classification	Total (%)	Kappa	Total (%)	Kappa	Total (%)	Kappa	Total (%)	Kappa
object-based	88.44	0.84	89.69	0.86	90.31	0.87	90.94	0.97
pixel-based	85.31	0.80	88.75	0.85	92.50	0.90	88.75	0.85
Slovakia	**MSS**		**TM**		**ETM+**		**ASTER**	
Classification	Total (%)	Kappa	Total (%)	Kappa	Total (%)	Kappa	Total (%)	Kappa
object-based	94.06	0.92	94.69	0.93	91.88	0.89	92.81	0.91
pixel-based	91.25	0.89	93.44	0.91	94.38	0.93	90.00	0.88

3.3 CHANGE DETECTION MAPS

A comparison of classification results aligned side by side (Figure 10 and Figure 11) takes into account the respective databases. But this kind of data presentation does not offer a clear view on the results. Therefore a change detection map was made that includes the information for every date in a single map that can be seen as a map of essential results.

The main challenge in showing the results was the graphical representation of years and classes relating the change. A varying combination of color and pattern was consequently developed (Figure 14 and Figure 15). Apart from the main structures, both changed or unchanged, discussed in section 3.2, these maps also allow studying changes of details and moreover highlight the time scale of changes, e.g. the construction of the highway in the Slovakian site (Figure 15), due to the possibility of direct comparison of changes.

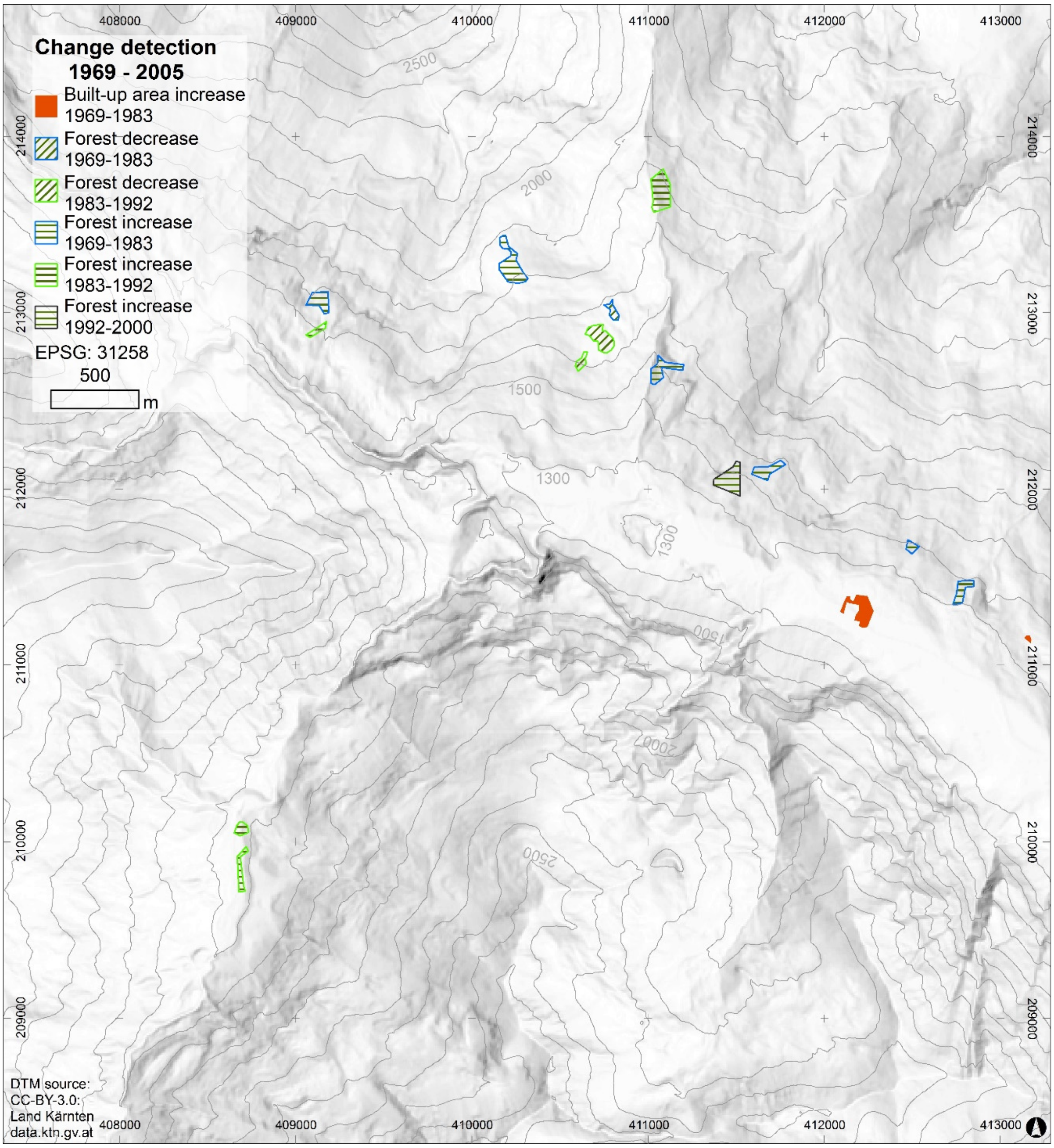


Figure 14: Change detection map of the Austrian site.

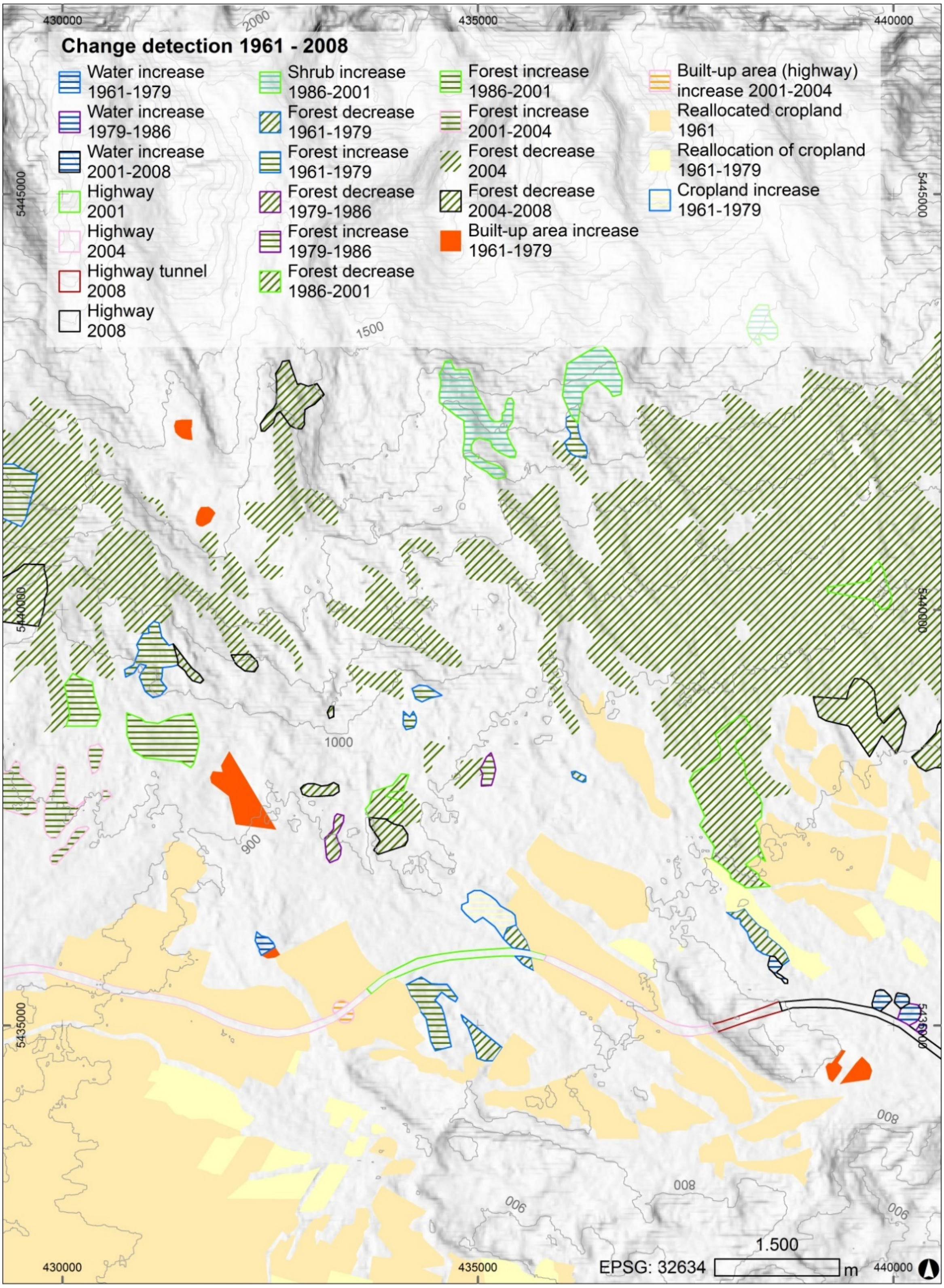


Figure 15: Change detection map of the Slovakian site.

4 CONCLUSION

Both case studies prove that even medium high-resolution data can be used for these classification approaches with the aim of a comparative high mountain geography. Very good results can be achieved. In spite of the generalized classes significant differences between the investigation areas can be shown. Furthermore all ASTER scenes were classified with the same algorithm which provided the basis for additional (worldwide) comparisons and analyses. This study can be a good basis for similar analyses and automated classifications apart from high mountain regions. Thus, according to the scale the conducted method is appropriate for LU/LC studies.

The development of both case studies was in general comparable with almost no large differences concerning the LU/LC areas. Of course, some exceptions are recognizable and focusing on details is quite important.

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MOUNTAIN AND HIKING CARTOGRAPHY

THE CREATION OF AN ORTHOPHOTO MAP OF KANGCHENJUNGA BY MEANS OF HISTORICAL AERIAL SURVEY OF SCHNEIDER / KOSTKA

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ABSTRACT

The aim of this initiative was to generate an aerial-map from a historic flight campaign by means of Structure from Motion (SfM) technology. These original analogue images (180 individual 6x6 cm Hasselbald slides from 1986) were provided by R. Kostka. The general workflow consists of image scanning, image matching and orthorectification of the images. The whole workflow was implemented with the photogrammetric-software Agisoft which is especially suitable for image-matching and orthomosaic-creation. With this product, it is possible to create an aerial-map out of the orthomosaic, which can be compared geographically with high resolution satellite images of the region.

Keywords: historical airborne images, structure from motion technology, Kangchenjunga/ Nepal

1 INTRODUCTION

Airborne imaging systems were commonly used in the 20th century to provide aerial images for the generation of topographic maps. Especially in mountainous regions the view from the airplane provides a good overview on remote regions which are very difficult to access.

Erwin Schneider used this technology to produce high-quality topographic maps from the highest mountains in the world. With the so called "Schneider – Maps," he created a map series which is still well known in the Himalayas, especially in Nepal, by both cartographers and alpinists (Haffner et al. 2004).

The airborne campaigns (beginning in the late 1950's through 1986) by Schneider aimed for photogrammetric-cartographic purposes. The aerial image series were used as a basic information source for generating topographic and thematic maps with various scales. Most of the maps were published within the framework of the Association for Comparative Alpine Research in Munich (Kostka 2004).

On 5th of December 1985, one of the last flight campaigns was done by Erwin Schneider together with Robert Kostka in the Kangchenjunga massif in the eastern part of Nepal (Figure 1). The Kangchenjunga is an 8585m high peak and is ranked as the 3rd highest mountain in the world just behind Everest and K2.

A geographic interpretation of the acquired images doesn't lay in the focus of Erwin Schneider´s interests. Nowadays, these historic images are valuable in the context of a changing mountain environment.

This article describes a workflow to create an geo-reference, orthomosaic image from the flight on December 5th 1986. The available images are scanned 6x6 cm slides in TIFF format. The general workflow is based on the photogrammetric process of "Structure-from-motion" technologies (Fonstad et al. 2013, Westoby et al. 2012). The workflow consists of image-matching, orthocorrection and geocoding of the image data. A more detailed explanation of the workflow is shown in chapter 3. After these processing steps, it is possible to create an aerial map out of the orthomosaic. The whole workflow was done with the photogrammetric software Agisoft PhotoScanPro which is especially suitable for image-matching and orthomosaic-creation even with non-oriented image data (Snavely et al. 2008, Westoby et al. 2012). These more than 30-year-old images are very valuable and can be compared geographically with recent high resolution satellite images of the region to detect landuse and landcover changes during a timespan when airborne image information from remote areas in the Himalayas are rare.

Figure 1: Location of Kanchenjunga (source: naturalearthdata.com).

2 DATA SOURCE

The data source consists of aerial images from a mountain flight of the two Austrian geodesists Erwin Schneider and Robert Kostka on the 5th of December in 1986. The observing platform was a Pilatus-Porter aircraft. This aircraft is especially suited for mountain flights in high-mountain-regions like the Himalayas because of its possible low flight-speed. This allows the generation of sharp images even in low altitudes. The pictures had been taken with three Hasselblad 500EL/M middle-format-cameras (Figure 2). All together there are 176 images most of them oriented in nadir direction and some taken with the two side-looking cameras. The observed area is in the western part of the Kangchenjunga Mountain Range along the valley of Mount Jannu. This high mountain landscape is covered with typical Himalayan glaciers, rivers, alpine pastures, debris and rocks. The main challenge in this workflow is to handle the extreme relief. The differences from the highest peak to the lowest point in the valley are around 4,000 m within few kilometers of horizontal distance. Other challenges within this data source are: no constant flight altitude of the aircraft; different flight directions; windy flight conditions; relatively old data set with less availability of recent natural and artificial features to obtain GCP points; analogue data which have been scanned (with 4800 dpi non-photogrammetric scanner, Figure 3); no height information; no interior orientation information; no reference data to provide good information about the exterior orientation.

Figure 2: Hasselblad 500 EL/M (source: http://camerapedia.wikia.com)

Figure 3: Data-Source (Scan).

3 SOFTWARE

Since there is no (interior and exterior) orientation information and no other geographical information available, a traditional workflow of image-orthocorrection is not possible. "Structure-from-Motion (SfM)" technologies, however, are applicable. Initially developed for building architecture and 3D representations of objects, computer vision SfM algorithms aim to reconstruct simultaneously camera positions and orientations, as well as a 3D-scene structure from a set of feature correspondences derived from overlapping pictures (James and Robson 2014, Westoby et al. 2012, James and Robson 2012).

SfM is a method of image measurement and is assigned to the field of computer-vision, which is concerned with the technical implementation of the human visual system and develops methods for "machine vision". SfM essentially describes the conversion of 2-dimesional image data into a 3-dimensional format. The basis for this is always a series of geometrically overlapping images, which are recorded from different positions and viewing directions. With SfM it is possible to calculate the camera positions and the orientations of the individual images to each other. This can be done by connecting image features which appear on several images individually. These points of interest (POI) are single points or edges which are recognized in the overlapping images. Due to the movement of the camera, the external orientation can be calculated and a relatively oriented point cloud of the previously determined POI's can be produced (Fisher et al. 2005, Resch et al. 2016). More detailed explanations and information about the different used algorithms are described in (Schönberger & Frahm 2016, Snavely et al. 2008, Westoby et al. 2012, Smith et al. 2015). In further processing steps outliers are removed and a polygonal model is generated from the calculated point cloud. Linked with the image information a 3-dimensional, photorealistic model can be generated.

Agisoft PhotoScan Pro is a tool which is capable of such a workflow. It's a photogrammetric software kit which is mostly used for the creation of 3D point clouds and textured models. But it's capable of orthomosaic creation out of this models as well (Agisoft 2016).

4 WORKFLOW

The analogue data had been scanned with a 4800 dpi non-photogrammetric scanner. The size of the scanner made it possible to scan six slides at once. After that step it was necessary to obtain an image subset for each slide. This was achieved by an image-cut in Photoshop. Each separate image could then be included in the following workflow in PhotoScan Pro.

The general workflow consists of (Agisoft, 2016): 1) Image Alignment 2) Dense Point Cloud Formation 3) Mesh Creation 4) Texture Creation and 5) Export Orthomosaic (Figure 4). The process in Agisoft PhotoScan Pro is a linear combination of these steps. This must be carried out in the correct order or else this process won't work at all. There are also very limited ways for the user to change the workflow for different scenarios. The workflow itself is very intuitive and easy to use. On the one hand this could be a benefit for users which aren't experienced in this kind of techniques but on the other hand there are very limited options in customizing the workflow. A detailed explanation of the agisoft-workflow and the different tools is shown in (Agisoft 2016).

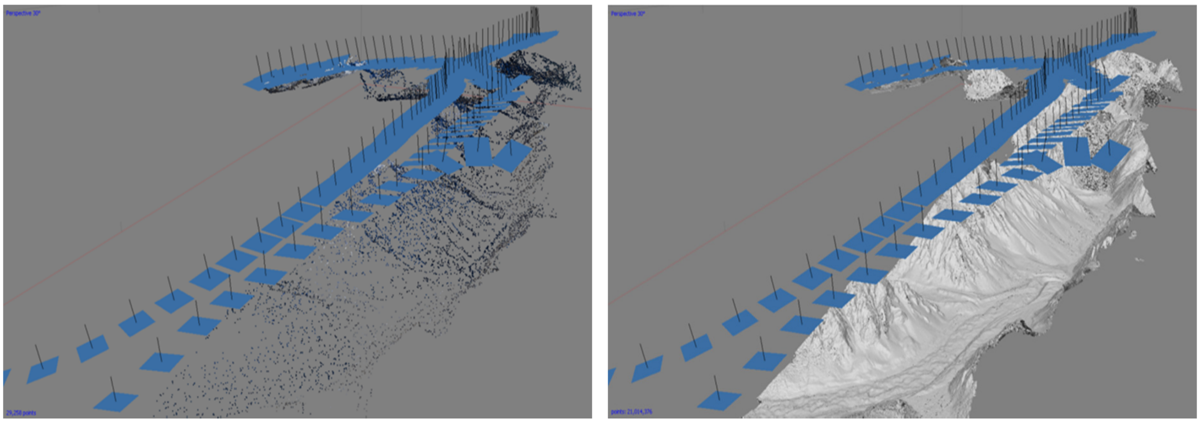
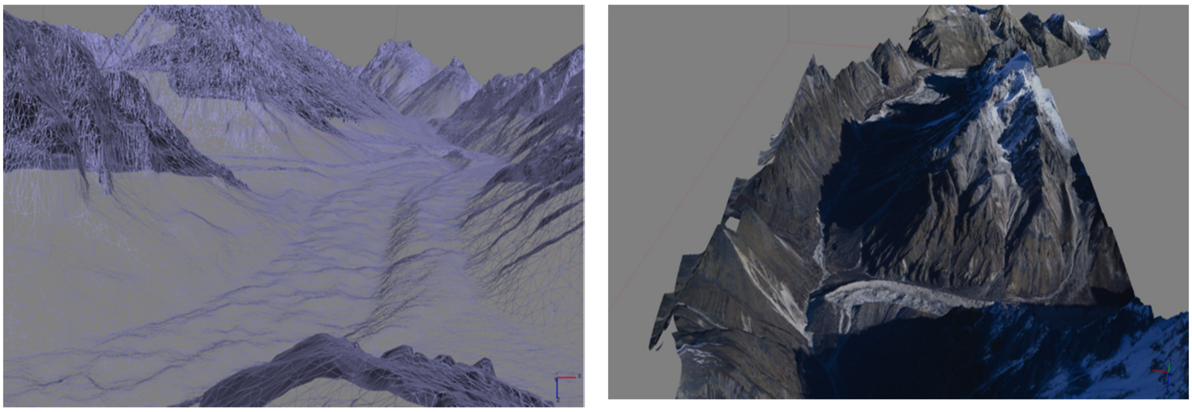


Image Alignment

Dense Point Cloud Formation



Mesh Creation

Texture Creation

Figure 4: Workflow.

At the beginning of the Structure-From-Motion workflow a new project was started and all 176 images were imported. At this point of the workflow it is common to add the position information of the image data. This must be skipped because there is no information available. The benefit of such information is quicker calculation and direct geocoding, but the software is also capable of running the workflow without position information. In this case, we only get relative position information in our results and must geocode the date afterward with a reference-data-set.

The first step of this Structure-From-Motion workflow is the "Photo Aligning". Inside the process PhotoScan is trying to find matching-points in the overlapping images. Out of this it is possible to calculate the relative camera-positions and create a 3D point cloud. It was not possible to include all given images in this final point-cloud. Around 40 out of 170 images could not be used. There are several reasons for this: One reason is that not all images are geometrical overlapping. This happens due to the great differences in the topography, and the flight height above ground. Other reasons are the low rate of detectable object features in several images due to less contrast (Figure 5) or snowy terrains (Figure 6) without any recognizable objects.

The next working step is to create the dense point cloud. The system multiplies the already existing Tie-Points by calculating further points out of the camera-positions and the image information. The amount of points inside this point-cloud ranges from 29,258 up to 21 million points. Next the point-cloud gets triangulated into a polygon-model using the "Create Mesh" tool. This 3-dimensional combination of triangles is the elevation model which will be used for the orthocorrection. But before that the system connects the image data with the polygon model to get a textured surface (Tool: Build Texture). In the last part PhotoScan flattens this 3D-model and exports the final orthophoto product.

Figure 5: Less contrast.

Figure 6: Glacier area.

The last part is the georeferencing of the scene. At this point the orthomosaic has no position information. The geocoding can be done in any GIS or Remote-Sensing software tool. In this case, we used Quantum-GIS and Google images of the region to achieve sufficient geoinformation for the images. The historical images are thirty years older than the reference date, so it's a challenging process to find suitable matching-points which didn't change within this timespan. This processing step is similar to the approach of (Gomez et al. 2015).

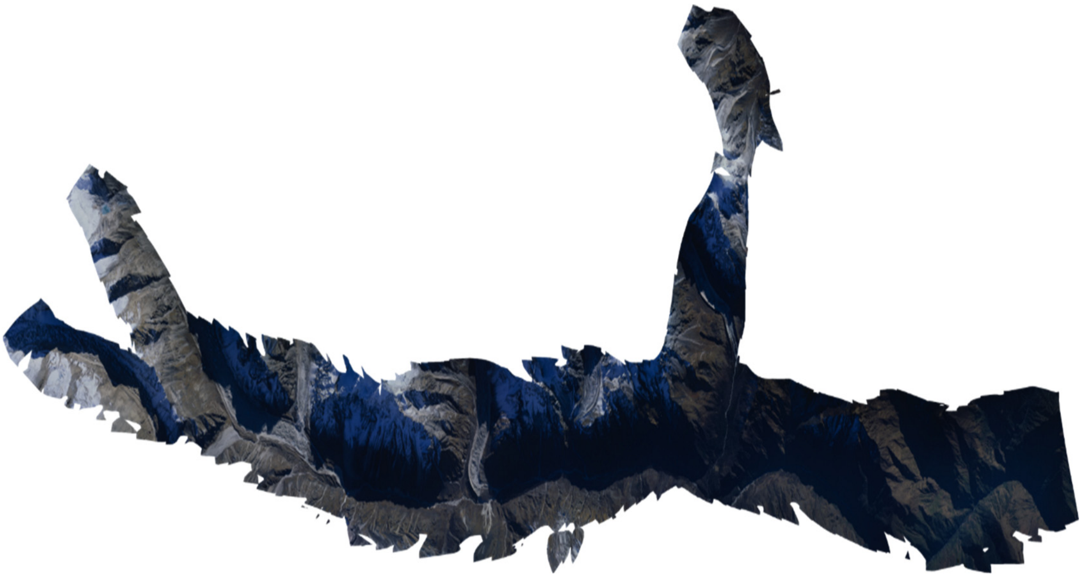


Figure 7: Orthomosaic.

5 CONCLUSION

The final product is an airphoto map (Figure 9) of the western parts of the Kangchenjunga from a geocoded orthomosaic of historical image data from Schneider/Kostka in 1986. The scale of this map is 1:10,000 (in A0) and it covers the central part of the observed area next to the only human settlement „Khangpachen" near the „Jannu-Glacier". In this map, glaciers, rivers and infrastructure are defined as map object. The geometrical accuracy of the output data is not part of this research but the quality is enough for image interpretation and different analyses in changing mountain environments. Figure 8 documents the changes of the glacier environment from 1986 to 2013. The general profit of this research is the ability to create geometrically corrected pictures and even maps out of non-oriented historical image data, which are available from Schneider/Kostka from other parts of Nepal.

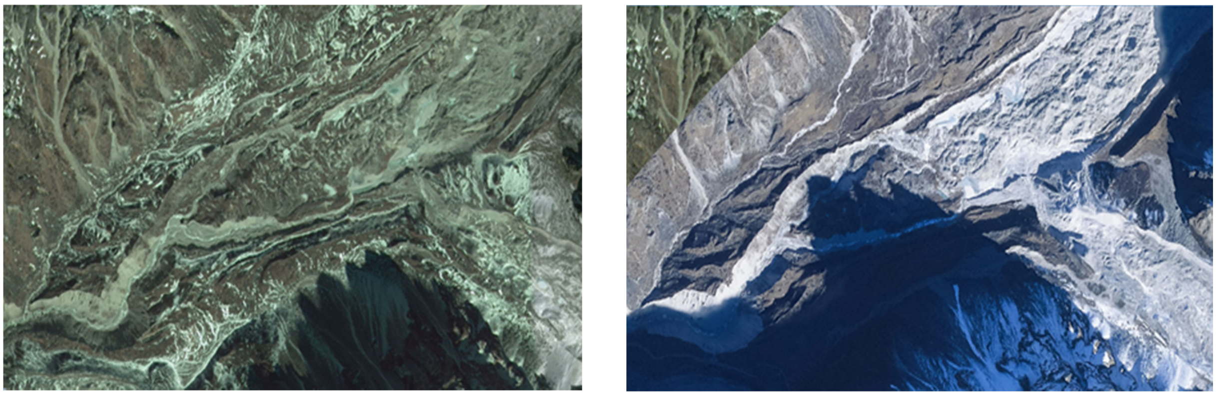


Figure 8: Kangchenjunga glacier - 2013 (left: Google Earth) and 1986 (right).

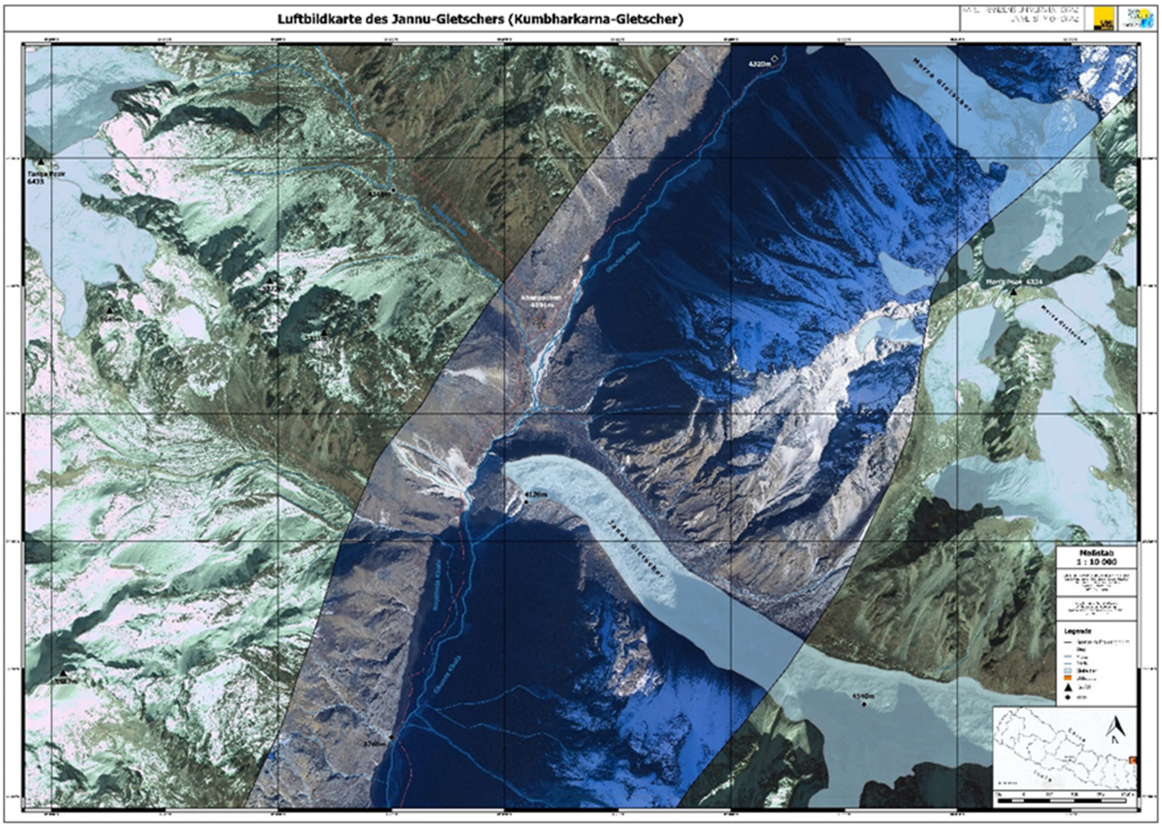


Figure 9: Airphoto-Map.

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MOUNTAIN AND HIKING CARTOGRAPHY

MOUNTAIN MAPS IN THE “SWISS WORLD ATLAS”

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ABSTRACT

This extended abstract describes some application cases of maps depicting mountainous regions in the SWISS WORLD ATLAS, the official Swiss school atlas. The atlas contains such maps at different scales, from synoptic physical maps of continents and countries to very detailed topographical and geomorphological maps of specific areas of interest. Within the project of renewing the entire atlas by 2017, a series of novel methods for relief representation were developed, mainly for shaded relief generation and automated rock drawing.

Keywords: Mountain maps, topographic mapping, school atlases, shaded relief, cliff representation

On secondary school level (7th to 13th class, ISCED 2 + 34), the SWISS WORLD ATLAS (SWA) is the most widely-used school atlas in Switzerland. The Swiss Conference of Cantonal Ministers of Education (EDK) decided in 1898 to issue an atlas for all secondary schools in Switzerland. The first edition in German was published in 1910, the French edition in 1912 and the Italian one in 1915. First editor-in-chief was Prof. August Aeppli, a secondary school teacher. In 1928, EDK called for proposals for a new, entirely revised version of the atlas. Prof. Eduard Imhof, who had founded the “Cartographic Institute” at ETH Zurich (the Swiss Federal Institute of Technology) shortly before, won the tender and remained editor-in-chief until 1978. Under his auspices, a major revision was done in 1962, changing from the classical hachure technique and lithography to halftone reproduction and offset printing technology. Under Imhof's successor, Professor Ernst Spiess, the next revision led to a new version in 1993, and a switch to digital technologies in 2002. Since 2009 a new editorial team at the institute was first working on an interactive version of the atlas which was published in 2010 together with an update of the printed version (Häberling et al. 2011). The on-line version consists mainly of existing maps from the printed version which are split up in thematic (raster) layers and enriched with additional attributive data, such as population figures for major cities. Furthermore, newly developed, special modules provide added value to existing maps and information graphics such as 3D models, astronomic simulations or map projections. Currently, the printed version of the SWA is entirely revised, it will be published in 2017.

Only 30 % of the Swiss territory, the so-called plateau, may be regarded as non-mountainous area, whereas 48% belong to the Alps, 12% to the Pre-Alps and 10% to the Jura. The depiction of the Swiss mountains and of other mountainous terrains all over the world was therefore an important topic in all former editions of the SWA as well as in the future edition of 2017. The new edition will consist to a large part of standardized maps, complemented by special thematic maps or maps of areas of specific interest. The standard types of maps in the SWA are (Hurni et al. 2015): Synoptic maps and relief maps of countries and region, Economic maps, Political maps, City maps, and special thematic maps. Furthermore, the atlas contains an introductory part with information about map use, and several thematic indexes and gazetteers.

Figure 1: Synoptic physical map of Europe using the Swiss-Style Colour Relief Shading.

First of all, reliefdepiction plays an important role in the synoptic physical maps of the continents. In the SWA the Swiss-Style Colour Relief Shading is applied, which basically combines a grey shaded relief with hypsometric tints from blue/green to yellow and white (Jenny and Hurni 2006). Figure 1 shows an extract of the synoptic physical map of Europe using the Swiss-Style Colour Relief Shading.

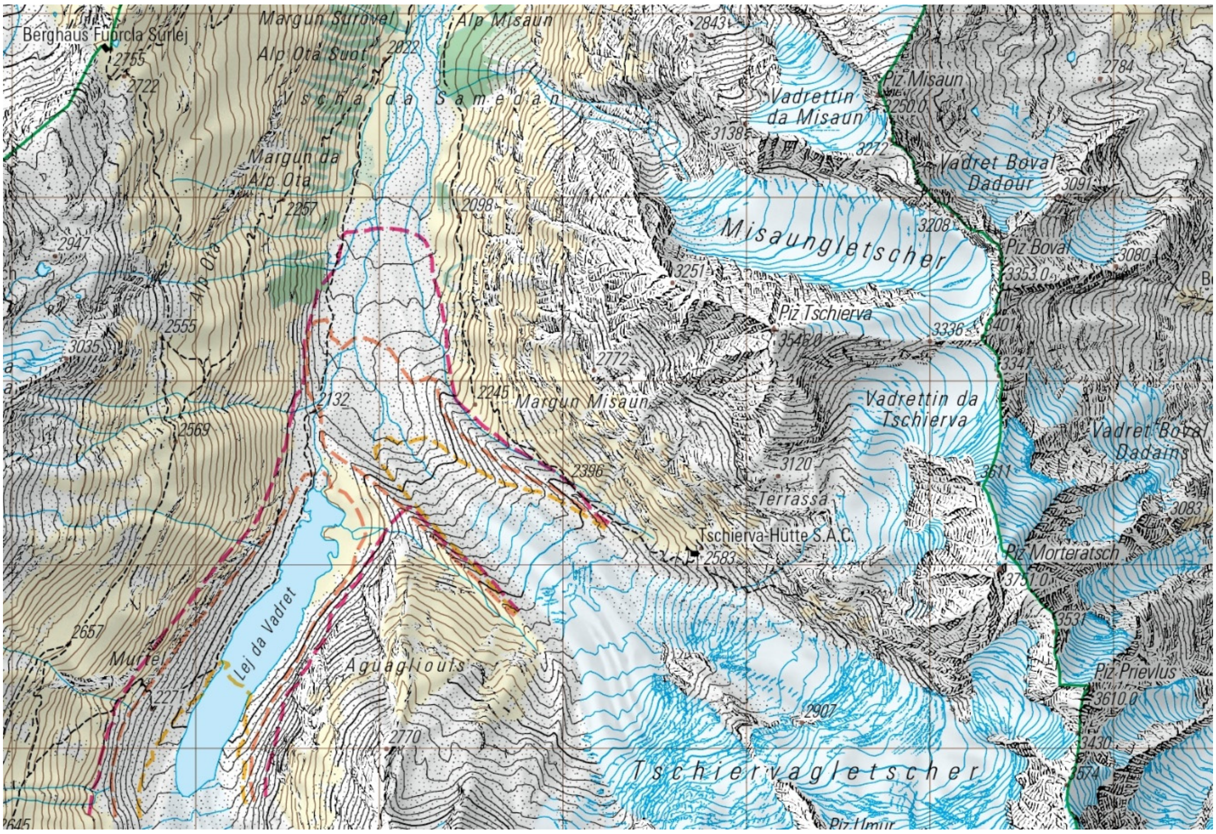

Figure 2: Topographic map 1:50,000 of Bernina area with historic glacier states.

Figure 2 represents an extract of a classical topographical map 1:50,000, based on vector data (e.g. contour lines) and other elements (cliffs, shaded relief) from existing national topographic maps. The extract was enriched with geomorphological symbology for glaciological phenomena.

For the map of Mount Everest 1:100,000 a shaded relief based on an existing DTM by ETH Zurich (Gruen and Murai 2002) was generalised and smoothed along the slope lines by preserving important edges (Geisthövel and Hurni 2015). This was used as modulation for the generation of fill hachures according to the Swiss style rock depiction (Jenny et al. 2015). Figure 3 shows the resulting fully automated rock depiction for the summit area of Mount Everest (Hurni et al. 2015b). The method is described in full detail in Geisthövel (2016).

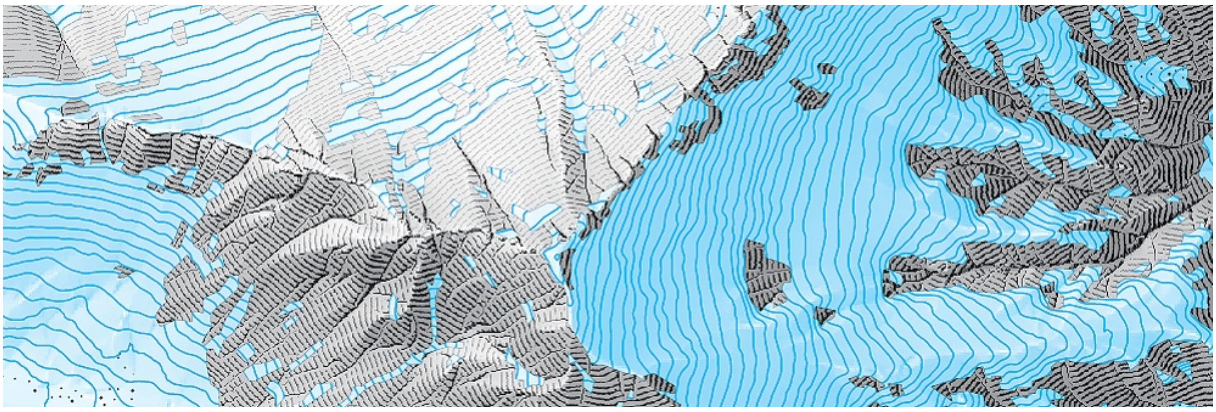

Figure 3: Automated cliff drawing for map of Mt. Everest 1:100,000.

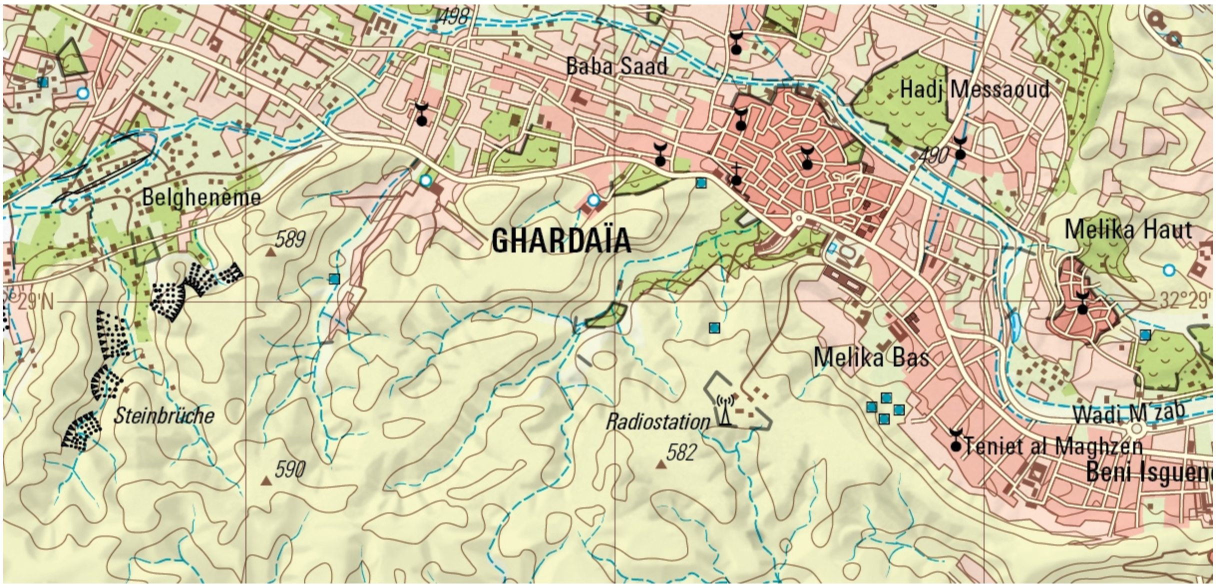

Figure 4: Map of Ghardaia, Algeria 1:50,000 with manually retouched analytical shading.

For a number of newly established, detailed topographic maps, shaded reliefs were needed to represent the terrain. Most of them were generated a defined workflow using the Blender 3-D-modelling, designing and rendering software. In some cases, the processed reliefs needed to be adjusted manually using retouching functions in Photoshop. Figure 4 shows an extract of the map of Ghardaia, Algeria, based on an analytical shading. Manual retouching was applied in order to emphasize the plateaus on the mountain tops around the city.

The collection of about 400 maps in the Swiss World Atlas shows that a significant part of those maps contain mountain related themes using different visualisation techniques (Häberling 2015). Digital base data with sufficient resolution is now available for almost all areas of the world. The workflow to produce all elements of the needed maps can be followed in an entirely digital manner, even for complex depictions such as rock and relief. Manual retouching can be applied where needed, also in a fully digital environment and always reproducible. The derivation of products for other media such as web maps is eased and allows for flexible applications.

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GLACIER-RELATED ASPECTS

QUANTIFICATION AND VISUALIZATION OF PERIGLACIAL SURFACE DEFORMATION IN THE INNERES HOCHEBENKAR CIRQUE, ÖTZTAL ALPS, AUSTRIA

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ABSTRACT

Inneres Hochebenkar is a glacial cirque (approx. 0.84 km^2) located in the Gurgl valley, Ötztal Alps, Tyrol. It holds not only a rock glacier (of the same name) but also a small glacier (Hochebenferner) in its root zone. During the Little Ice Age (last glacial maximum at around 1850) the Inneres Hochebenkar cirque was largely covered by the Hochebenferner Glacier, which has now receded to a small remnant (8.3 ha in 2006). The main focus of the present paper is to document the past and also more recent surface change of the periglacial environment of the Inneres Hochebenkar cirque. Remote sensing data, such as time-series of aerial photographs (1953-2010) and airborne laser scanner data (2006, 2010), were used to retrieve quantitative information on surface change, i.e. horizontal movement and/or surface height change. The results obtained are presented graphically (two separately moving rock glacier units connected by a small unit of inactive, but melting permafrost at the lower end of the cirque) and numerically (e.g. maximum mean annual creep velocities of up to 46.7 cm/year for the time period 2003-2010 and maximum surface lowering of -10.8 m for the time period 1953-2006). Special attention is also paid to proper visualization, i.e. computer animations, of areas of presumed surface change using time-series of both high-resolution orthophotos and shaded reliefs.

Keywords: permafrost, rock glacier, surface deformation, photogrammetry, Inneres Hochebenkar

1 INTRODUCTION

Glaciers are visible expressions of the cryosphere, which also includes permafrost. Mountain permafrost, i.e. alpine frozen ground, is present in the Austrian Alps and the focus of ongoing research (Krainer et al. 2012). In marked contrast to glaciers (frozen water), permafrost cannot be identified easily in the field. However, so called *rock glaciers*, which are creep phenomena of (discontinuous) mountain permafrost, can indicate permafrost conditions in the periglacial environment (Barsch 1996, Haeberli et al. 2006).

Climate change has significant influence on the cryosphere. Atmospheric warming during the last 150 years has caused strong glacier recession and also permafrost degradation. Recent studies focusing on rock glacier kinematics document ongoing environmental change, e.g. in the European Alps (Delaloye et al. 2008, Kellerer-Pirklbauer and Kaufmann 2012). Speed-up of rock glacier surface movement and, in some cases, strong changes in surface morphology, i.e. surface lowering and collapse, have been reported. Both processes destabilize the rock glaciers and may cause subsequent rapid mass movements (Schoeneich et al. 2014).

Recently, Krainer et al. (2015) carried out a study at the *Inneres Hochebenkar cirque* (‘*kar’* is the German word for cirque) with special emphasis on its morphology and hydrology. The cirque holds not only a rock glacier (of the same name) but also a small glacier. Their study was supported by area-wide measurements of surface kinematics (1953-1997) carried out by other authors. The aim of the present paper, however, is to extend the observation period of change detection up to the year 2010. This will be facilitated by the combined analysis of new aerial surveys conducted in 2003 and 2010 and additional airborne laser scanning (ALS) data acquired in 2006 and 2010. Based on these new data we aim to answer the research question whether or not the surface kinematics of the Inneres Hochebenkar rock glacier have changed significantly. We will assess not only the horizontal flow velocity but also surface elevation change of the suspected rock glacier area in the periglacial part of the cirque.

The remainder of the paper is structured as follows: Section 2 gives a brief introduction to the study area. This is followed by a summary of previous work (permafrost studies, cartography, SAR interferometry, and photogrammetry) carried out in the study area. Section 3 presents the new data to be analyzed. Both image-based and DEM-based change detection will be addressed in Section 4. The results obtained are presented in Section 5. The paper concludes with a discussion and an outlook.

2 STUDY AREA

The study area of the Inneres Hochebenkar cirque (46°49'33" N, 11°00'33" E) is located in the Ötztal Alps, Tyrol, Austria (Figure 1). It can be accessed by foot (hiking trail no. 922) from the nearby village of Obergurgl (1,907 m, Gurgl valley). A detailed geomorphological map of the Inneres Hochebenkar cirque is given in Krainer et al. (2015). The cirque (approx. 0.84 km^2) is open to the west and its confining mountain ridges reach heights beyond 3,000 m. The main, central part of the cirque is covered by ground moraines deposited by Hochebenferner Glacier during the Little Ice Age (maximum glacial extent ca. 1850). The lower part of the cirque is occupied by the Inneres Hochebenkar rock glacier (Krainer and Ribis 2012) comprising two main tongue-shaped units (northern unit: from 2,694 m to 2,840 m, southern unit: from 2,650 m to 2,810 m). The root zone of the cirque holds the remnants of Hochebenferner and another small rock glacier (Figure 2).

The cirque located north of Inneres Hochebenkar holds the Äußeres Hochebenkar rock glacier, Austria's prime rock glacier. It is well-known for its long record of continuous photogrammetric and geodetic measurements (Kaufmann 2012, Nickus et al. 2013). A virtual overflight of the study area showing both Äußeres and Inneres Hochebenkar rock glacier can be accessed through Kaufmann (2016).

Our research work presented in this paper covers a rectangular mapping area as outlined in Figure 1.

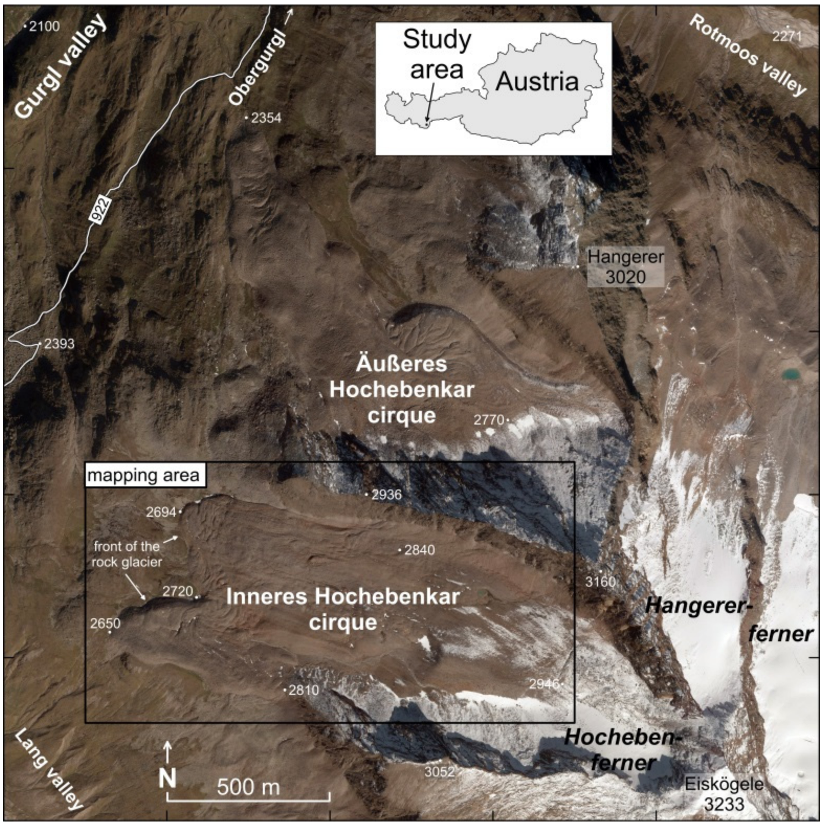

Figure 1: Location map showing both cirques of Äußeres and Inneres Hochebenkar. The mapping area is outlined by a box. Orthophoto of 11 September 2010. Orthophoto © Land Tirol.

Figure 2: Terrestrial view of the Inneres Hochebenkar cirque as seen from Ramolhaus (alpine hut, 3,005 m) in easterly direction. Photo taken on 31 August 2015 by A. Kleb.

3 PREVIOUS WORK

This section includes background information/material which helped us in carrying out our study and, most importantly, all previous work on the detection and mapping of surface movement/deformation of the Inneres Hochebenkar rock glacier.

3.1 PERMAFROST STUDIES

Permafrost-related studies at the Inneres Hochebenkar cirque were carried out by Haeberli and Patzelt (1982), and more recently by Krainer et al. (2015). Haeberli and Patzelt prepared, e.g. two separate maps indicating the occurrence of permafrost and active layer thickness. Both maps are based on field observations, such as basal temperature of the winter snow cover, refraction-seismic profiles, and summer temperature variations of springs. The work of Krainer et al. focuses on the hydrology of the cirque measuring the electrical conductivity and nickel concentration of spring water.

3.2 OTHER MAPS

The area was covered by several topographical mappings which provide the information on the historical glacier extent. The glaciation of the Inneres Hochebenkar cirque during the 19th century can be assessed based on old maps (tiris 2016). A good example is the map of the survey '*Dritte Landesaufnahme*' 1864-1887, which shows that Hochebenferner Glacier was already receding (Figure 3). The maximum extent of glaciation was reached around 1850, which marks the end of the Little Ice Age. Thus, most probably the Inneres Hochebenkar cirque was not completely glaciated at that time.

In 1936 the Inneres Hochebenkar cirque was surveyed by terrestrial photogrammetry in preparing a 1:25,000 map (sheet Gurgl) of the Ötztal Alps (Pillewizer 1957). The map was published in 1949 by the Austrian Alpine Club (Figure 4).

The 1:10,000 map 'Gurgler Ferner 1981' also comprises the Inneres Hochebenkar cirque (Figure 5). The above mentioned maximum glacial extent is indicated in the map in red color (solid line = confirmed by field evidence, dashed line = vague). For explanatory notes on the 'Gurgler Ferner 1981' map, see Patzelt (1986).

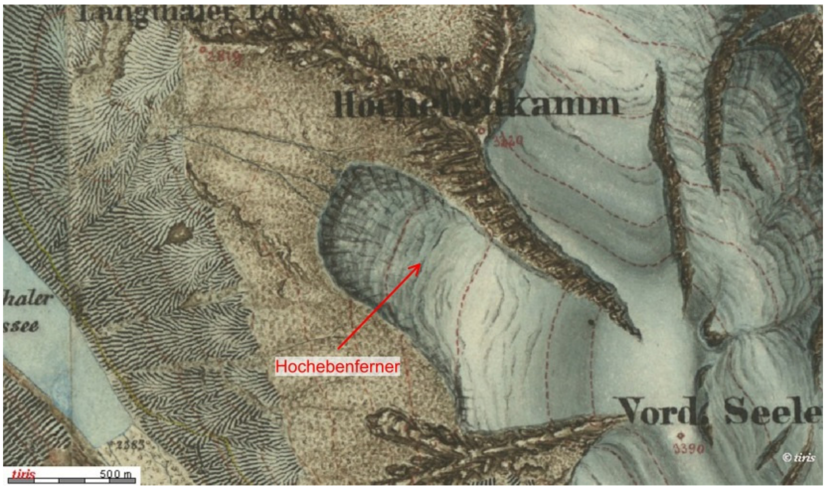

Figure 3: The Inneres Hochebenkar cirque with Hochebenferner Glacier (survey 1870-1873). 'Dritte Landesaufnahme' survey 1864-1887, source: tiris (2016).

Figure 4: The Inneres Hochebenkar cirque (terrestrial photogrammetric mapping, 1936). Clip from the map 'Ötztaler Alpen, Blatt Gurgl' 1:25,000, published in 1949. The location of two terrestrial photogrammetric profiles is indicated in red color.

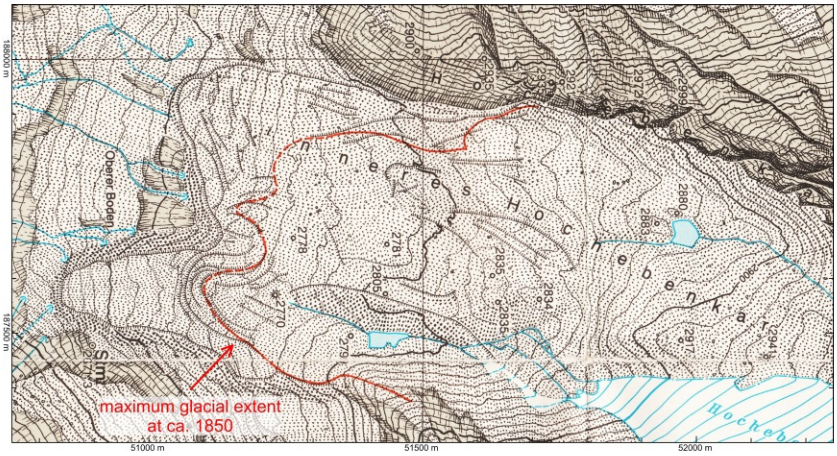

Figure 5: The Inneres Hochebenkar cirque (aerial photogrammetric mapping, 1981). Clip from the map 'Gurgler Ferner 1981' 1:10,000, published in 1986.

3.3 MEASUREMENT OF FLOW VELOCITY

Wolfgang Pillewizer was the first to measure surface flow velocity at the Inneres Hochebenkar rock glacier (Pillewizer 1957). In 1953 he set up a terrestrial photogrammetric baseline at 2,686 m north of the southern unit of the rock glacier in order to measure flow velocity by repeat photography (Figure 4). A second survey was carried out by the same author in 1955. The horizontal displacements of five points located at the upper edge of the frontal slope were determined. Pillewizer calculated a mean annual flow velocity of 1.10 m a^{-1} for the period 1953-1955.

Another terrestrial photogrammetric profile at the Inneres Hochebenkar rock glacier was set up and re-visited by Egon Dorrer in the framework of the course '*Kurs für Hochgebirgs- und Polarforschung*' held in Obergurgl (Vietoris 1972). The baseline had been installed in 1959 on a stable rock outcrop at 2,800 m as indicated in Figure 4 (drawn after Vietoris 1972). The profile extends across the supposed rock glacier flow direction and covers only morainic surface points of the central part of the cirque. This baseline was re-visited in 1966. No movements were detected, and the northern unit of the rock glacier was thus considered as inactive.

The velocity field of the Inneres Hochebenkar cirque was mapped for the first time applying satellite radar interferometry (Rott and Siegel 1999, Nagler et al. 2002). Their work was based on ERS-1 and ERS-2 synthetic aperture radar (SAR) images. Comparative motion fields were obtained for two interferometric pairs in July/August 1995. The analysis clearly showed two separate moving units, a northern and a southern one. Calculated displacement rates were several centimeters within the 35 days repeat cycle.

High-resolution surface velocity fields were derived from interannual aerial photographs (several epochs between 1953 and 1997) acquired from the Austrian Federal Office of Metrology and Surveying (Kaufmann and Ladstädter 2002a, 2002b, 2003). Kaufmann and Ladstädter computed 3D displacement vectors following a stringent photogrammetric approach based on preliminary (quasi-)orthophotos. Image matching was not done in image space using the raw image data, but in object space using this special type of quasi-orthophoto. The results obtained confirm the earlier findings of Rott and Siegl (1999). The flow patterns of the two moving units of the rock glacier could be retrieved with high spatial and also good temporal (multi-year) resolution. Maximum mean annual flow velocities of up to 55 cm a^{-1} for the northern unit and 49 cm a^{-1} for the southern part were measured for the time period 1953-1969.

4 DATA ACQUISITION

The present study is based on aerial photographs and airborne laser scanning (ALS) data. Aerial survey data from five epochs (1953, 1969, 1981, 1990, and 1997) were taken from a previous project. Additional, more recent data stem from aerial surveys carried out in 2003 and 2010. Image data and elements of exterior orientation of both surveys were provided by the Office of the Tyrolean Regional Government. Some characteristic parameters of the aerial surveys are given in Table 1. Change detection analysis was carried out using grayscale images (Figures 6 and 7).

Table 1: Aerial surveys 1953-2010.

Date	Flying height above ground (m)	Camera type	Scale/ GSD*	Remark
31.08.1953	3,250	analog	1 : 15,450	B&W
07.10.1969	4,430	analog	1 : 29,150	B&W
07.09.1981	2,930	analog	1 : 19,150	B&W
10.10.1990	5,240	analog	1 : 34,300	B&W, snow cover
11.09.1997	5,580	analog	1 : 36,550	B&W
05.09.2003	5,360	analog	1 : 17,650	color-positive
11.09.2010	2,810	digital	17* cm	R, G, B, NIR

*… ground sampling distance

Multi-temporal digital terrain models (DEMs) of the study area were made available for the epochs 1953 and 1997 (see above) and additionally for 2006 and 2010 (Table 2). The latter also included the digital surface models (DSMs). ALS data were provided by the Office of the Tyrolean Regional Government.

Table 2: Digital elevation/surface models 1953-2010.

Date	Grid spacing	Origin	Remark
31.08.1953	2.5 m × 2.5 m	photogrammetric mapping	DEM
11.09.1997	2.5 m × 2.5 m	photogrammetric mapping	DEM
23.8.2006	1 m × 1 m	ALS	DEM and DSM+
09.10.2010	1 m × 1 m	ALS	DEM and DSM

+… see Figure 8

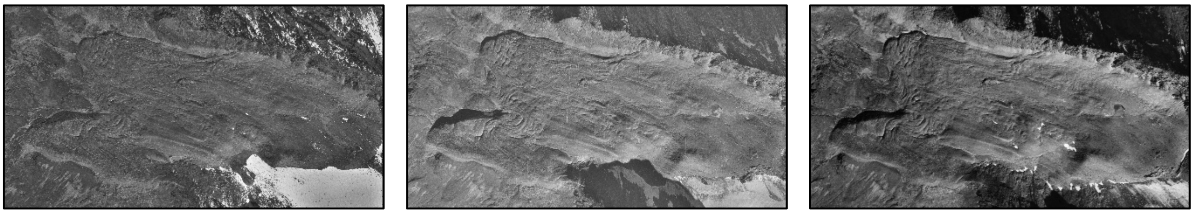

Figure 6: Aerial surveys of 1953 (left), 1969 (middle), and 1997 (right).

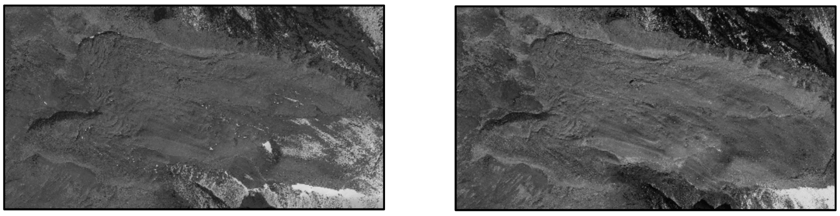

Figure 7: Aerial surveys of 2003 (left) and 2010 (right).

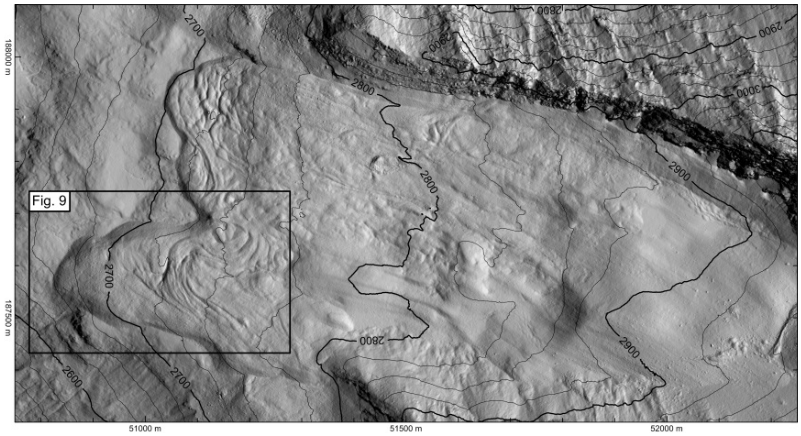

Figure 8: Shaded relief of the Inneres Hochebenkar cirque. Source: ALS-based digital surface model (DSM) 2006.

5 METHODS

Surface deformation can be best described by a dense field of 3D displacement vectors. These vectors can only be determined by observing identical surface points in space and time. Different remote sensing techniques and computational methods are available to solve this task (Kääb 2005). As already mentioned in Section 3.3, Kaufmann and Ladstädter (2002a) have developed a photogrammetric method for deriving these 3D displacement vectors in a stringent way. Under special conditions, i.e. if the DEMs of the multi-temporal stages are known, the 3D problem can be reduced to a 2D one. Image matching of the multi-temporal orthophotos will thus provide the correct 2D, i.e. horizontal, component of the displacement vector. Subsequently, the third, i.e. vertical, component of the displacement vector can be retrieved indirectly from the Z-values interpolated from the respective DEMs.

3D displacement vectors of the Earth's surface can also be deduced from surface geometry only, i.e. through matching of multi-temporal DEMs or DSMs (Bollmann et al. 2015).

However, in many applications the vertical component of the displacement vector is of secondary importance. Instead, surface elevation change is computed by simply subtracting multi-temporal DEMs.

5.1 IMAGE BASED CHANGE DETECTION

The computation of 2D (horizontal) displacement vectors is based on orthophotos. We have developed a toolbox of Matlab routines to highly automate the computation. Orthophotos of all epochs were computed on an Intergraph digital photogrammetric workstation (ImageStation) at a ground sampling distance (GSD) of 20 cm. The proper DEM for epochs for which no contemporary DEM was available was selected in such a way as to best approximate the topographic situation at the time of acquisition of the aerial photographs to be rectified.

Displacement vectors were computed for a regular grid (5 m × 5 m) of points. Image matching is based on the computation of the normalized cross-correlation coefficient (valid solutions ≥ 0.4) and applying back matching (threshold ≤ 1 pixel) for consistency check. The correlation window size was set to 31 × 31 pixels, which corresponds to 6.2 m × 6.2 m in object space. Subpixel accuracy was achieved by parabolic interpolation in the neighborhood of the correlation maximum in x and y direction.

Blunder detection of erroneous measurements is based on smoothness constraints of the vector field. The direction and magnitude of each displacement vector is statistically tested considering *a priori* measurement precision. A further consistency check (optional) compares the direction of the displacement vector with the aspect of the terrain derived from a coarse DEM (2006) at 5 m grid spacing. Spatially singular displacement vectors without control of neighboring measurements are removed. The number of remaining blunders/outliers will vary depending on the acuity of the thresholds selected for the various consistency checks, but will still be low. Remaining blunders are removed interactively using an appropriate editing tool.

The precision of the displacement vectors obtained is evaluated in stable areas in the forefield of the rock glacier, where the displacements should be zero (cp. Figure 9). The statistics, i.e. mean value and standard deviation (SD/σ), provide information about systematic shifts and measurement precision. Systematic effects are rectified in the final result. The significance level for horizontal movement was always set to 3-times of SD/σ.

All relevant information of the computation was stored in an ASCII table for further analysis and visualization. We used SURFER (Golden Software) as a flexible tool for the tasks addressed. Figure 9 depicts the mean annual horizontal flow velocity as interpolated isolines (isotachs). The local pattern of surface movement is revealed by a displacement vector overlay. Shaded relief and orthophotos as a backdrop and/or terrain contour lines as an overlay may support further interpretation (Figure 9).

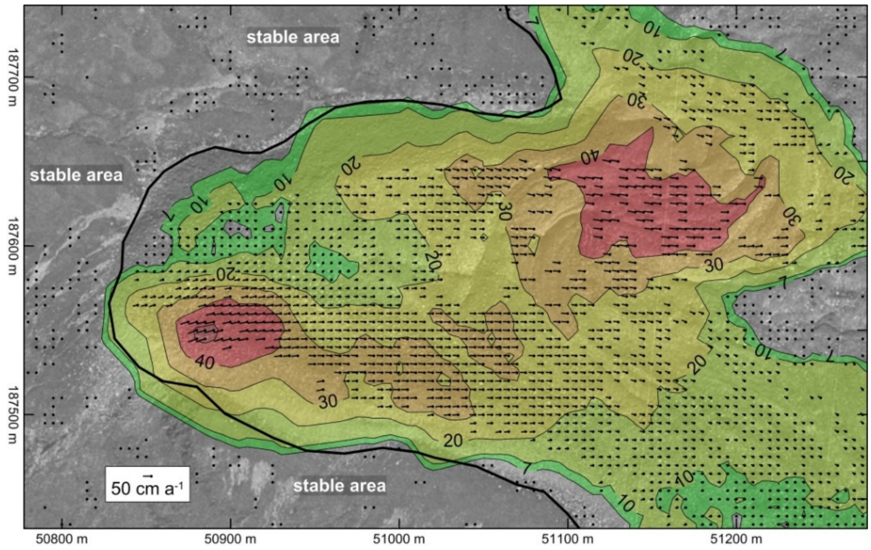

Figure 9: Mean annual horizontal flow velocity of the southern unit of the Inneres Hochebenkar rock glacier for the time period 1953-1969. For location see Figure 8.The significance level of movement is at 7 cm a-1 (3 σ).

5.2 DEM/DSM-BASED CHANGED DETECTION

In this case the computation of 2D (horizontal) displacement vectors is based on multi-temporal elevation data only. The investigations were restricted to the ALS datasets because of resolution and accuracy aspects. The processing workflow outlined above for orthophotos as base data for change analysis did not need to be changed at all. The image matrices (orthophotos) were simply replaced by the respective height/elevation matrices (DSMs). The grid spacing of the measuring points was 10 m and the correlation window size remained the same, i.e., 31 × 31, corresponding to 31 m × 31 m in object space. Accuracy analysis was carried out in the same way as outlined in the previous section.

The temporal change in surface elevation was computed using all available DEMs by simply subtracting the respective datasets at a common grid spacing of 2.5 m. Systematic shifts in horizontal and vertical direction of the DEMs relative to each other need to be corrected (Kääb 2005). This can be accomplished in stable areas. The statistical analysis provides insight into the achievable measurement precision of surface height change.

6 RESULTS

In this paper we focus on the horizontal flow velocity of the Inneres Hochebenkar rock glacier and we only look at surface elevation change for supporting information.

6.1 HORIZONTAL FLOW VELOCITY

Older image data (aerial surveys 1953-1997) were re-processed applying the procedure outlined in this paper. Table 3 lists all evaluations based on the same statistical parameters. Selected results showing the mean annual horizontal flow velocity of the Inneres Hochebenkar rock glacier are shown in Figures 10-14.

Table 3: Computation of horizontal flow velocity for the Inneres Hochebenkar rock glacier.

Time interval	No. of valid measurements	Significance level♣ of flow velocity (cm a^{-1})	Max. flow velocity (cm a^{-1}) – northern unit	Max. flow velocity (cm a^{-1}) – southern unit
1953-2010	12,009	±2.5	36.4	36.7
1953-1969	10,625	±7.0	56.5	52.7
1969-1981	10,390	±10.0	34.0	37.8
1981-1997	19,456	±6.5	31.8	39.8
1981-1990	9,921	±8.5	26.2	39.5
1990-1997	too few points	---	---	---
1997-2010	24,293	±7.0	33.1	40.1
2003-2010	29,279	±10.0	32.9	46.7
2006-2010♦	10,556	±8.5	24.6	57.2

♣… 3 σ, ♦… evaluation of DSMs

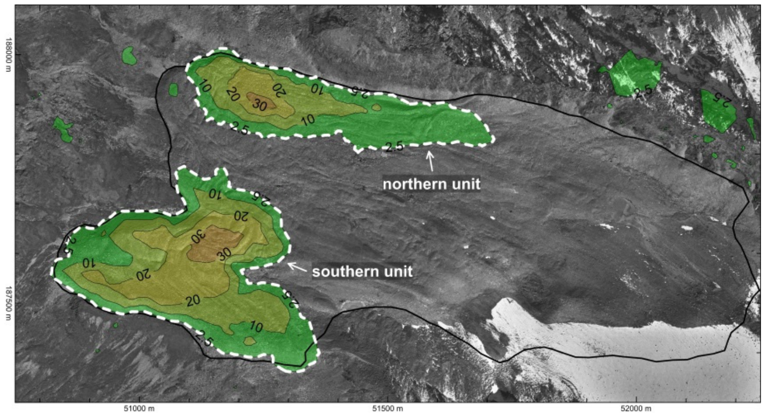

Figure 10: Mean annual horizontal flow velocity for the time period 1953-2010, isotachs (cm a^{-1}), significance level at 2.5 cm a^{-1} (3 σ).

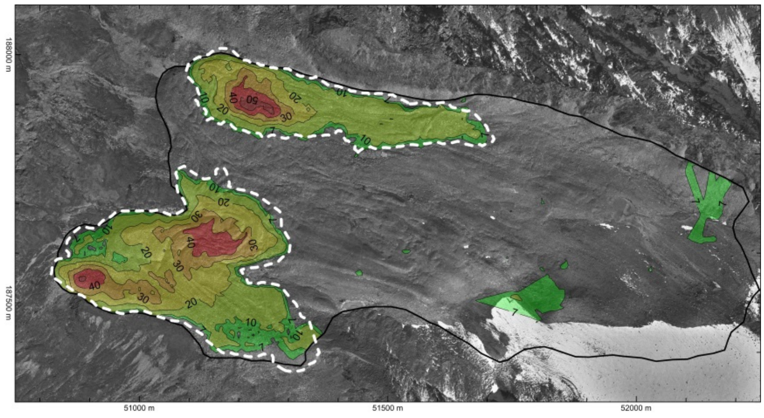

Figure 11: Mean annual horizontal flow velocity for the time period 1953-1969, isotachs (cm a^{-1}), significance level at 7 cm a^{-1} (3 σ).

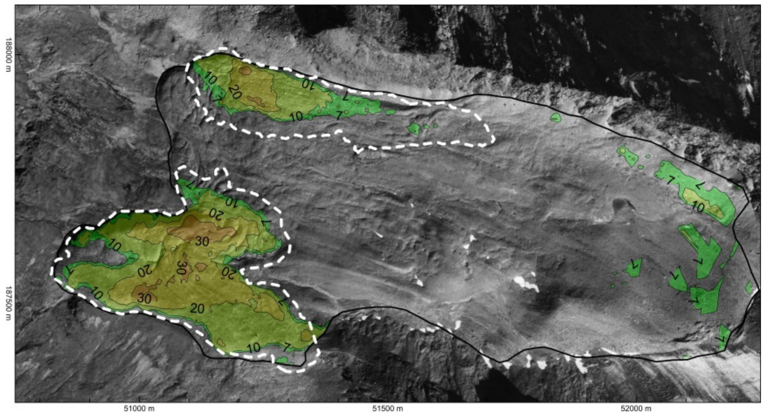

Figure 12: Mean annual horizontal flow velocity for the time period 1997-2010, isotachs (cm a^{-1}), significance level at 7 cm a^{-1} (3 σ).

Figure 13: Mean annual horizontal flow velocity for the time period 2003-2010. Isotachs (cm a^{-1}), significance level at 10 cm a^{-1} (3 σ).

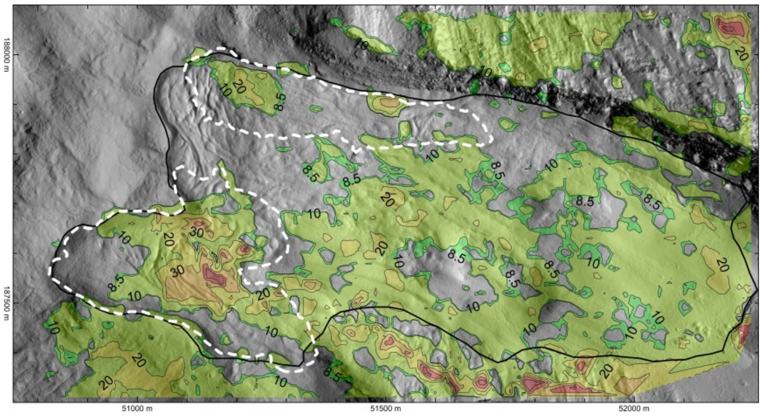

Figure 14: Mean annual horizontal flow velocity for the time period 2006-2010. Isotachs (cm a^{-1}), significance level at 8.5 cm a^{-1} (3 σ) for an area west of the northern unit.

6.2 SURFACE ELEVATION CHANGE

The mapping of significant surface height change is difficult because the photogrammetric DEMs are of low quality and the ALS-based DEMs show inhomogeneous systematic errors in elevation due to systematic errors in geo-referencing (Figure 14). This means that the quantitative analysis of the computed surface elevation change is rather difficult and interpretation can only be done qualitatively in combination with other information, e.g. flow velocity. The surface elevation change of the Inneres Hochebenkar rock glacier was always the highest in the wrinkled area of the southern unit: -9.0 ±1.7 m (3 σ) for 1953-1997 and -3.9 ±1.5 m (3 σ) for 1997-2006, respectively.

7 DISCUSSION AND OUTLOOK

The present study confirms the results obtained in previous studies by Kaufmann and Ladstädter (2002a, 2002b, and 2003): the lower section of the Inneres Hochebenkar cirque holds two independently moving parts, i.e., the northern and southern units of the Inneres Hochebenkar rock glacier. Both areas with statistically significant movement (1953-2010) are outlined in Figure 10 with a thick white dashed line. The activity of the southern unit over time was slightly higher compared to the northern unit. The wrinkled pattern of the surface topography of the southern unit is certainly caused by the special kinematics of this area (see Kaufmann 2016a). Surface deformation in this area goes along with marked surface lowering.

The highest flow velocities (1.10 m a^{-1}) for the Inneres Hochebenkar rock glacier were measured by Pillewizer at the southern unit in the time period 1953-1955. In the overlapping subsequent observation period 1953-1969 the flow velocity decreased significantly with maximum flow velocities hardly exceeding 50 cm a^{-1} at both units. The northern unit was initially moving faster than its southern counterpart, but also slowed down faster over time. A recent increase in flow velocity of the southern unit is speculative. The evaluation of a more recent photo flight (2015), which is not yet available for the public, will answer this question.

Permafrost degradation/melt at the Inneres Hochebenkar rock glacier is rather difficult to quantify since the error levels of the DEMs involved are too high. However, we found strong indications that the lower (non-moving) end part connecting both moving units has undergone substantial surface lowering (2.0-4.7 m in 1953-1997).

Aerial photogrammetry has proven to be a valuable tool for change detection analysis on a multi-annual/decadal time scale. Dense image matching will allow the automatic generation of high-resolution DEMs. Thus, *true orthophotos* can be obtained more easily. Precise orthophotos and high-resolution DEMs combined will allow more accurate 3D surface change detection.

The potential of the available multi-temporal ALS data could not be fully exploited because of obvious geometric problems in fusing the datasets of 2006 and 2010. These systematic registration errors can hardly be corrected by the user. Using the standard 1 m grid data we were (theoretically) able to compute horizontal flow velocities with a precision of 8.5 cm a^{-1} (3σ-level) for a time period of 4 years.

ACKNOWLEDGEMENTS

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SNOW-SKI-RELATED ASPECTS

GENERATION OF CARTOGRAPHIC PRODUCTS FOR AN ANDEAN HELICOPTER SKIING REGION

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ABSTRACT

This paper describes the conception and realisation of a series of maps covering the helicopter skiing region “Puma Lodge“ in the central Chilean Andes. The generation of various thematic maps with information regarding off-piste ski descents is set forth. Further, the generation of a 360° cartographic panorama for a scenic Andean observation point is also explained.

Starting with the acquisition of the appropriate Chilean IGM (Instituto Geografico Militar) topo-sheets and adequate satellite imagery, the creation of an applicable geo-database is described. Extensive field work carried out by a group of 10 cartographers resp. cartography students led to the generation of an access sketch map from Santiago de Chile International Airport to the skiing station “Puma Lodge” east of the city of Rancagua (total distance approx. 120 km), a hiking sketch map of the lodge’s close surroundings, the aforementioned annular cartographic panorama for a scenic outlook above the lodge, topographic maps 1:25,000, 1:50,000 and 1:100,000, both with depiction of the off-piste skiing routes, as well as a series of nadir-view and oblique-angle (bird’s eye view) image maps representing close-to-nature visualisations of the individual open-terrain ski-runs. The latter cartographic products also include true-length ski run profiles and indicate areas of particular high-alpine danger for open-terrain skiing activities like vertical rock-escarpments and – most of all – snow avalanche risks.

Keywords: off-piste skiing map, helicopter skiing map, slope inclination map, avalanche map, image map, bird's eye view, 360° annular panorama

1 INTRODUCTION AND MOTIVATION

In March 2010 one of the very few internationally certified Chilean UIAGM mountain guides, Francisco Medina Schlotterbeck, met his mountain guide colleague and long-standing friend Manfred Buchroithner in the climbers camp at the banks of Laguna Verde at an elevation of 4,350 m and addressed him: "Manfred, I need good maps!" – "What for?" – "For a newly established helicopter skiing concession south of Santiago."

It turned out that Francisco had been assigned manager of a five-star hotel – "Puma Lodge" – located east of the City of Rancagua at an elevation of 1,325 m, (at that time) recently built as the centre of a large helicopter skiing region (Figures 1 and 2).

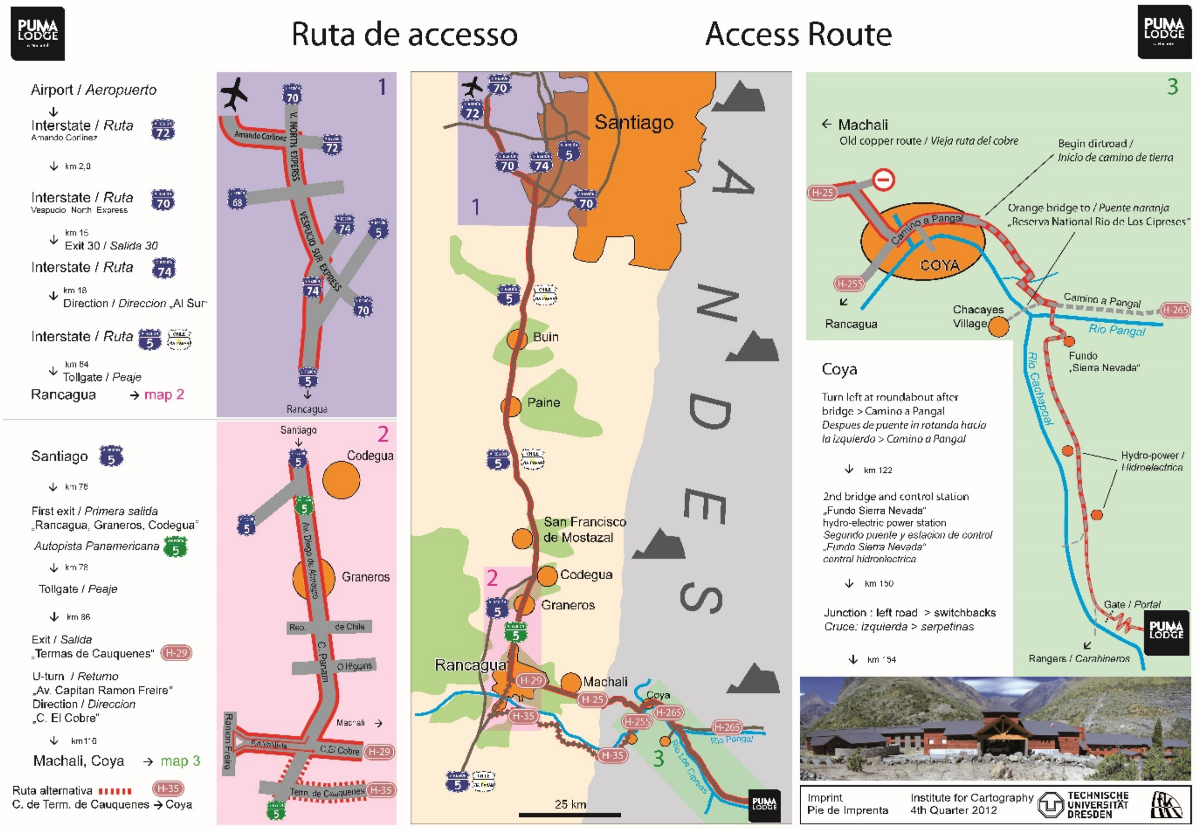

Figure 1: Access sketch map for Puma Lodge. The central part shows the general overview from Santiago International Airport to Puma Lodge with three indicated and colour-coded detailed maps which are displayed on the left and right sides. This A4 "map leaflet" was generated on request of Puma Lodge by TU Dresden students as a digital and analogue "flyer" for the guests of Puma Lodge.

After in-depth considerations about the environmental sustainability of this endeavour and the conclusion that a helicopter skiing approach covering such a large region is by far more sustainable than the erection of a road and cable car infrastructure, in April 2011 cartography students of TU Dresden were informed about this possibility. Many of them volunteered, and eventually seven students were selected to participate in the "Puma Lodge Project". In November 2011 Manfred Buchroithner had a one-week inspection of the heli skiing concession area, partly by helicopter. Flying with one of the helicopters operating for the skiers, a Eurocopter AS355 F1 Ecureuil 2 (Twin Squirrel), it became even more obvious how environmentally friendly these aircraft are, especially in terms of fuel consumption and noise generation.

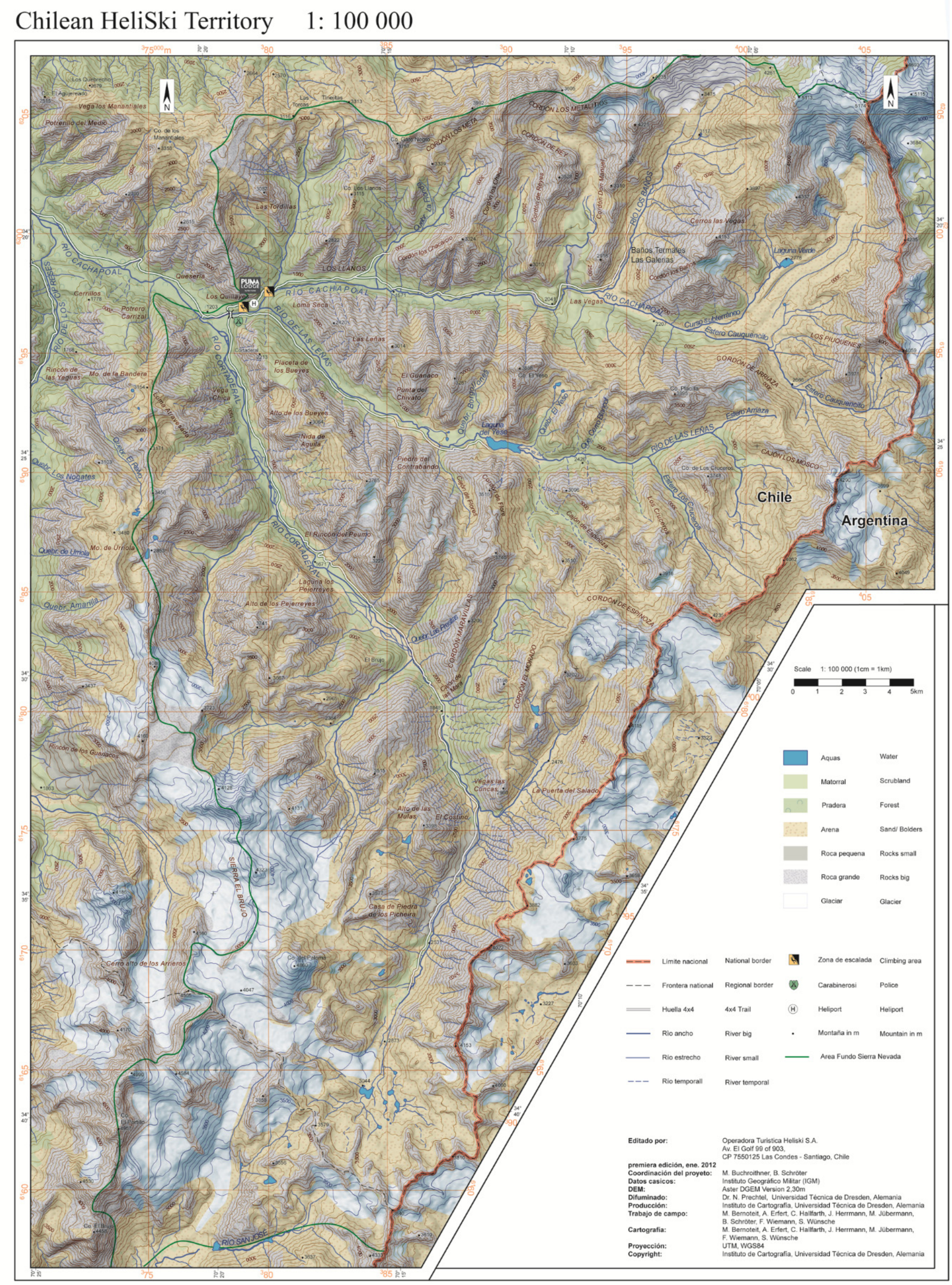

Figure 2: 1:100,000 topographic overview map of the whole Puma Lodge helicopter skiing concession area.

2 REGION

The mapping region is located in the central part of the Chilean Andes and covers an area of approx. 5,000 km². It comprehends deeply incised valleys and high, glaciated peaks, reaching from around 1,300 m up to more than 5,000 m (Figure 2). Both snow coverage and snow quality as well as altitude and available slope inclinations make this landscape ideal for deep-snow skiing.

3 WORKING SCHEDULE AND PRODUCTS ENVISAGED

Based on the aforementioned reconnaissance visit on March 1st 2012 the mapping team flew to Chile, and by April 7th the field-mapping activities were concluded. As from June 2012 the delivery of the final mapping products began: A comprehensive package of maps had been negotiated with the contractors. They comprised the following products:

- topographic overview maps (1:50,000; 1:100,000) depicting all off-piste ski runs
- topographic detailed maps 1:25,000 depicting all off-piste ski runs
- an access sketch map Santiago/Chile Airport – Puma Lodge at A4 format
- a hiking sketch map of Puma Lodge surroundings (1:3,500, A4 format)
- risk maps of the individual off-piste ski runs in oblique view at A4 format
- design of a 360° panorama of a scenic outlook close to Puma Lodge
- a 1:100,000 trekking map of neighbouring Rio Los Cipreses National Reserve (immediately adjacent (west) to the heli skiing area) including a 1:25,000 detailed map.

4 INPUT DATA AND PREPARATORY WORK AT TU DRESDEN

Prior to the actual preparatory cartographic activities the following input data were collected:

- topographic maps of the Instituto Geografico Militar [IGM] (Figure 3)
- digital geodata of IGM
- satellite imagery [Landsat 7, Bing, Google Earth]
- digital elevation models [ASTER 2 GDEM, SRTM 3 DEM] (Figure 4).

All these materials were then brought into appropriate form to be used during the field campaign, both digitally (on suitable devices) and analogue on paper. Furthermore, an optimised digital elevation model (DEM) of the whole helicopter skiing concession area was generated from the input DEMs listed above (Figure 5).

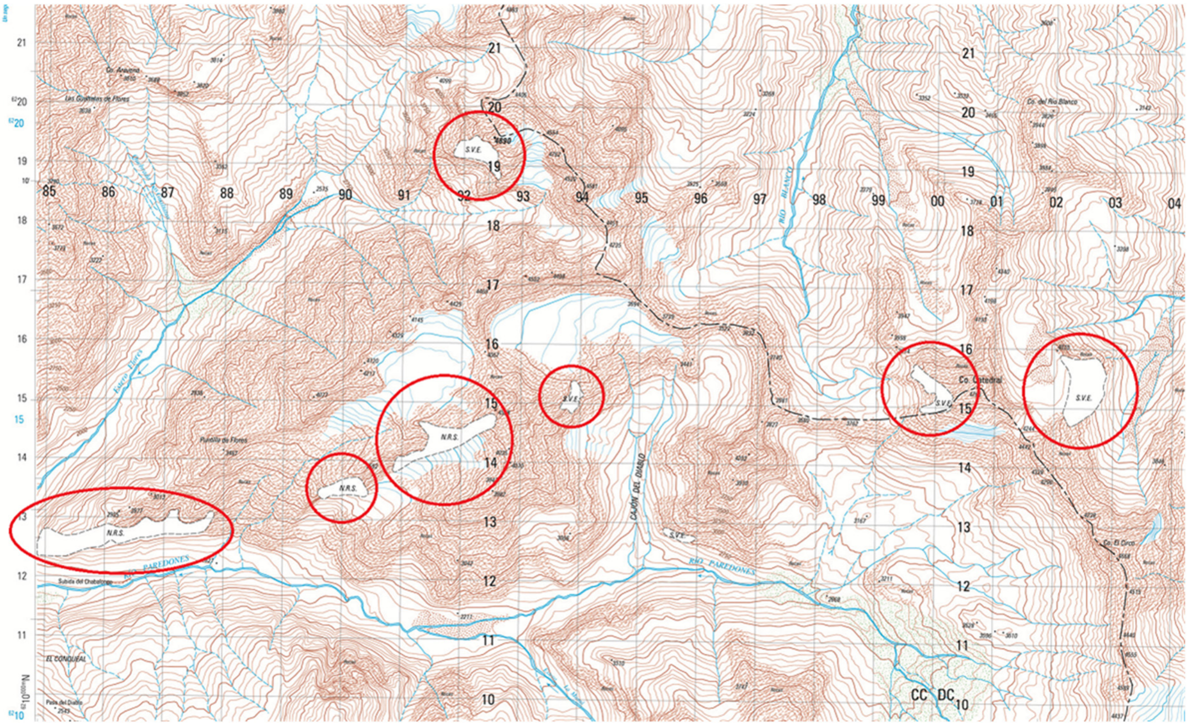

Figure 3: Example of a faulty 1:50,000 topo sheet of IGM showing patches void of geoinformation due to either shadows too dark for stereo-restitution or cloud cover.

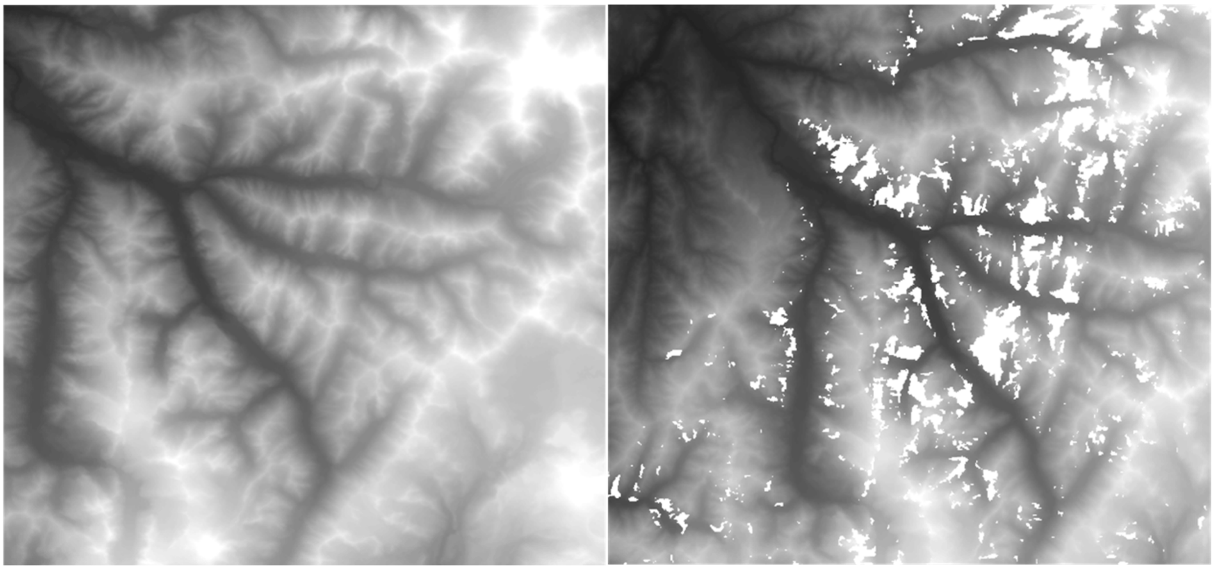

Figure 4: Two DEMs of the helicopter skiing concession area (left: ASTER 2 GDEM, right: faulty SRTM 3 DEM).

Figure 5: Visualisation of the optimised DEM of the helicopter skiing concession area.

5 FIELDWORK

The six-week fieldstay was carried out under the guidance of Manfred Buchroithner, Dirk Burghardt and Benjamin Schröter. After an initial joint "learning period" of six days the fieldwork was subdivided in three- to four-day campaigns realised by two to three individual groups (Figure 6). During these "outings" the cartography students slept in tents and recovered afterwards at Puma Lodge for two nights. The field-mapping results were integrated and pre-processed during these recovery hours.

Based on the use of the initial input data mentioned above the terrain campaigns yielded numerous notes in the analogue field books including drawings and sketch maps as well as a lot of recorded GPS data. The high-relief topography implies that also "binocular mapping" over longer distances had to be applied.

Figure 6: Left: Crossing torrential mountain rivers. Right: Remote campsite amidst the mighty Andean peaks.

6 CARTOGRAPHIC PRODUCTS

In consultation with the responsible staff of Puma Lodge several cartographic products with extensive information were defined to be delivered in addition to the proper ski-run representations. Amongst others the generation of topographic maps was requested, since the official topo sheets by IGM were all outdated and did neither reflect the current topographic situation nor standards. For the purpose envisaged it was requested that these maps (also) contained a synthesis of information layers like:

- trail network (based on GPS data and satellite imagery)
- hydrological network (distinction between perennial and periodic rivers/streams)
- various boundaries (mostly administrative)
- surface cover (based on fieldwork and satellite imagery)
- tourism information (based on information from Puma Lodge staff and fieldwork).

6.1 TOPOGRAPHIC OVERVIEW MAPS (1:50,000; 1:100,000)

These maps were meant to depict all off-piste ski runs at two different, more general scales and – consequently – also different degrees of detail. They are supposed to give the skiers an overview of the off-piste skiing potential in the whole concession area and to serve for planning purposes of the skiing activities (Figure 7).

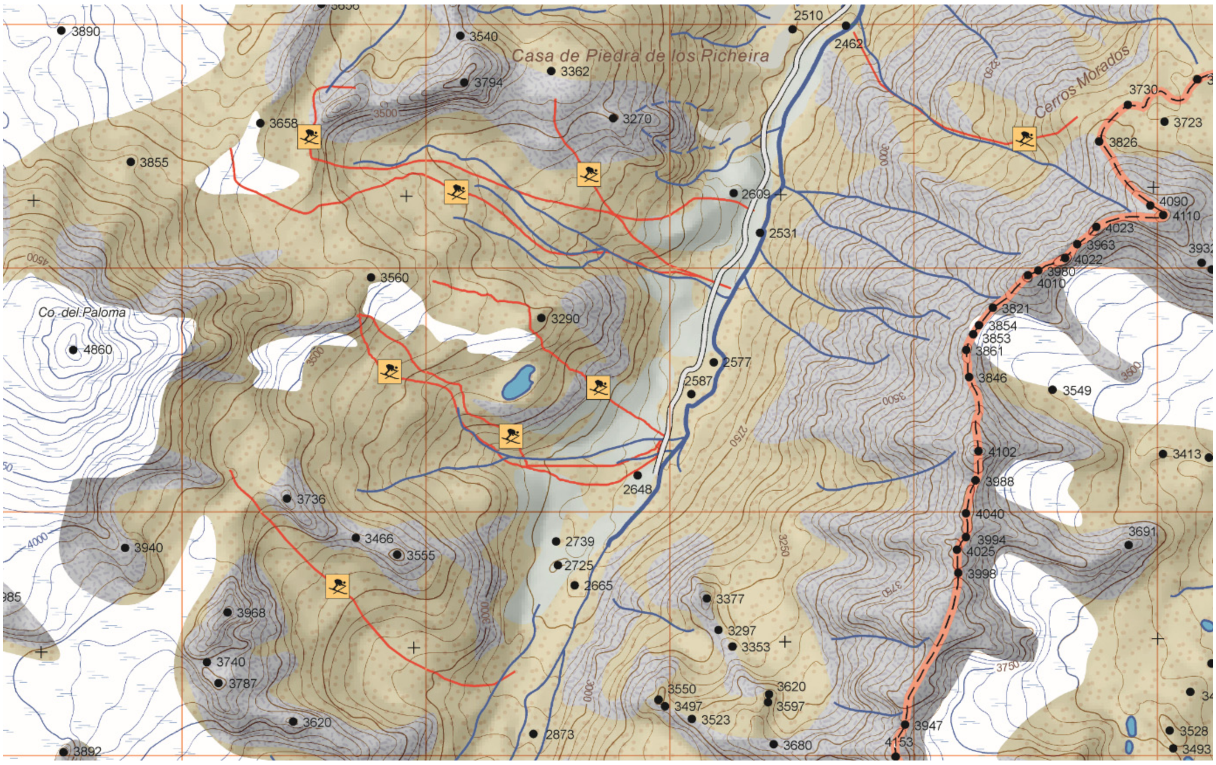

Figure 7: Section of the 1:50,000 topographic overview map showing all the common off-piste ski runs. Please note that this map does not represent the final map product.

6.2 TOPOGRAPHIC DETAILED MAPS (1:25,000)

The purpose of these maps is to depict all off-piste ski runs at a decently detailed scale which can already be used for more detailed planning (Figure 8).

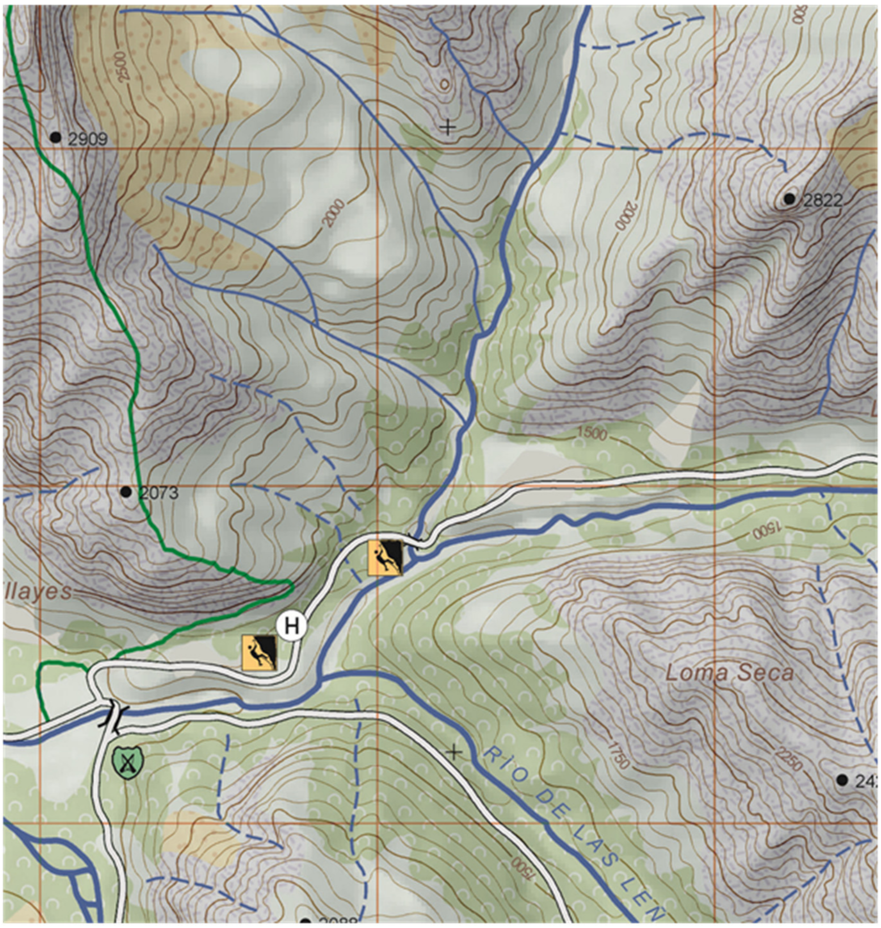

Figure 8: Example of the 1:25,000 topographic map of the concession area.

6.3 ACCESS SKETCH MAP SANTIAGO/CHILE AIRPORT – PUMA LODGE AT A4 FORMAT

The usability of this A4 format cartographic product generated on request of the Puma Lodge operators has already been demonstrated in the introduction of this publication. The access map is shown in Figure 1.

6.4 HIKING SKETCH MAP OF PUMA LODGE SURROUNDINGS AT A SCALE OF 1:3,500

This rather sketchy type of map was made on special request by the proprietaries of Puma Lodge and was developed for all-year use but in particular for weekend guests during the summer half-year. It depicts an area of slightly more than 600 m in both west-east and north-south direction (Figure 9).

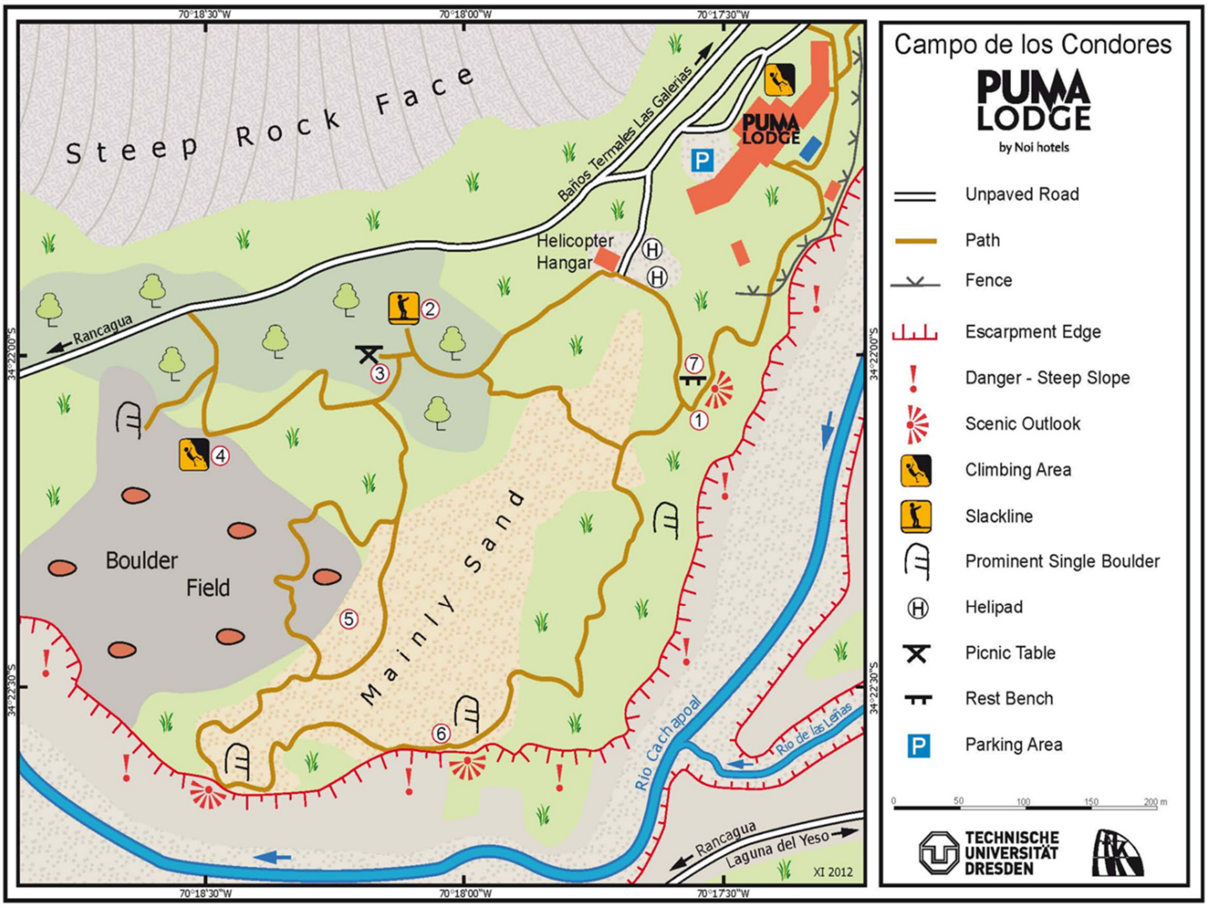

Figure 9: A4 format sketch map of the surroundings of Puma Lodge.

6.5 RISK MAPS OF THE INDIVIDUAL OFF-PISTE SKI RUNS IN OBLIQUE VIEW AT A4 FORMAT

On special request by the UIAGM mountain guide Francisco Medina detailed-scale cartographic products of the individual off-piste ski runs were produced (Figure 10). These runs are natural, unaltered mountain slopes with specific features and obstacles that are not always obvious but need to be known in order to guarantee safe skiing conditions.

For the sake of an optimised, nearly orthogonal depiction of the run slopes, Manfred Buchroithner decided for an oblique projection based on high-resolution remote sensing imagery displaying the whole ski run in the largest scale possible for an A4 format. The oblique image-map shows the two risk classes “Dangerous Area” (red) and “Attention Area” (orange) which are defined by risks like rockfall, extremely steep slopes, crevasses and avalanche potential. The map size is 17 x 17 cm and has a scale of either 1:15,000 for ski runs shorter than 3 km or 1:30,000 for runs equal to or longer than 3 km. A scale bar on the lower left corner provides the required information about the chosen scale.

In addition, a “long-distance” view of the respective ski run in transverse disposition with the indicated run route was included. It covers about one sixth of the A4 sheet and is supposed to serve the planning, since this rather distant view gives a general impression of the terrain and the course of the run.

Beside a small location chart in the upper right corner showing Puma Lodge as reference point, the major streams, administrative boundaries and the actual ski run, a true-length profile also assists preparatory activities for skiing. Apart from that, other valuable parameters like coordinates, run length, elevation difference as well as average and maximum slope angles are listed.

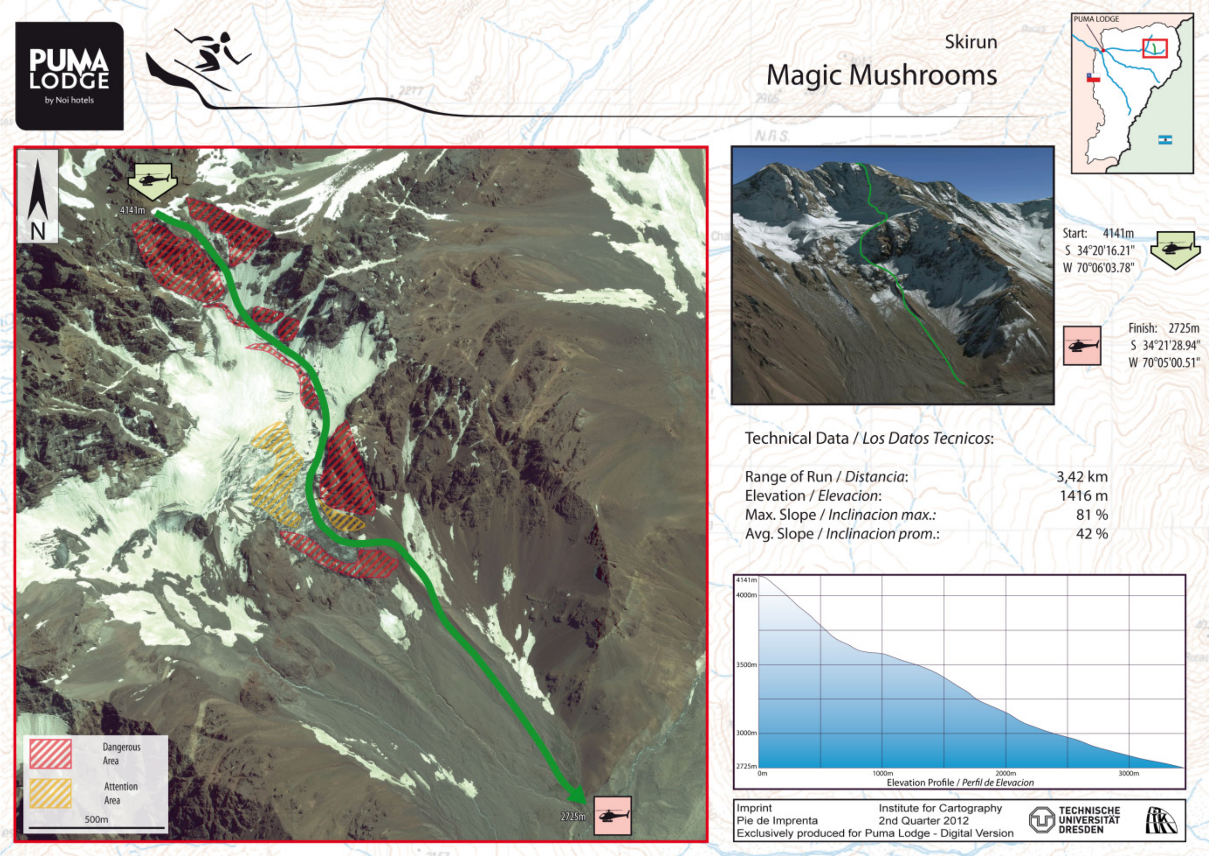

Figure 10: Example of an A4 format risk map of an off-piste ski run. Please note that the viewing angles of these cartographic products are not necessarily the same ones.

6.6 DESIGN OF A 360° PANORAMA FOR THE MIRADOR LAS ORCHIDIAS

Just about a slow one-hour climb or rather hike above Puma Lodge there is a scenic outlook – in Spanish "mirador" – called Las Orchidias ("The Orchids"). It provides an impressive overview of the landscape around the hotel and it was the particular wish of the owners of Puma Lodge to develop an annotated annular line-drawing panorama that explains the spectacular view from this excellent vista point. Since it is not so commonly known that annular 360° panoramas represent a rare but very distinct type of cartographic product, the authors wanted to make the production of it replicable by means of a series of figures which are in the following arranged in the order of generation (Figures 11-16). As for the theoretical background the reader is kindly referred to Rohrhofer (1985).

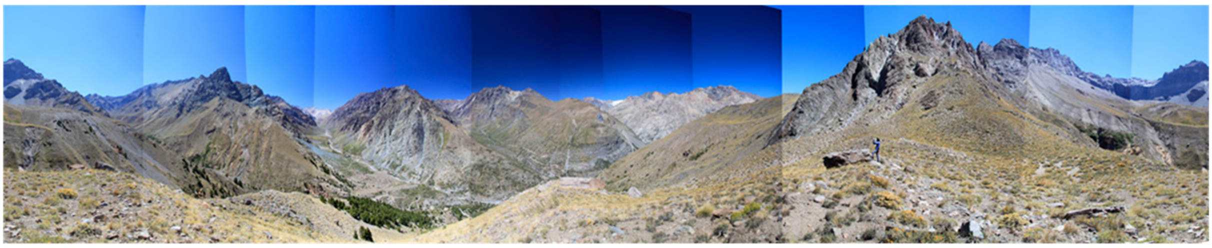

Figure 11: "Straight" photo panorama as seen from Mirador Los Orchidias. The panorama was assembled from 13 individual images.

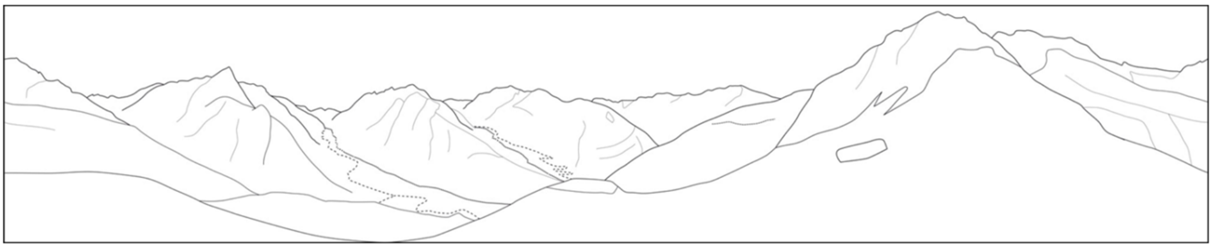

Figure 12: "Straight" contour line panorama.

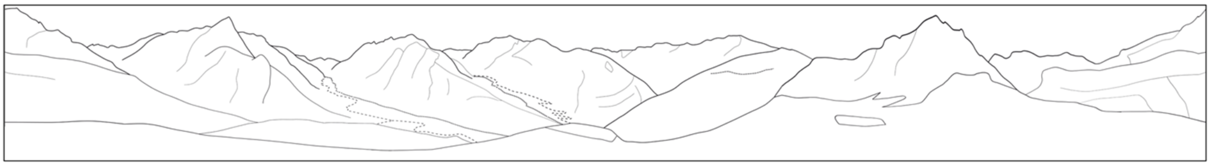

Figure 13: Processed "straight" contour line panorama.

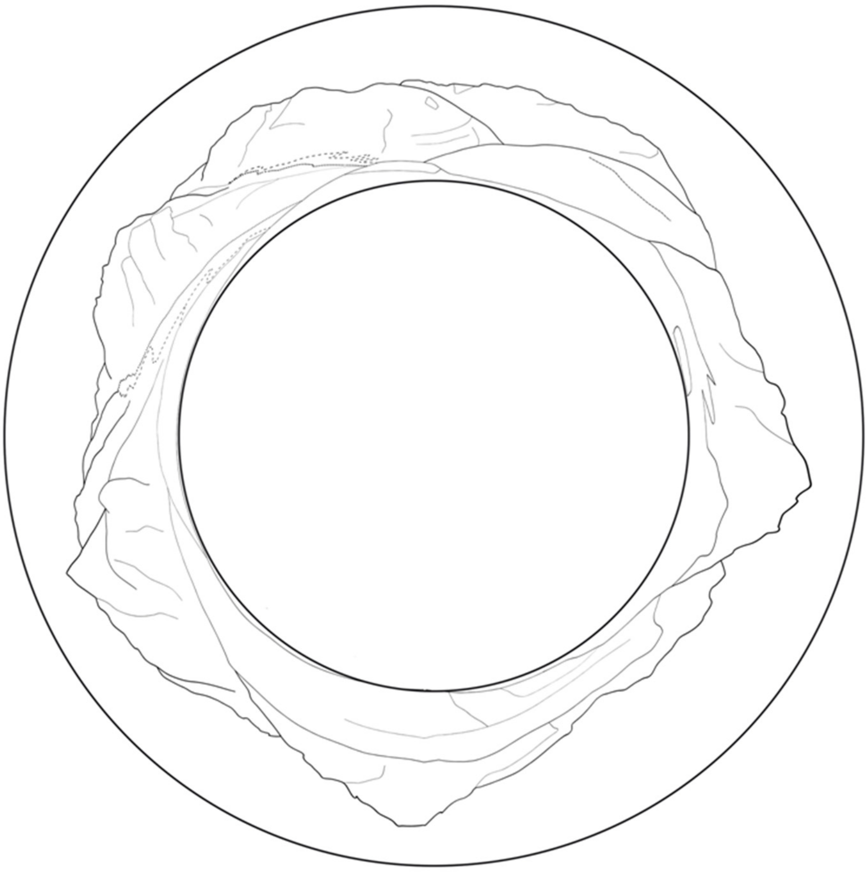

Figure 14: Generation of annular line panorama.

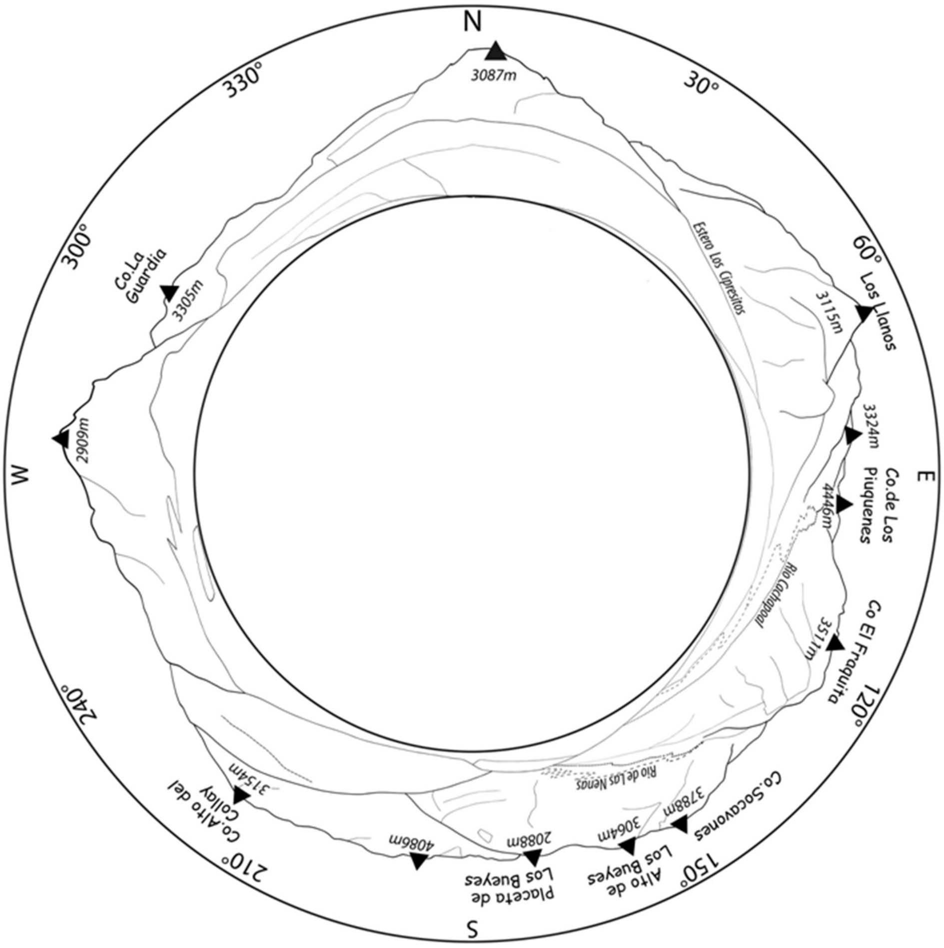

Figure 15: Adding of labelling and collateral information to the annular panorama for the Mirador Las Orchidias as it was eventually displayed at the scenic lookout.

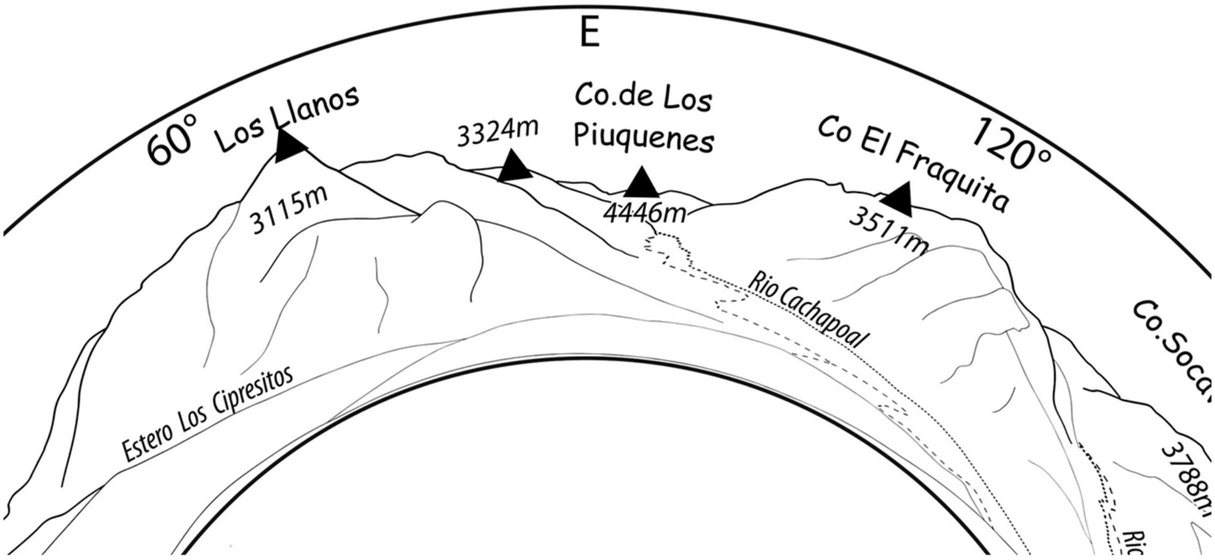

Figure 16: Detail of the labelling and the collateral information of the annular line panorama of Figure 15.

6.7 TREKKING MAP OF NEIGHBOURING RIO LOS CIPRESES NATIONAL RESERVE

This map at a scale of 1:100,000 with a detailed map of the northern part of the depicted terrain at a scale of 1:25,000 covers the region immediately adjacent (west) to the helicopter skiing concession. It was printed on tear- and waterproof stone paper and published in 2013 by Viachile Editores, Santiago, within the Andean map series of the Trekkingchile Foundation (http://www.fundaciontrekkingchile.cl).

Figure 17: Section of the 1:100,000 Trekkingchile map of the Rio Los Cipreses National Reserve.

7 CONCLUSION

In short terms, the benefits and milestones of the "Puma Lodge Project" can be described as follows:

- support of a helicopter skiing area at the expense of the construction of environmentally destructive terrestrial infrastructure
- gaining of fieldwork experience including the planning of pedestrian field campaigns for seven students of cartography
- gaining of experience in generating a rather rare form of cartographic product (360° annular line panorama of a scenic outlook) for the cartography students
- gaining of various soft skills like distribution resp. allocation of responsibilities and collegiality for the students
- getting acquainted with one of the most impressive parts of the Andes for the cartography students

- first exact cartographic depiction of off-piste ski runs in a defined oblique projection for South America, one of the first ones worldwide
- cheap acquisition of a set of map products for the operators of the Puma Lodge helicopter skiing concession and for the owners of the Puma Lodge hotel
- cheap generation of a trekking map of the Rio Los Cipreses National Reserve.

Neither from the side of the Puma Lodge proprietaries and staff nor from the student's assessments any negative aspects could be identified.

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SNOW-SKI-RELATED ASPECTS

A COGNITIVE APPROACH FOR INNOVATIVE SKI MAP DESIGN: THE FRENCH ALPS CASE STUDY

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ABSTRACT

This article presents preliminary results from ongoing research that aims to suggest innovative, efficient representation of geographic information in the mountains. The study is based on visual-cognitive approaches which investigate the reading-comprehension of a particular territorial representation: ski area maps. Paper ski maps are related to practices of space and sport activities which are ever changing in time and that require regular adaptations to their representations. According to mountain operators, the information provided by paper ski maps no longer meets the needs of most customers; the question now arises about their adaptation to new digital practices. The article focuses on a visual-cognitive approach carried out to highlight the depicted geographic information most helpful to users-skiers when making decisions.

Keywords: effectiveness in map design, ski maps and panoramas, use and user representation, eye-tracking experiments.

1 INTRODUCTION

1.1 THE CONTEXT

This article is part of research in progress, the MECOMO[1] project. It is a multidisciplinary work carried out by historians (LARHRA), computer scientists (LIG), geographers and cognitive scientists (INRIA-GRA), about the study of an evolving representation of a territorial model: the design of ski resort trail maps.

From a historical point of view, it is part of the revival of studies on the history of territories and innovation, especially applied to mountains, in coordination with the work of the International Society for Alpine History.

From an IT point of view the digitalization of real-time information, immersive environments, and scalable applications, are technological paths to explore, in order to respond more adequately to the new practices in winter sports.

From a geo-cognitive point of view the project takes up the challenge of understanding the cognitive mechanisms underlying the production and interpretation of these plans, in order to restore the practice of this artifact over time.

This article aims to present the preliminary results from the geo-cognitive approach. The remainder of the article is organized as follows. Section 1 presents the related works on panoramic and ski trail mapping as well as the overall issue of the study. Section 2 describes the global methodology applied to the study. Section 3 details the experimental protocol for setting up two experiments, including their results. In Section 4 these results are discussed with regard to our research questions and Section 5 presents conclusions and proposes future works.

1.2 RELATED WORKS

The project relates to other studies undertaken by members of the “Commission on Mountain Cartography, International Cartographic Association”. It is based on findings about semiotic categorization of mountain panoramas (Patterson 2000, Tait 2010). Trail maps for ski areas are iconic images of the sport of skiing and its relation to the terrain upon which ski resorts are built. The development of these maps has paralleled the development of lift-served skiing. The combination of larger areas to map and increasing money in the sport has led to a shift from simple way-finding maps to more elaborate mountain portrayals (Patterson, 2000). Artists have employed three main types of views for ski mountain resorts: planimetric, profiles and panoramas maps. Planimetric views are images viewed from directly above for the entire skiing area. Profile views are generally very simple elevation views of the mountain from a very low oblique angle or ground level that have little or no three-dimensional character and look into the mountain with little or no perspective. Panoramic views are by far the most common type of map: they are oblique perspectives from any angle and they often are not topographically accurate (Tait 2010).

Patterson (2000) notes, in discussing the work of Heinrich Berann (1915-1999), one of the earliest panoramic mountain ski map painters, that with a panorama, “something truly magical happens. Readers feel drawn into the panorama as if they were flying high above the land.” The panoramic ski map may be particularly evocative of the mountain terrain for skiers, for

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[1] “MECOMO – MEmory, COgnition and MOdelling of mountain landscape”

whom the image may replicate the feeling of flying down the mountain on skis. Panoramas respond to the desire for resorts to look impressive to potential visitors. Ski area operators often want their particular mountain to "look bigger" and ask the artist to distort the mountain for this purpose. This request can pose a serious challenge that in some cases is resolved by local distortion of the mountain terrain and camera view (Patterson 2000).

Landscape artists have addressed such challenges by applying local deformation to map objects in hand-painted hiking and skiing panoramas. Using digital means, the painters' techniques may be translated into geometry deformation algorithms for digital panorama creation. An algorithmic solution based on inverse distance interpolation and moving least squares has been developed. Based on the observation of Berann's techniques, this solution allows the cartographer to deform a digital terrain model by intuitively manipulating the surface in a 3D display (Jenny et al. 2011). Digital imitation of the techniques of panorama painters has also been improved by combining local terrain deformation and progressive bending algorithms with painterly rendering methods for panoramas (Bratkova et al. 2009). Relying on these findings, our approach looks instead to the evolving use of ski maps by skiers according to a cognitive perspective. This also fits with works that evaluate the effectiveness of panoramic maps (Spengler and Räber 2014, Schobesberger and Patterson 2008) and differs however from these studies in the development of a visual analysis-based approach. From a methodological point of view, it relies on current Swiss research on real-world mobile eye-tracking (Keifer et al. 2014). However, it somewhat differs from the latter because the stimulus falls within the natural environment and not the urban one.

1.3 OVERALL ISSUE

Though the research on panoramas and ski maps has been extensively detailed in the US, as far as we know, there are no similar scientific projects on this topic in France.

Figure 1: Alpes d'Huez ski trails maps, made by *Atelier Novat*.

Our case study concerns mountain representations based on the artistic style of "*Atelier Novat*", the pioneer French ski mapmaker that uses the panoramic view. The Atelier Novat was founded in the 1960s by Pierre Novat then living in Val d'Isere. He was asked by the sport director there to make an addition to the resort panorama initially painted by Berann, but who was overbooked and could not do the extra work. At that time, Pierre did not yet know that he was destined to become the premier French panoramist. It was the beginning of a 35 year career and the production of 250 panoramas. It was only in the early 1990s that Arthur, Pierre's son, introduced computers to the atelier for the production of illustrated panoramas. Like other "panoramic" artists, those at *"Atelier Novat"* used their expertise to combine landscape features in a single mountain panorama that normally would only be visible from multiple view points. The result: a panorama that is realistic, easy to read, but subtly distorted. Figure 1 shows an example of a ski trail map in French Alps, Alpes d'Huez ski resort, made by Arthur Novat from *Atelier Novat.*

Ski maps are built from land morphology, local knowledge, and marketing applications. One of their main features is that the landscape is not realistically represented; it is in actuality a distortion. Mountain distortion has a historical explanation. Since the 1930s, ski resorts, tourist centers, and sporting organizations in the mountains have needed cartographic representations in print, bound with fixed dimensions. Paper ski maps are related to practices of space and sport activities which are ever changing in time and which require regular adaptations to their representations. According to some mountain operators, the information provided by paper ski maps no longer meets the needs of a large number of customers which calls into question their adaptation to new digital mapping practices (iPhone, tablets). At present, in France, the Atelier Novat's market has been largely taken over by companies linking digital mapping (GIS) to mobile Apps, for use as 3D ski maps. Despite their high technology, these solutions are subject to (as former paper ski maps) representation issues of information: which one? and how? They are challenged by an increasingly dynamic and rich display of geographic information on diminishing screen sizes.

The overall issue for a cognitive approach to innovative ski maps design, can be investigated through two main research questions:

1. What geographic information (and its representation) make ski maps effective to perform a user-skier's task?
2. What is the impact of (the representation of) mountain local distortion on user-skiers comprehension?

2 METHODOLOGY

In order to answer to these questions our methodology relies on theoretical frameworks of mental representations. Human activity is based on mental representations that are actually personal reconstructions of the "reality" made by the subject, based on his perceptual systems and previous knowledge. Both internal (cognitive) and external (graphics, language or physical) representations provide the forms in which information can be structured, stored, analyzed, understood and communicated to (NRC 2006). The internal spatial representation for handling spatial images in the brain requires spatial skills such as visualization, orientation and spatial relations (Egarty et al. 2006). The external spatial representation refers to the organization, interpretation and communication of information with maps, charts or images. In our case study, mental representations refer to the natural and anthropogenic elements (objects) depicted on the ski map. The study investigates the user's capacity to recognize these objects and to extract the relevant information. The expert-artist's mental representations, and the resulting graphic objects, are known from previous works (Balzarini et al. 2015).

The methodology presented in this article focuses essentially on the initial query while recommendations will be suggested for the second one.

Mental representations can be identified through the study of user-skier's *knowledge and heuristics* (1). This can be achieved through verbal data collection and analysis according to the experimental techniques from Chi (1997) and Ericsson (2006), which provide insights corresponding to all the concepts, objectives, roles and relationships initiated by a subject when performing a task. These techniques are commonly used in psychology to reconstitute a cognitive structure.

Mental representations can be also identified through the study of *visual attention* (2). This can be carried out with eye-tracking equipment which records human eye movements (Ware 2008). Our visual system is very powerful and perception allows us to detect useful information from a visual scene. In a visual search task, the eye moves rapidly from fixation[2] to fixation. The dwell period is generally between 200 and 600 msec and the saccade takes between 20 and 100 msec. A simple heuristic strategy appears to be employed by the brain to plan a sequence of eye movements. For example, if we are scanning a supermarket to look for oranges, regions of space with the color orange will be set up for searching. Millions of features are processed simultaneously to create objects. An o*bject* describes the temporary grouping of a collection of visual features together with other links to verbal-propositional information (Ware 2008). Thus, if we can track someone's eye movements, we can follow along the path of attention deployed by the observer.

Both methodological approaches are implemented with an experimental protocol that combines two successive phases: the verbal data and the gaze data protocols.

3 THE EXPERIMENTAL PROTOCOL

3.1 EXPERIMENT 1: THE VERBAL DATA PROTOCOL

Skiers' knowledge and heuristics can be determined by listing a set of propositions, a set of concepts, a set of goals, or a set of rules from "what" he has said (the content). However, to explore the knowledge, the researcher must then assess the relations within such a set. Verbal data were collected and analyzed according to "*think-aloud protocols*" (Ericsson 2006) and "*explaining protocols",* (Chi 1997). In the first technique, the subjects are asked to verbalize the information that they considered while solving a problem. The intent is to capture the processes of solving a problem or making a decision (i.e. doing some task). In the second technique, the subjects are asked to verbalize explanations, descriptions, justifications, and rationalizations. The intent here is to capture the representation of the knowledge that a solver/user has and, to a lesser extent, the processes of problem solving. In our case study, knowledge was represented over the practical application of spatial analysis concepts and cartographic design.

Experimental questions: What concepts and graphic representations does the subject verbalize while reading a ski map? What depictions are hard to interpret?

Participants: we observed 20 subjects asked to perform a task when *reading a ski map.* Subjects were between 18 and 65 years old, including 12 women and 8 men. They were distributed into 3 groups according to their skiing ability: 2 subjects in the novice skier group (C1), 10 subjects in the intermediate group (2) and 8 in the advanced group (C3). Skiing ability was defined by auto-evaluation according to the "Ecole de Ski Français' standards". They were also spread into 2 groups according to 2 different ski resorts: Alpes d'Huez (Figure 1)

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[2] See Section 3.3 for more details.

and Villard de Lans, situated in the French Northern Alps. The maps of these two ski resorts were chosen because they are representative of regional ski resorts in terms of size (large and medium) and attendance. The subjects were not familiar with these resorts.

Modalities: subjects were observed in "controlled conditions" supported by an interview grid and based on operational assumptions. Subjects were asked to perform two tasks. Task 1 was ski area evaluation: they familiarized themselves with the ski resort and had to verbalize salient elements in the map that caught their attention (map objects, focal points …). Task 2 was a decision-making task: they had to explain the itineraries that they traced to reach a specific location (following ski runs). They were interviewed according to thinking-aloud and explanation techniques.

Material: an interview grid, a video-audio camera, paper ski maps in real formats and felt pens were given to the subjects to depict their proposed skiing routes and they underlined salient graphical elements.

Data: we collected sketches, drawings and about 15 hours of video audio recording, which were transcribed.

Verbal Data analysis is a technique for quantifying the subjective or qualitative coding of the *contents* of verbal utterances. Once the corpus to be coded was decided, we then had to segment the verbal utterances to identify the unit of analysis. The defining break can occur at many points, revealing units of varying granularity, such as a proposition, a sentence, an idea, an interchange as in conversational dialogue, or an episode. In the segment protocols we searched for verbatim, tags or keywords, such as "mountain" or "valley", "ski track" or "names of localities", "green, red" "and so on, in order to form semantic groups which design conceptual categories. The coding scheme we developed was a taxonomic categories scheme. The units of analysis were organized on a taxonomy founded on the characterization of tasks, actions and (graphics) objects. Verbal data analysis was also supported by sketch and drawings analysis. The matching of speech elements (*verbatim*) and drawings can confirm that a graphic and conceptual object was used by the subject.

3.2 PRELIMINARY RESULTS FROM VERBAL DATA

Analysis from verbal data and from sketches led to qualitative results. These results include the identification of generic map rules (0) in user practice, the identification of graphic objects (1) and the main difficulties in ski map comprehension (2).

(0) The identification of a generic procedure was not foreseen initially in our experimental questions. But the analyses of many common goals of the skiers enabled us to build it. It allowed us to identify the moments where the map is a real support for decision making. The various actions correspond to objectives and we will show how reading and understanding the graphic objects facilitates (or does not) the achieving of these objectives. Table 1 shows user practice generic process.

Table 1: Generic rules in use practice of ski maps.

Basic rules for ski map using procedure			
E1	Get start	E11	define a departure point
		E12	define a point of arrival
E2	Define itineraries	E21	assess the landscape and pleasant places
		E22	assess the difficulty of the ski runs, length and capacity of ski lifts
		E23	find networks connections
		E24	find break places
		E25	find panorama places
E3	Decide of the return pathway	E31	find easy ways to get to the starting point

(1) Graphics objects were organized in a five categories taxonomy. These are detailed below in Table 2:

Table 2: Categories of graphics objects identified in Atelier Novat ski maps.

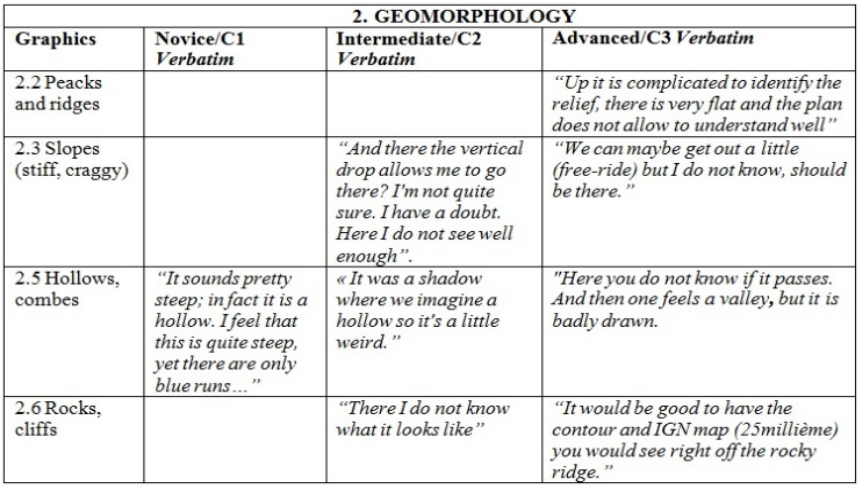
	Categories				
	1. Geography	**2. Geomorphology**	**3. Tracing**	**4. Structures**	**5. Nomenclatures**
Graphics Objects	1.1 Domain boundaries	2.1 Terrain profile	3.1 Colored ski runs	4.1 Pictograms	5.1 Names of the ski runs
	1.2 Sunlight exposure,orientation (shadows contrast)	2.2 Peaks and ridges	3.2 Ski runs geometry	4.2 Buildings	5.2 Names of the ski lifts
	1.3 Focal point	2.3 Slopes (stiff, craggy …)	3.3 "Green" areas	4.3 Roads	5.3 Elevation values
		2.4 Corridors	3.4 Ski lift		5.4 Place names
		2.5 Hollows			
		2.6 Rocks, cliffs			
		2.7 Fir trees			
		2.8 Snow and ice (hues variance)			

The graphical elements typical of a ski map are shown in Figure 2. This picture is not in the actual format of a ski map, it was magnified to improve legibility.

Figure 2: A detailed depiction of the graphical elements found on a ski map from Novat.

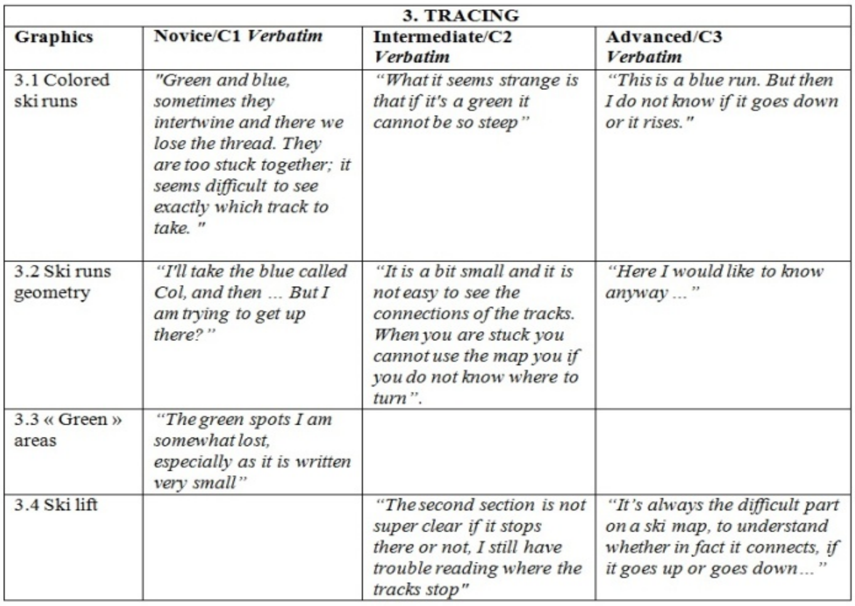
(2). Decision making and ski area familiarization is, not necessarily easy for skiers. To address this issue, we intend to focus on the difficulties experienced by skiers during information processing. Difficulties may be manifested by misunderstanding, uncertainty, inconsistency, lack of details, and illegible map representations. We categorized them by graphics object type. For instance, the most significant verbatim response related to the objects of Geomorphology and Tracing categories are illustrated in Table 3 and Table 4.

Table 3: Sample of verbatim expressing difficulties about geomorphic representations.



2. GEOMORPHOLOGY			
Graphics	**Novice/C1** ***Verbatim***	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
2.2 Peacks and ridges			*“Up it is complicated to identify the relief, there is very flat and the plan does not allow to understand well”*
2.3 Slopes (stiff, craggy)		*“And there the vertical drop allows me to go there? I'm not quite sure. I have a doubt. Here I do not see well enough”.*	*“We can maybe get out a little (free-ride) but I do not know, should be there.”*
2.5 Hollows, combes	*“It sounds pretty steep; in fact it is a hollow. I feel that this is quite steep, yet there are only blue runs…”*	*« It was a shadow where we imagine a hollow so it's a little weird.”*	*"Here you do not know if it passes. And then one feels a valley, but it is badly drawn.*
2.6 Rocks, cliffs		*“There I do not know what it looks like”*	*“It would be good to have the contour and IGN map (25millième) you would see right off the rocky ridge.”*

Table 4: Sample of verbatim expressing difficulties about tracing representations.



3. TRACING			
Graphics	**Novice/C1** ***Verbatim***	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
3.1 Colored ski runs	*"Green and blue, sometimes they intertwine and there we lose the thread. They are too stuck together; it seems difficult to see exactly which track to take. "*	*“What it seems strange is that if it's a green it cannot be so steep”*	*“This is a blue run. But then I do not know if it goes down or it rises."*
3.2 Ski runs geometry	*“I'll take the blue called Col, and then … But I am trying to get up there?”*	*“It is a bit small and it is not easy to see the connections of the tracks. When you are stuck you cannot use the map you if you do not know where to turn”.*	*“Here I would like to know anyway …”*
3.3 « Green » areas	*“The green spots I am somewhat lost, especially as it is written very small”*		
3.4 Ski lift		*“The second section is not super clear if it stops there or not, I still have trouble reading where the tracks stop"*	*“It's always the difficult part on a ski map, to understand whether in fact it connects, if it goes up or goes down…”*

The difficulties were quantified according to the frequency of appearance in the discourse of the subjects (skiers). From a total of 55 expressions of difficulties identified in the utterances of the corpus, 30.9% were related to representations of geomorphology, 27.3% of tracing, 18.2% of structure, 16.4% of geography and 7.3% of nomenclature.

Deeper analyses from reading of the Alpes d'Huez ski trails map about the type of difficulty related to the geomorphic and tracing representations showed the following percentages: 100% of participants reveal uncertainty [“*I'm not sure that…*”], 44.4% of participants reveal a visibility problem [“*Not easy to see or to read*...], 33.3% of participants reveal a problem of understanding [*"I don't know..."*] and 22.2% of participants reveal an inconsistency on the ski map [*"It's a little weird..."*].

According to our experimental questions (see section 3.1), these preliminary results provided an inventory of ski-users' concepts and graphics representations and it also highlighted some difficulties in reading-comprehension of a ski map. In order to get deeper insights, a more detailed quantitative approach was necessary to measure the use of graphic objects. This was implemented through experiment 2, discussed next.

3.3 EXPERIMENT 2: GAZE DATA PROTOCOL

From a geographic information (GI) point of view, ski maps result from assembling a combination of graphics-geographic objects, such as ski trails and colored slopes tracing, vegetation, peaks, rocks, shadows and light, buildings, etc. In our case study, the experiment we developed for measuring visual attention on GI employed wearable eye-tracking techniques. Eye trackers measure a person's visual attention to a stimulus. These basic recordings are called *gazes*. It is generally assumed that perception takes place only if a gaze remains almost completely still for a minimum amount of time. Thus, gazes are often aggregated spatio-temporally to *fixations.* A transition between two fixations is called a *saccade*, which is caused by a rapid movement of the eye. A comprehensive overview on eye tracking hardware and methodology can be found in Holmqvist et al. (2011) and Duchowski (2007), (Kiefer et al. 2014). Eye tracking studies for cartographic stimuli date back to the 1970s and 1980s. Recent work has focused on the usability aspects of interactive maps, such as effectiveness and efficiency of different map designs (Çöltekin et al. 2010), the effectiveness of label placement or user group differences (Ooms et al. 2012a). The design of a map and the usability of the system in which it is shown are most likely to influence way-finding and self-localization decisions (Kiefer et al. 2014).

Experimental questions: what areas of the ski map are explored by the gaze? What are the most gazed at graphic objects and why? What areas of the ski map pose difficulties?

Participants: subjects were between 25 and 55 years old, including 5 women and 5 men. They were distributed into three groups according to their skiing ability: two subjects were in the novice skier group (N), five subjects were in the intermediate group (I) and three in the advanced group (A). Skiing ability was defined by auto-evaluation according to the "Ecole de Ski Français' standards".

Figure 3: Participant during the eye-tracking experience, wearing Tobii Glasses.

Modalities: subjects were observed in a controlled environment that mimicked real-world conditions: in labs, the ski map at actual size was mounted on the wall. Subjects were asked to perform two ordinary tasks: exploring the ski resorts features and assessing its usefulness (T1); creating a route between two fixed locations, explaining how they decided on which path to take (T2). Each subjects' session took about 15 minutes. Figure 3 shows a participant during eye-tracking experience.

Material:

- the interview grid to control the session;
- Ecole de Ski Français website to define by auto-evaluation subjects' alpine ski level;
- One copy of a pocket-sized ski map (Les 3 Vallées), to introduce the session;
- Alpes d'Huez ski trails wall map (size A0, 119 x 84 cm);
- the Tobii Pro Glasses 2: this mobile binocular eye-tracking system includes four eye cameras, a wide-angle HD scene camera (90 deg.) for peripheral viewing, and a sampling rate of 50 Hz.

Data collection: 3036 video frames for T1 and 2120 for T2. 60 minutes of total video-audio recordings.

Metrics: Fixation count and Fixation duration, with respect to the independent variables (alpine skiing ability and graphic categories).

Gaze data analysis: gaze data were processed by Tobii Analyzer software with Custom I-VT filter. This filter refers to the Velocity-Threshold Identification (I-VT) fixation classification algorithm that is a velocity based classification algorithm (Salvucci et al. 2000). The general idea behind an I-VT filter is to classify eye movements based on the velocity of the directional shifts of the eye. The velocity is most commonly given in visual degrees per second (°/s). If it is above a certain threshold the sample for which the velocity is calculated is classified as a saccade sample and below it is seen as part of a fixation (Olsen 2012). The Tobii Custom I-VT filter we applied had the following main settings: I-VT fixation classifier: 100 degrees/second and Minimum fixation duration: 100 ms.

Gaze data were analyzed with classical techniques:

- Heatmaps: a heatmap uses different colors to illustrate the number of fixations participants made within certain areas of the snapshot[3] or for how long they fixated within that area. Red usually indicates the highest number of fixations or the longest time, and green the least, with varying levels in between.
- Areas of interest (AOI): an AOI is a polygonal area in the stimulus the researcher considers relevant for the research question at hand. If a fixation occurs in an AOI, it is generally assumed that the participant perceived the object surrounded by the AOI (Kiefer et al. 2014). AOI enable numerical/statistical analysis based on regions or objects of interest in the snapshot images. 30 AOI were defined for Task 1 and 20 AOI for Task 2.
- Correlation between Heatmaps, AOI and verbal annotations.

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[3] Fixed reference image of the visual scene (Tobii Analzyer Real World Mapping software)

3.4 PRELIMINARY RESULTS FROM GAZE DATA

Preliminary qualitative results, and more specifically Heatmaps, allowed us to answer the first experimental issue (see paragraph 3.3). They showed that in (the first 90 seconds of) a ski area evaluation task (T1), subjects explored essentially the central area of the map. In a way-finding task (T2) subjects explored the main ski trails and the trails connecting points of interest. Heatmaps indicated an overall lack of interest with horizons and the panoramic map margins, regardless of subjects' skiing ability. Figure 4 shows an excerpt of Heatmaps for T1.

Preliminary quantitative results from AOI analysis allowed us to address the second experimental issue. They showed that the graphic objects representing ski trails and slope tracing are the most gazed at features when performing a ski area evaluation (T1) and also for the way-finding task (T2). Figure 5 shows the T2's AOI in a snapshot; the black line indicates the "ideal" itinerary that the participants had to find between the two locations. Naturally, the participants' routes varied and they could not quickly find the correct path. AOI techniques allowed us to calculate which areas the participants gazed at when making decisions.

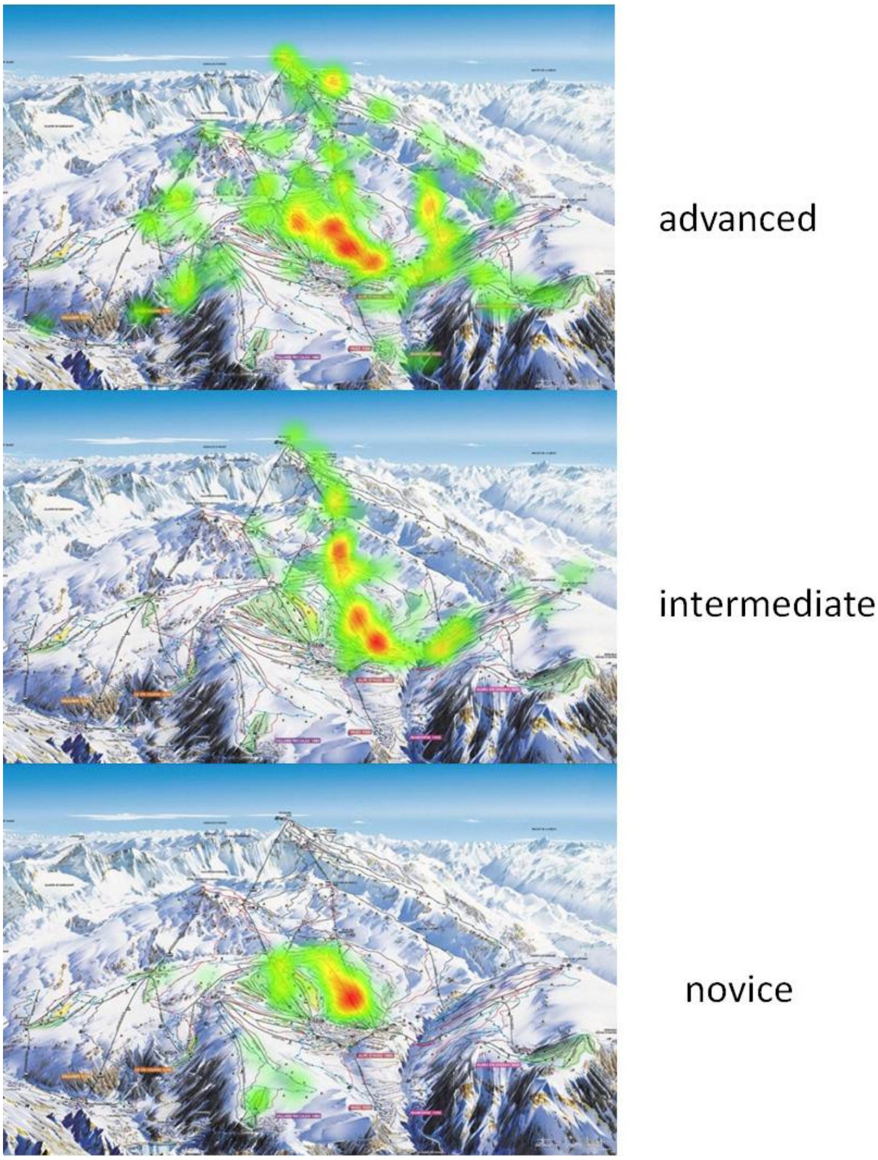

Figure 4: Examples of heatmaps for exploring and assessing the ski resort task (T1) grouped by skiing ability.

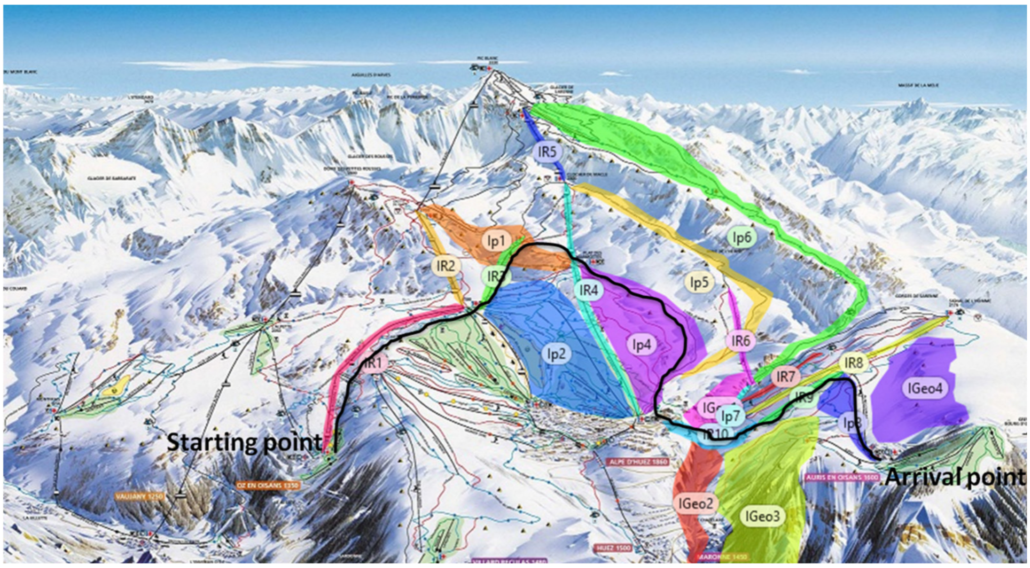

Figure 5: AOI for Task 2. The black line indicates the (ideal) route between the starting and the arrival points.

Graphics objects representing the geomorphology and the relief (i.e.: peaks and ridges, slopes, rocks, snow and ice, sunlight exposure, horizon...) are likely to influence user-skier decision-making. Figure 6 shows the distribution of the total fixations count for T2 by participant's ski level. The category "Geomorphology" groups objects that describe the geomorphology and the relief. The category "Tracing" groups objects that represent the ski lifts and ski trails.

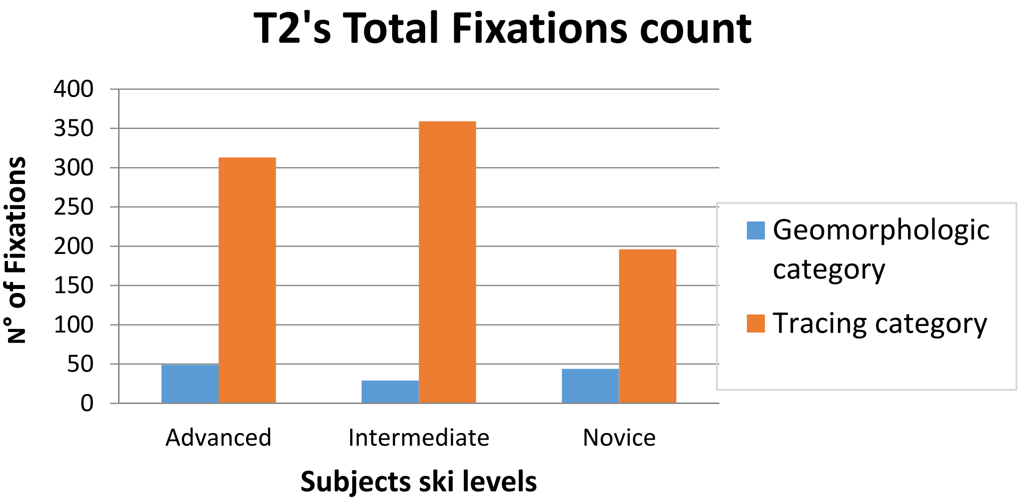

Figure 6: Total fixation count for graphic objects gazed during a creating route task (T2).

Finally, *combining gaze data and verbal data notations*, allowed us to answer the third experimental question and identify the "critical areas" of the map, those that cause misunderstanding, doubt, and uncertainty. They corresponded to highly distorted terrain containing important connecting routes. These areas had a very high visual attention rate. A significant example was the crossing area from the central site of Alpes d'Huez to Auris en Oisans domain. Practically all the heatmaps showed a high focus of gaze and speech analysis indicated significant difficulty in understanding the information. Figure 7 shows one of the heatmaps of the crossing area, correlated with sample Verbatim.

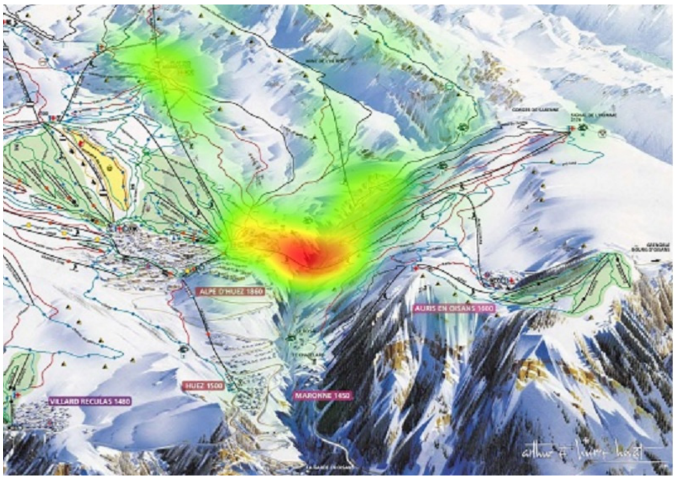

Figure 7: Excerpt of Heatmap and Verbatim from the crossing area between Alpes d'Huez and Auris en Oisan.

Verbatim

"I can go by here, but it looks a bit confusing, I do not know why, maybe it's closeness to the slopes, the mountain ..."

" This passage troubles me because I do not understand with this shadow, if the *only way to cross is that track…I do not know in which direction goes this curve. I hesitate to venture out there"*

4 DISCUSSION

These preliminary results are not suited to generalization and require validation by a larger investigation. Nevertheless, the visual-cognitive approach, based on verbal analysis and mobile eye-tracking techniques, allowed us to highlight the information necessary for a user to understand the natural environment and to assess whether it suited his needs. In response to our first research question, ski area evaluation and path definition tasks, the most helpful information referred mainly to ski trails, ski runs and their connection points. Tracks located in the center of the map, which corresponds to the central area of the resort with the major ski trails axes, attracted the greatest attention. The interest in tracks is not surprising if one refers to Field's (2010) outcome. His work shows that a schematic map of Breckenridge ski resort (designed similar to the London Tube map!) was better at aiding navigation and easier to interpret than the panoramic version.

Information related to the landscape seems very poorly understood. This leads us to discuss the second research question. The panorama terrain was relatively unexplored, especially at the map margins. The terrain only draws attention if it is confusing, mostly due to local distortion. The concepts of local distortion and panorama production are intrinsically linked: the first is essential to create the second. Local distortions to terrain are unreal depictions invented by the artist out of necessity: they're spatial decisions at a specific time in a specific situation. They are typified by graphical rotation, exaggeration, reduction and replication of shapes, enlargement, etc. As a result, objects are visible in the 2D scene, although they are invisible in the real-world scene (Balzarini et al. 2015).

Our preliminary results show that troubles in interpretation (misunderstanding, uncertainty) seem to be more evident in locations where there has been significant terrain distortion by the panoramic artist. A clear example is the representation of the area of Auris en Oisans, situated on the Alpes d'Huez ski map. The artist says that *"if I made a servile representation, I […] fill the view with something that is not interesting. So I prefer to turn the village of Auris, so that all tracks are on the profile nearby Alpes d'Huez. So I prefer not to take care of the real topography but mostly take care of representation as I want to give*". The consequences of this action are that both villages are too close together and visible, the distribution of ski lifts and ski runs is concentrated only on the slope overlooking Alpes d'Huez, and some ski lift alignments do not follow the landscape. (i.e. Auris Express chairlift). Furthermore, these distortions foster misunderstanding, inconsistencies and uncertainties about the up and down directions of the tracks and intersections, located exactly in the area of Auris en Oisans. All subjects participating in the study asked for more realistic views of the ski areas. Figure 8 shows the real and the depicted location of the villages of Auris en Oisans and Alpes d'Huez.

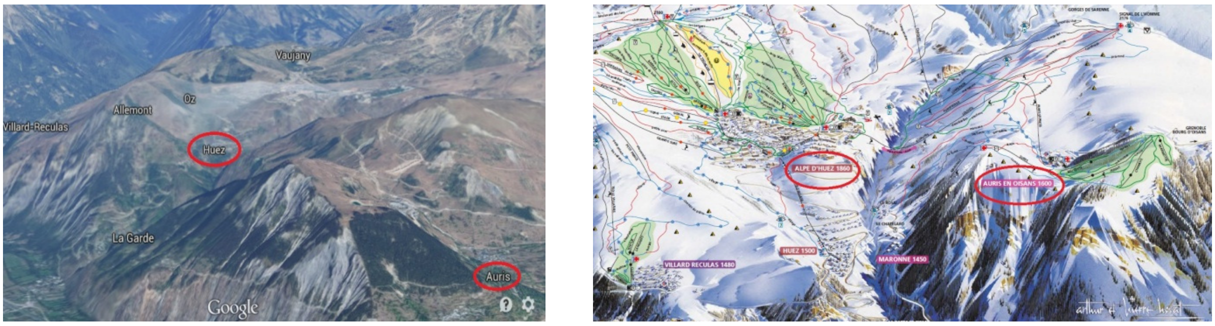

Figure 8: Position of Auris en Oisans and Alpes d'Huez from Google maps images©2015 (left) and the position of the two locations from Atelier Novat (right).

Although panoramic views are still fascinating, immersive environments have now replaced them. With the latest generation of 3D ski maps (i.e. Fatmap Apps) we can see undistorted mountain area views represented at different scales. These maps no longer include the whole horizon. Instead, they provide more detailed and functional information within a limited geographic area. However, cognitive research on the impact that these technological solutions have on user behaviors, needs more attention.

Thus, the main contribution of our results is in terms of methodology, which can bring relevant tools for further analysis of digital ski resort mapping.

Taking a socio-historical perspective, these results help to enhance the discussion on the challenges of renewal of (geographical) information design for an environment with strong territorial features, such as winter sports resorts. Dealing with the diversification of needs and requirements of users, the mountain operators, supported by the scientific research, should reflect on the relevance and effectiveness of the message they want to convey to the tourist. Nevertheless, one thing remains unchanged: despite the enriching information that technology can provide (flow information in real time, digital terrain models, etc.), mountain operators still want ski area maps to convey a message of vastness, beauty and dreams. In this respect, the aesthetic and emotional roles of panoramas still need to be evaluated along with other information.

5 CONCLUSION

This article reports on our preliminary cognitive research on ski map effectiveness. The role of panorama depiction and terrain distortion received considerable attention.

The case study focused on ski maps produced by Atelier Novat, the pioneer of French panoramic cartography.

The main goal was obtaining insights about what and how information is processed by users when performing ordinary tasks with ski maps. We undertook this research because our belief that paper ski maps may no longer meet skier's new needs and practices. Panoramic ski maps have dominated for over 40 years, influencing the reading habits of generations of practitioners and tourists alike. Aware of this heritage, at this stage of the study, we wish provide qualitative and quantitative recommendations in order to enhance the design of ski map in the digital era.

Deeper insights are expected from future research. These will involve experiments on visual matching process between objects in the natural environment and objects in the map, experiments on visual attention in digital ski map prototypes, as well as a large scale survey.

In conclusion, in the "situated information" era, this study provides a basis for innovative geo-visualization design, according to new practices in mountain mapping: a representation of the environment more realistically, targeted and adapted to the needs that can allow practitioners to better monitor their safety and comfort.

ACKNOWLEDGEMENTS

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SNOW-SKI-RELATED ASPECTS

AVALANCHE AWARENESS ACCESSING VIDEO CLIPS FOR EFFICIENT GEO-COMMUNICATION – MAPS, DIAGRAMS AND STORYTELLING IN ACTION

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ABSTRACT

This contribution deals with the utilization of video clips for efficient geo-communication in avalanche warning services worldwide and exemplifies various methods of implementation. Within this framework characteristic video clips with specific cartographic content will be deconstructed in order to understand geo-relevant information and thus offer insight in the multitude of possibilities to communicate avalanche awareness. Thereby various options for integrating maps as well as map related representations will be specifically addressed. As an analysis tool, a modular system is used to capture and structure essential cartographic design techniques. This form of abstraction is used subsequently to simplify the reproduction of video clips with geo-relevant content.

Various modules that are being currently adopted at several avalanche warning services will be analyzed. The result of the analysis will be presented and used as a framework to demonstrate their practical customization. On the one hand, the modular system will be exemplified in video clips based on the ten avalanches patterns developed by the Avalanche Warning Service Tyrol, Austria. Thereby the combination of the AIDA principles (Attention, Interest, Desire and Action) will be described. On the other hand, a semi-automatic video clip production process will be introduced to underpin the feasibility of such a procedure embedded in a real time environment documenting the current avalanche and snow conditions. Both approaches are being currently investigated as well as preliminary adopted by the Avalanche Warning Service Tyrol, Austria.

Keywords: avalanche awareness, geo-communication, video clips, storytelling

1 INTRODUCTION – AVALANCHE AWARENESS

Alpine Space in general is often seen as a fascinating and enjoyable environment for all kinds of ventures; however it comprises potential risks that must be taken into consideration when residing within such settings. Year round mountaineers and hikers must be aware of this fact. Especially during the snow covered season avalanche danger plays an important role in mountainous areas. Consequently avalanche assessment requires thorough examination and intensive monitoring. Regional as well as national Avalanche Warning Centers worldwide have set their goals to facilitate awareness and recognition of the potential danger of avalanches and, consequently increase prevention of avalanches in open terrain. This is achieved through risk assessment that is being made available to the public (Mair 1999: 110ff.). Local weather and snow data are monitored and used to assess the potential danger. The collection, processing and communication of geo-relevant information in this case is of paramount importance (Land Vorarlberg 2016). In particular, the efficient communication of complex issues to the general public – in the sense of geo-communication – represents a major challenge.

2 GEO – COMMUNICATION

According to Bollmann et al. (2002) geo-communication underlies the principle of sending and receiving spatial information in a standardized environment. The content must first be brought into a suitable form for communication in order to be transmitted in a further step via an information carrier from the transmitter to the receiver. If the content has a spatial reference the main information carrier for transmission is traditionally the map. However various tools and formats utilizing modern technology provide nowadays a broad spectrum of possibilities. In this context multimedia formats play an important role (Kriz 2013: 10) whereby video clips are especially significant.

Related to geo-communication maps, diagrams and texts are primarily used to enable the above-mentioned prevention of avalanches. However, the Austrian Avalanche Warning Centers are aware that the aforesaid information carriers are not always sufficient enough to reach their goals. According to Consortium of the Austrian Avalanche Center (ARGE – Lawinenwarndienste Österreich 2015: 33) statistics show only a slight decrease of avalanche victims in Austria over the last 20 years. The discussion among experts in the season report of the Austrian Avalanche Warning Centers 2014/15 „Lawinenlagebericht – Das ungelesene Wesen“ (ibid.: 260) highlights the dissatisfaction with the current forms of communication.

Consequently, the search for alternatives opposed to the traditional settings of available avalanche reports is of great importance due to the fact that the syntactic, semantic and pragmatic rules of existing information carriers are more often not understood by the general public (Kriz 2013: 12). Therefore, the inclusion of external methods is necessary to achieve the goal of avalanche prevention. If geospatial information is emotionalized one speaks of geo-communicational storytelling. Thus, the need for an appropriate information carrier is indispensable to meet on the one hand the demands of geo-relevant information transfer and on the other hand to emotionalize the process. According to Mallon (2003: 2) video clips are suitable for storytelling whereby a multimedia presentation of the aforementioned content is meaningful.

Considering alternative forms of communication for Avalanche Warning Centers, video clips can serve as a new information carrier and offer the possibility to combine geospatial content with emotions.

3 STORYTELLING – AIDA

Storytelling without emotions and dramaturgical structuring leads to no feasible result. Therefore, an established concept for controlled management of emotions is necessary. In 1898 E.S.E. Lewis introduced one of the oldest scientifically proven advertising principles called AIDA: *Attention, Interest, Desire and Action* (Jacobi 2013: 54). By going through all four stages, the emotions of the addressee are conducted in accordance to the content (Ostheeren 2003: 227). This approach can be used today for avalanche prevention to emotionalize storytelling.

By means of the first stage *Attention* awareness of the recipient is obtained. The so-called eye-catcher is of special importance and can achieve its objective by using impressive images. However, if a video clip just starts with introductory text, it must take over the role of the eye-catcher and compensate the absence of a striking introduction.

According to Lewis the second stage after *Attention* is *Interest*. Critics point to the disagreement of the order due to the fact that *Interest* is also often used as a first stage (ibid.: 57). In order that the awareness is not interrupted specific modules within this stage serve as suspense activators. To stimulate the awareness of the potential danger of avalanches animations are suitable that communicate the basic functionality of such events. This way the addressee can learn the basic principles of avalanches without being confronted with them in reality.

Based on the information from level two *Interest* level three *Desire* is generated and coincides with the purchase of a promoted product in advertising. Regarding the awareness of the potential danger of avalanches the aim of this stage is to stimulate a desire of the addressee to handle the avalanche problem in reality. The above-mentioned suspense built upon the deliberate omission of reality-based information can be resolved here by showing for example video clips of avalanches triggered by skiers in the backcountry.

In order to conclude the AIDA concept the final stage *Action* is of great relevance. In advertising *Action* means to purchase the promoted product that leads consequently to marketing success. Generally speaking this process can be described as implementing what has been learned in the first three stages into practice. In cartography this procedure is defined according to Hake et al. (2002) as the tertiary model. This process finds its use in raising awareness through the presentation of an application-oriented guidance in the fourth stage of the AIDA concept. As a basis for planning the communication of spatial information the inclusion of a map that is efficiently designed is beneficial.

Considering the oldest advertising concept AIDA, all four stages can be seen as empty containers which build the emotional framework for geo-relevant information integration. Hence the AIDA concept serves as a clear guide for the structure of storytelling.

4 AVALANCHE STORYTELLING CONTAINER MODULES

The previously discussed concept in chapter "Storytelling - AIDA" can be seen as a container that must now be filled with content. To identify and tackle this process a survey was undertaken of existing selected video clips of potential avalanche hazards from avalanche warning centers worldwide (AWS 2016). By breaking down the evaluated information into individual components knowledge retrieval was pursued. All examined video clips were divided for easier detection into categories and their components broken down into specific modules.

The analysis showed that all examined video clips can be subdivided into three areas: *Current Situation, Avalanche Investigation, Facts Worth Knowing*. The components of each area can then be divided into primary and secondary containers. The properties of the primary container can be described as basic elements. These are needed for the video clip production and post processing. Consequently, video clips have always an assured basic set of primary components.

The secondary container components distinguish themselves by clarity which again is accompanied by high complexity. This can be seen as transformation of the basic elements into a finished concept. Thus the secondary container modules fulfill the requirements of AIDA to achieve emotional integration of geo-relevant information.

Four selected examples illustrate this conceptual approach:

1. Introduction video sequence of the Utah Avalanche Center.
2. Animation sequence of the Canadian Avalanche Warning Service.
3. Video sequence of the Utah Avalanche Center showing an avalanche event.
4. Map use New Zealand Avalanche Warning Service.

4.1 INTRODUCTION VIDEO SEQUENCE

Video clips of the Utah Avalanche Center always start with the same intro so that the assignment of the following content is clear. The introduction consists of the primary module components text, animation and video as well as the secondary module element logo. The logo is made up of the text and animated graphics (= animation). Combined with the module element video it can be seen as a separate secondary component.

Figure 1: Screenshot from the introduction video sequence of the Utah Avalanche Center.

4.2 ANIMATION SEQUENCE

To show how a weak layer develops within a snowpack an animation according to the definition of Tversky et al. (2016: 247) is presented in a video sequence by the Canadian Avalanche Warning Service. This type of computer animation can be seen as a standalone primary module element and communicates particularly complex processes in a very simplified and abstract manor.

Figure 2: Screenshot taken from an Animation sequence of the Canadian Avalanche Warning Service showing how a weak layer starts becoming a snowpack.

4.3 EVENT VIDEO SEQUENCE

A genuine video sequence of a realistic event can produce a profound impression in contrast to an animated sequence. As shown in an example below the message “How is an avalanche triggered in open terrain” is clearly communicated.

Figure 3: Screenshot from a video sequence of the Utah Avalanche Center showing how an avalanche is triggered.

4.4 MAP USE

The use of maps in video clips can be seen as a separate module. In contrast to the primary container modules described above such as text or video maps can display very complex scenarios in a very effective and efficient way. Their depiction is however dependent on design issues that have a high impact on how these spatial representations are perceived and finally understood. Designing a map that is equally appealing as well as informative and then integrating the result in a story is a demanding task for itself. This also somehow explains why only one map was found in the evaluated video clips despite the high potential of efficient spatial communication. In the video clip of the New Zealand Avalanche Warning Service the integration of the map is filmed off a screen unfortunately in a very unsuitable way. However generally speaking this approach gives the use of maps a large amount of potential for optimization.

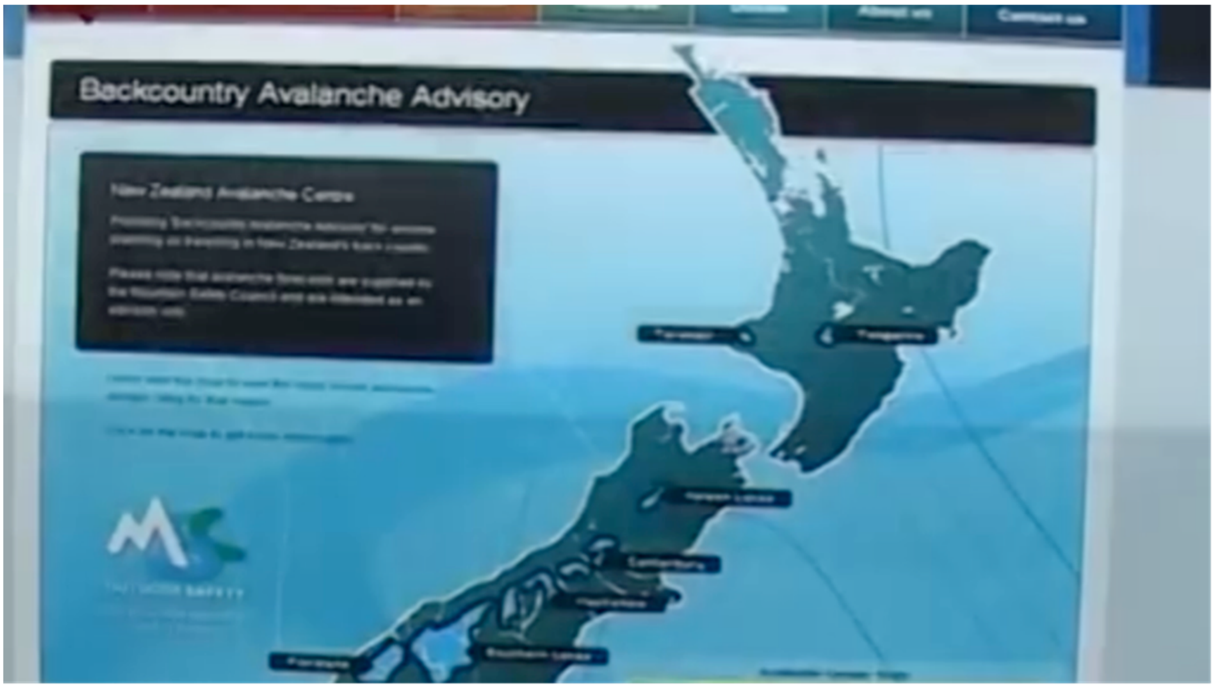

Figure 4: Screenshot of a map of the New Zealand Avalanche Warning Service that was filmed from a screen.

5 MAP INTEGRATION

The integration of maps in videos as static or dynamic installations can be implemented in various different ways. The question however arises what additional benefit do these maps have when included in video clips. The added value is clearly seen when dynamic effects are integrated in the representation. This is based on the assumption that on the one hand the communication of temporal issues are important for the general understanding of chronological processes. On the other hand the presentation of spatial information is necessary for the extraction of locational information. With the appropriate integration of maps in a video clip both critical features merge and eventually lead to the efficient symbiosis of spatio-temporal information. However to ensure this effective geo-communication in a video clip it is not primarily necessary to have both mentioned features co-exist in one installation. It is more important to ensure that both temporal as well as spatial issues are addressed in either one or the other module. Therefore, the map can be seen as an important but not as a mandatory part of a video clip. Efficient communication of geo-related information does not depend on the defined containers and the fancy dynamic features that are implemented but moreover how the story is conveyed, applied, orchestrated and finally carried out.

The integration of maps in video clips allows numerous possibilities of representation that can enrichen and support the overall information transfer. In general video clips utilize three categories of map integration:

1. Map as a navigational source.
2. Map as a thematic information carrier.
3. Map as an esthetical design factor.

5.1 MAP AS A NAVIGATIONAL SOURCE

Orientation in the field plays an important role for risk assessment. A large scale topographic map can be regarded as one the most appropriate instruments for such tasks (Bollmann et al. 2002). When combining maps as a navigational source in video clips it is important to understand the power of maps as well as their dimensional characteristics. The classical planimetric 2D map view gives a good overall understanding of terrain however requires a high level of user expertise to extract relevant information. 3D static as well as dynamic map representations on the other hand communicate an easy understandable and familiar view of the earth's surface however restrict the observer to predefined areas of interest.

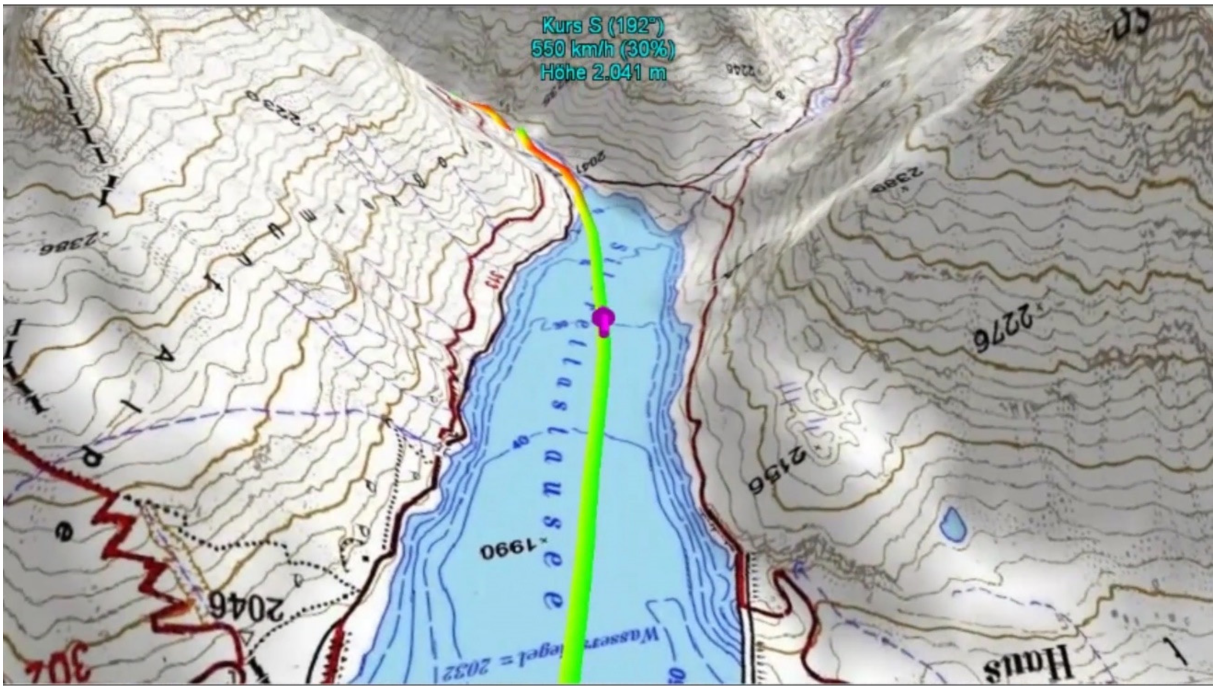

Figure 5: Screenshot of a 3D animation of the Austrian Alpine Club Map displaying a ski touring route.

5.2 MAP AS A THEMATIC INFORMATION CARRIER

As previously mentioned most avalanche relevant issues that deal with risk assessment have a spatial reference. For examples the regional danger levels, temperature distribution or the location of current avalanche events are amongst other topics that are being addressed and communicated regularly by the Avalanche Warning Services. Since domain experts have recognized that spatial representations have proven to be extremely efficient, it is obvious to integrate the produced maps in video clips in order to communicate this information to the public. However to enhance such static depictions within the communication process the use of pseudo dynamic methods such as animated progressive sequencing is promoted. These maps consist of text, area, line and point related information that can be projected on a topographic base map utilizing animation effects to produce pseudo dynamic effects.

5.3 MAP AS AN ESTHETICAL DESIGN FACTOR

Maps claim, among other things, to be carriers and promoters of esthetics (Spiess 2002: 14). Thus maps can be altered in video clips to enhance design topics instead of primarily emphasizing on navigational and orienteering issues. The following example underlines this approach showing the logo of the Austrian Alpine Club in the foreground with a contour line map in the background implying indirectly navigational competence.

Figure 6: The contour lines serve as a design element.

6 AVALANCHE CENTERS AND MODULE EFFICIENCY

In order to understand the effective usage of the above described container modules five Avalanche Warning Centers worldwide (Switzerland, Norway, New Zealand, Canada and USA (AWS 2016)) that have been identified to have active video clip communication in their portfolio were evaluated and compared. In the investigation three points were critically examined and analyzed to outline communication efficiency of video clip usage. First, the availability and accessibility of information was evaluated, where the video clips can be found on the web and how they are presented. Secondly, the components were verified how timely the issues are and what topics were given priority. Finally the qualitative implementation of the AIDA principles was analyzed. All evaluated Avalanche Warning Centers reveal spatial information even though the effectiveness of communication is to some extent ambivalent. The comparison in Table 1 shows that the amount of modules is not crucial for efficient communication. Although three Avalanche Centers (Utah, Canada and New Zealand) use more or less the same number of modules a clear distinction between them can be determined.

Table 1: The used modules for each Avalanche Warning Service. Blue = primary module container, red = secondary module container.

AWS Switzerland	AWS Norway	AWS New Zealand	AWS Canada	AWS Utah/USA	modules
X	X	X	X	X	video
X			X	X	animation
	X	X			fixed image
		X	X	X	text/annotation
X	X	X	X	X	speech
X		X	X	X	sound/noise
		X	X	X	music
		X	X	X	intro
	X	X	X	X	title
	X	X	X	X	logo
			X	X	teaser
		X			map
	X	X		X	interview
		X	X	X	outro/credits

The Utah Avalanche Center realization is in comparison the most efficient due to the fact that the content is regularly updated and constantly adapted to the users' needs, however lacks map integration. The Canadian and New Zealand achievements are both favorable however still possess a high potential for effective spatio-temporal optimization. Both Swiss and Norwegian only represent basic features and do not fully coincide with the described basic container-module framework.

7 COMBINATION OF MODULES AND AIDA

To increase the efficiency of geo-relevant communication in video clips as mentioned above it is necessary to focus on the selection, implementation and combination of the above specified modules. The AIDA concept serves here as a framework that can be also understood as an empty container that is filled subsequently with content. Therefore, through the combination of geo-communication utilizing the conceptual approach of storytelling together with selected modules desired results can be achieved.

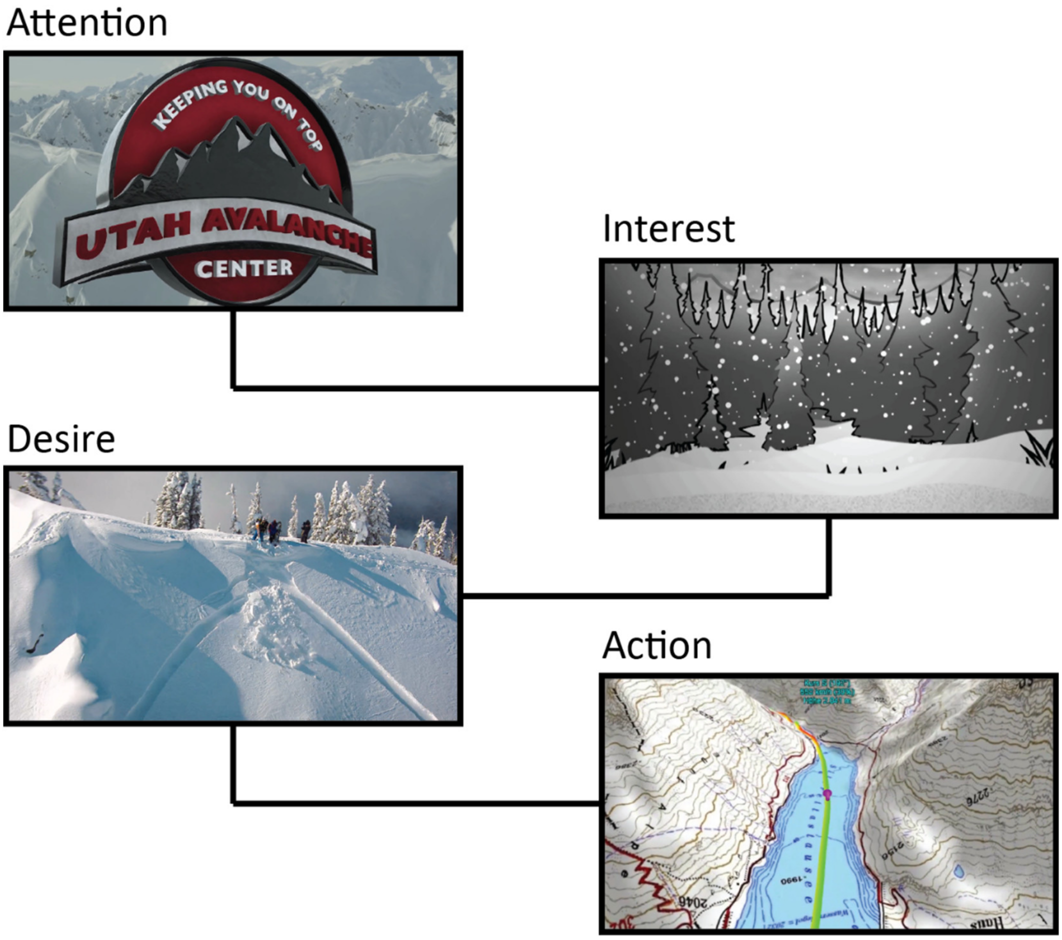

Figure 7: Combination of the four AIDA principles implemented with different modules.

The intro of the Utah Avalanche Center is predestined for the AIDA principle *Attention* due to the eye-catching effect of the logo. The animation of the weak layer development within a snowpack of the Canadian Avalanche Warning Service can be used for the AIDA principle *Interest* to arouse curiosity as well as to communicate specialized knowledge to the public. The AIDA principle *Desire* gives the viewer a reference to reality through a video sequence of an avalanche event. Finally a map with an active proposal to go outdoors is connected to the AIDA principle *Action* to animate the user to transfer theory into praxis.

The entire process of choosing the right and meaningful modules within the AIDA framework demands a lot of skill and know-how so that ultimately a video clip is produced that can satisfy the ambitious objectives of effective geo-communication. The approach also foresees to simplify the process whereby a semi-automatic procedure is pursued.

8 MODULAR SYSTEM

The approach that has been described above is based on a system that is currently being developed and is established on three guiding principles: the *Combination of Modules, Interchangeability* as well as *Semi-automatic Usability*. This system however requires the creation of predefined containers as well as the availability of suitable video-editing software. Furthermore it also houses templates for recurring standard settings such as *Weather, Current Situation, Accident Investigation or Facts Worth Knowing*. Depending on the situation predefined templates can be used to take advantage of the structure whereby the content is simply replaced. Within the project, all video sequences are defined in distinct entities, whereby in principle the objects can be replaced with new ones. There are blocks consisting of a video and audio track and are thus ready for use, but there are also those that need to be redesigned for each new video clip. Thereby, further steps are necessary to accept attributes and effects of previous sequences and exchange them with new ones. This step is software dependent and must be done proactively. The more complicated the sequences are the more steps need to be actively carried out by the user. Simple, already ready to use modules accelerate the video production process keeping however in mind that repeating the same scheme too often with little variety makes the video clip dull and boring and thus losing the suspense factor.

The modular system can be regarded as a semi-automatic procedure. It accelerates the video production process and reduces the storytelling prerequisites to accomplish efficient geo-communication.

9 CONCLUSION

The problems of inefficient communication of geo-relevant issues to the general public have been recently addressed by the Consortium of the Austrian Avalanche Center (ARGE – Lawinenwarndienste Österreich 2015: 260) and have led to a broad discussion amongst experts. The approach in this article pursues these objectives and tries to show how to combine geo-relevant issues with the AIDA concept utilizing the communication channel video clip as a suitable form of new media integration. The combination exists of video clips that transport geo-relevant topics as well as the AIDA concept that broaches the issue of emotions by means of storytelling.

A semi-automated prototype system was implemented in the winter season 2014/15 at the Avalanche Warning Service Tyrol to test the proclaimed procedures. Predefined templates such as *Weather, Current Situation, Accident Investigation and Facts Worth Knowing* were accessible for selection and for further processing. This way previously defined and designed modules could be easily reused and ultimately replaced.

Although the production of video clips with only basic knowledge is possible the system is not yet implemented for operational use. Whether avalanche prevention can actually be enhanced with this system remains open, due to the fact that no analysis has yet been undertaken to explore the effectiveness of the system. Nevertheless, it can be assumed that the value and use of such a system will gain relevance in the near future.

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FIGURES

Figure 1: Screenshot from the introduction video sequence of the Utah Avalanche Center. https://www.youtube.com/watch?v=1KYwEk4G9Js (accessed July 11, 2016).

Figure 2: Screenshot taken from an Animation sequence of the Canadian Avalanche Warning Service showing how a weak layer starts becoming a snowpack. http://old.avalanche.ca/cac/training/online-course/avalanche-formation/snowpack-layering (accessed July 11, 2016).

Figure 3: Screenshot from a video sequence of the Utah Avalanche Center showing how an avalanche is triggered. https://vimeo.com/144545554 (accessed July 11, 2016).

Figure 4: Screenshot of a map of the New Zealand Avalanche Warning Service that was filmed from a screen. https://www.youtube.com/watch?v=rtVImAwVLJ4 (accessed July 11, 2016).

Figure 5: Screenshot of a 3D animation of the Austrian Alpine Club Map displaying a ski touring route.

Figure 6: The contour lines serve as a design element. https://youtu.be/9mQNIX_sTpo (accessed June 2, 2015).

Figure 7: Combination of the four AIDA principles with different modules. Source: self-compilation

HISTORICAL ASPECTS

DEVILLE & LAUSSEDAT: FRANCE'S CONTRIBUTION TO PHOTOGRAPHIC SURVEYING IN THE CANADIAN ROCKY MOUNTAINS, 1885-1924

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ABSTRACT

The work of Édouard-Gaston Deville and Aimé Laussedat introduced photographic surveying to the Canadian Rocky Mountains. This article will examine Canada's survey and mapping history with regards to Deville and Laussedat, and the contributions that they made to cartography and the emerging science of photogrammetry in Canada and elsewhere.

Keywords: Édouard-Gaston Deville, Aimé Laussedat, France, Canadian Rocky Mountains, photographic surveying, photogrammetry

1 INTRODUCTION

In 1885 the Canadian Pacific Railway was completed across the great divide of the Canadian Rocky Mountains. Practical solutions were required in the survey and mapping of this mountainous terrain. The science of photographic surveying and the designing of instruments for field use came as a direct result of Édouard-Gaston Deville, as Surveyor General of Canada beginning in 1885.

Figure 1: Édouard - Gaston Deville (left) – Dominion Land Survey, Ottawa. Aimé Laussedat (right) – Canadian Alpine Journal 1907, Alpine Club of Canada.

As we look more closely at the personal life histories of two men, Édouard Deville and Aimé Laussedat, we will discover France's contribution to photographic surveying in the Canadian Rocky Mountains. Like a tapestry of interwoven threads, Deville's relationship with Laussedat shows the influential foundation of the nineteenth century science of photographic surveying in France and the establishment of Canada's own unique survey methods and instruments.

A brief biography of both Édouard Deville and Aimé Laussedat will contribute to a clearer understanding of their connection in a historical setting.

2 ÉDOUARD-GASTON DEVILLE

Édouard-Gaston Deville was born in La Charité, France, on February 21, 1849. He was educated at the French Naval School at Brest and entered the French navy where he conducted extensive hydrographic surveys beginning in 1868. Upon retirement from the navy in 1874, Deville had achieved the rank of captain.

Emigrating to Canada in 1874, Deville established himself as a highly skilled surveyor and leader, holding the following positions: Provincial Land Surveyor, Quebec, 1874; Dominion Land and Topographical Surveyor, 1878; Inspector of Surveys, 1881; and Chief Inspector of Surveys, Department of the Interior in 1882 with the Federal Government. Deville was next appointed Surveyor General of Dominion Land Surveys, Canada and filled this position from 1885 until 1922 after which he was appointed Director General of Surveys for the Department until his death in Ottawa, on September 21, 1924.

M.P. (Morrison Parsons) Bridgland, an outstanding and contributing Dominion Land Surveyor (D.L.S.) with regards to photographic surveying in the Canadian Rocky Mountains, published *Photographic Surveying,* Bulletin No. 56, Department of the Interior, Canada in 1924. Bridgland acknowledges in the publication Deville's contributions in the following words:

"The introduction of photographic surveying into Canada was due to Dr. E. Deville, Surveyor General of Dominion Lands. He was quick to realize its value for mapping the extensive

mountain regions of Western Canada, and, being a man of high scientific attainments, he designed instruments which he considered specially suitable for the requirements of the rough and rugged country in which they would have to be used. These instruments are still in use, almost in their original form, though minor alterations have been made and modern lenses have replaced those originally used in the cameras." (Bridgland 1924: 2)

The most important book written and published by Édouard Deville in Canada was *Photographic Surveying Including the Elements of Descriptive Geometry & Perspective, 1895.* Combined with M.P. Bridgland's *Photographic Surveying,* these two publications give the most detailed scientific review of Photographic Surveying methods and equipment used in the Canadian Rocky Mountains.

3 AIMÉ LAUSSEDAT

Aimé Laussedat was born in Moulins, France, on April 19, 1819. He was educated at the Ecole Polytechnique and graduated as an *Officer of Engineers* in the French army. In later years, Laussedat became Director of the Conservatoire National des Arts et Métiers.

In 1895 Deville published *Photographic Surveying* which gives acknowledgement of Aimé Laussedat's work in the following words: *"Wherever photographic surveys are now made, they are executed by the application of the principles laid down by Laussedat"*(Deville 1895: iii)

As a French army engineer, Colonel Aimé Laussedat began the study of perspective geometry in 1849 using the "*Camera Lucida*" (Chambre Claire) for survey and mapping. Deville wrote the following for the Alpine Club of Canada's *Canadian Alpine Journal* in memoriam of Laussedat's death in 1907:

"He was best known as the father of Photogrammetry. He was first to lay out the principles of the art and to indicate its applications. His papers, published in 1854, 1859 and 1864, contain a full treatment of the subject and little has been added to his methods since their publication. It was in Canada that Photogrammetry received its first practical and extensive application."(Deville 1907: iii)

Eduard Doležal of the Technical University of Vienna and founder of the Austrian Society of Photogrammetry gave the following statement at the L'Académie des Sciences, Paris 14th June 1909:

"… this illustrious French scientist (Aimé Laussedat) whose memory will never be erased from the minds of geodesists globally who owe him the ingenious tranformation of a simple camera into an instrument of measure and the idea of images registered on photographic plates for any topographic operations." (Dolezal 1909: 1572)

Aimé Laussedat died in Paris, France, on the March 18, 1907. In his final years, Laussedat compiled his life's work in a three volume book published in 1898, 1901 and 1903 sequentially. *Recherches sur les instruments, le méthodes et le dessin topographiques (Research on Topographic Instruments, Methods and Drawings).* It is one of the most extensive historical and scientific publications with regards to surveying and the development of photographic surveying in nineteenth century France and other European countries. Deville and Canada's survey methods and achievements were acknowledged by Laussedat.

4 PHOTOGRAPHIC SURVEYING IN THE CANADIAN ROCKY MOUNTAINS

Deville, as Surveyor General of Canada, developed and implemented photographic equipment resulting in the first practical survey in the field. Under J. J. (James Joseph) McArthur, D.L.S. and W. S. (William Stewart) Drewry, D.L.S. surveying began in 1886. The result was a successful series of topographic maps covering two thousand square miles at a scale of 1:40,000 and a contour interval of 100 feet (Figure 2). The *Forty-Mile Creek, 1890* sheet shows a contoured map and beautifully shaded relief lithographic print process (Figure 3).

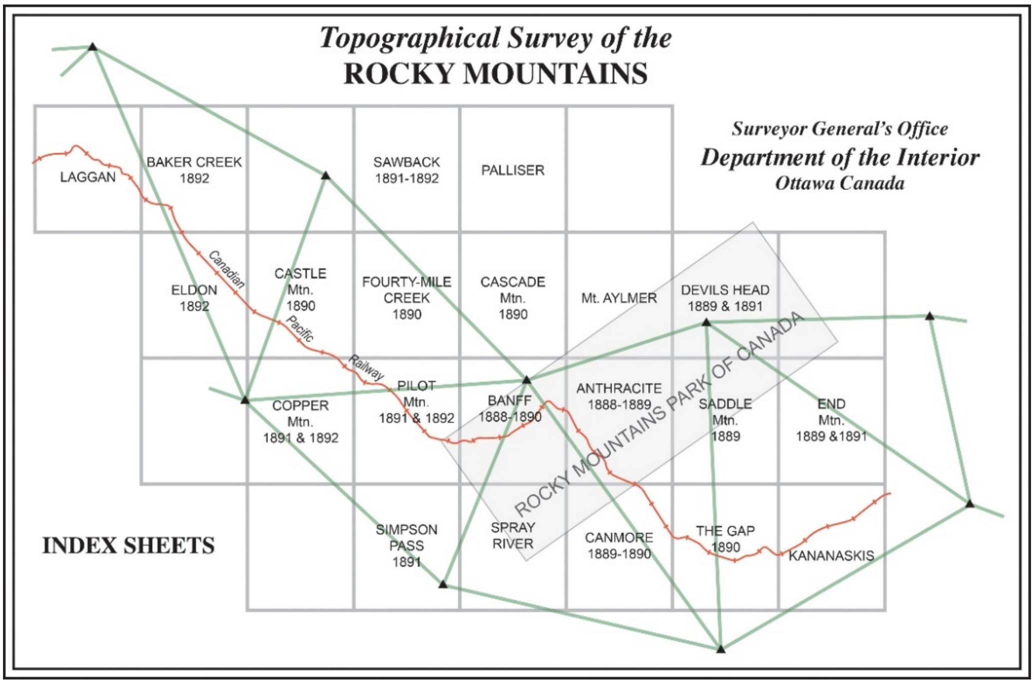

Figure 2: Index to sheets of the Topographical Survey of the Rocky Mountains.Surveyor General's Office, Department of the Interior, Ottawa. Redrawn from original.

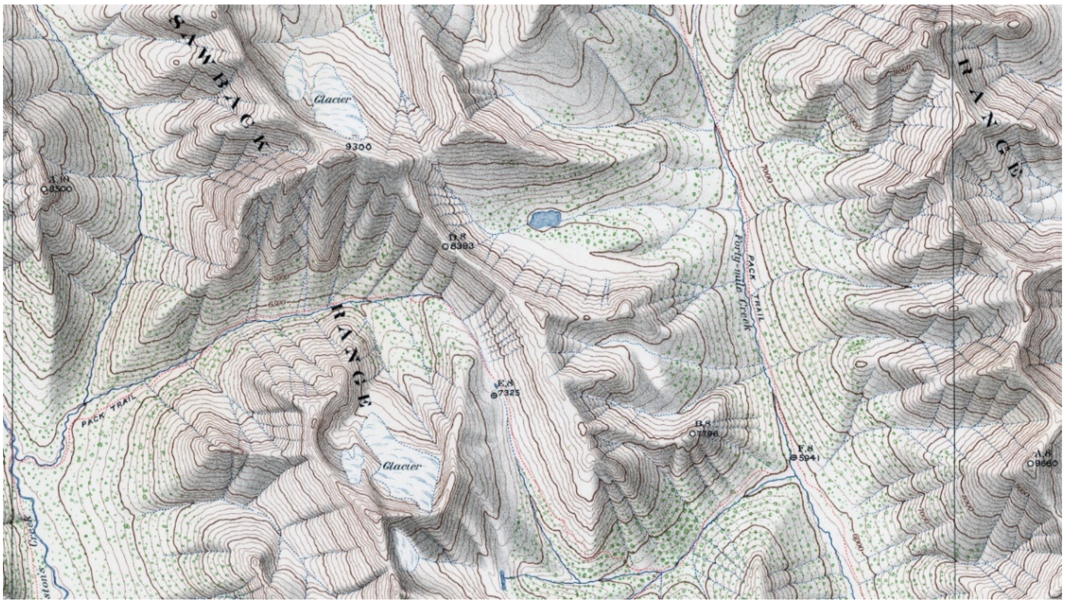

Figure 3: Forty-Mile Creek 1890. Topographical Surveys Branch, Department of the Interior, Ottawa. Triangulation by W.S. Drewry D.L.S. and Topography by J.J. McArthur, D.L.S.

Deville was able to represent Canada's major accomplishments in photographic surveying on the international stage *at the World's Columbian Exposition* in Chicago, 1893. At the same time Laussedat was also represented in France's exhibit at the exposition. John Adolphus Flemer, a Topographics Engineer, gives the following account in his published work titled *An Elementary Treatise of Photographic Methods*:

"A phototopographic map of a part of the Rocky Mountain Park, comprising a dozen sheets of about sixty square miles each, published on a 1:40,000 scale, formed one of the most interesting exhibits of the government of the Dominion of Canada … France had an interesting exhibit … showing photographic surveying instruments and map specimens, in illustration of topographic and astronomical results, gained chiefly under the direction of Col. A. Laussedat and taken from the collections of the Conservatoire National des Arts et Metiers, Paris, of which institution Col. Laussedat is now director." (Flemer 1906: 8, 29)

In December 1893, Deville wrote an abstract report for the *Engineering News and American Railway Journal* titled *Application of Photography to Surveying.* Reference is made to the Columbian Exposition in Chicago that same year and the display of the Topographical Survey. Deville also makes reference to Laussedat's application of perspectives used in surveying:

"The first application of mathematical perspectives to surveying is due to Colonel Laussedat, of the French army; in 1850 he conducted a series of experiments before a commission appointed by the War Office. His perspectives were obtained by the camera lucida (Figure 4). *A year or two afterward he substituted photography for the camera lucida; this, of course, did not cause any change in the method, which remains the same, no matter how the perspectives are obtained, and which he described in 1854."* (Deville 1893: 491)

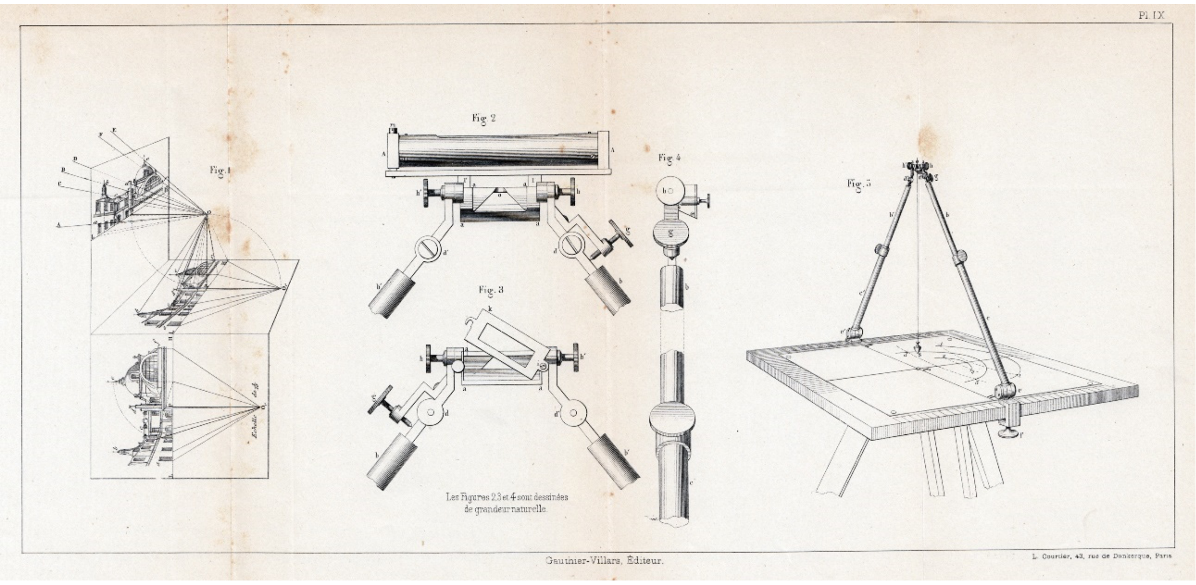

Figure 4: Camera lucida (Chambre claire). Recherches sur les instruments, le méthodes et le dessin topographiques, Tome II. Colonel A. Laussedat, Paris 1901.

The overall report by Deville describes, "*work accomplished and its results*" going on to explain that a photographic survey requires a highly skilled topographer and assistant. After a season in the field, the mathematics of perspective were used in plotting the topography from the developed glass photographic plates at the mapping office.

4.1 STEREOSCOPE IN PHOTOGRAPHING SURVEYING - DEVILLE

Édouard Deville published an article titled *"On the use of Wheatstone Stereoscope in Photographing Surveying"* in the *Proceedings and Transactions of the Royal Society of Canada. Second Series – Volume VIII. Meeting of May, 1902.* Acknowledgment is given to the Carl Zeiss' Optical Works, Jena, Switerland and Dr. C. Pulfrich with regards to an instrument in development *"for the purpose of making accurate measurements on stereoscopic views".* Deville expresses a lament with regards to his own past and experimentation with methods of stereoscopic photography and instruments based on the Wheatstone Stereoscope were being experimented with (Figure 5).

"Another solution of the problem of stereoscopic surveying occurred to the writer (Deville), *and experiments were commenced in 1896; owing to pressure of other duties, they had to be abandoned. In view of the attention now given to the subject, a description of the instrument devised at the time may offer some interest. The apparatus is a Wheatstone or reflecting stereoscope provided with such adjustments as are necessary for plotting topographical plans."* (Deville 1902: 63)

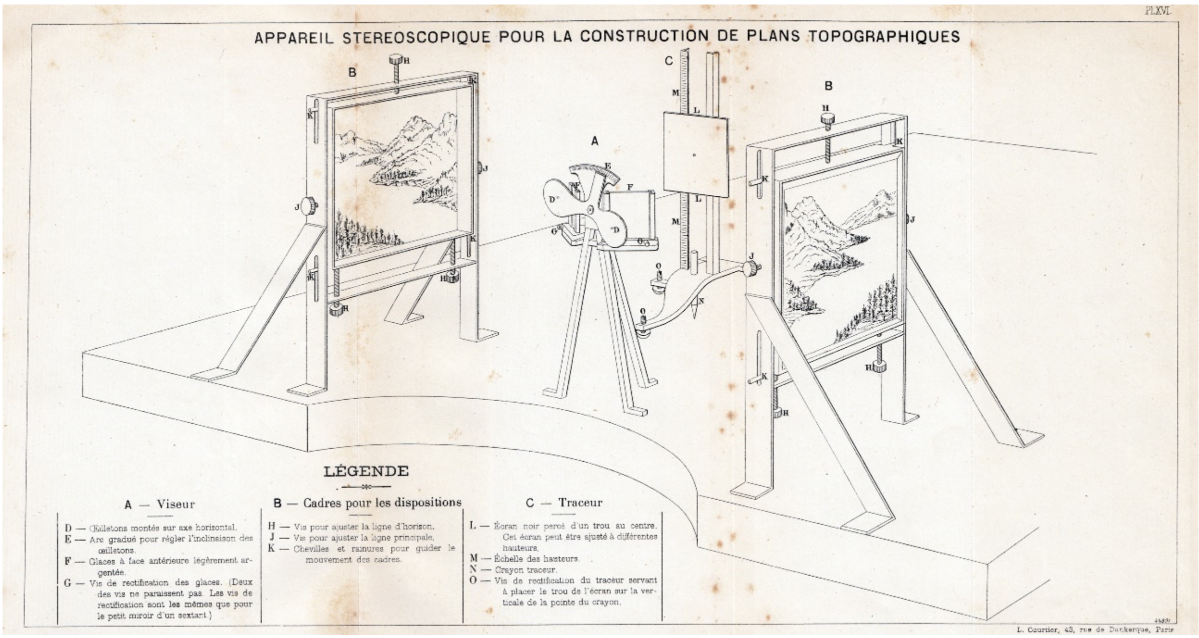

Figure 5: Stereoscopic apparatus for the construction of topographical plans. *Recherches sur les instruments, le méthodes et le dessin topographiques, Tome II.* Colonel A. Laussedat, Paris 1901.

4.2 THE SELKIRK RANGE – BRITISH COLUMBIA

The Selkirk Range, British Columbia by Arthur O. Wheeler was published by the Department of the Interior in 1905 – Volume I. and 1906 – Volume II. Volume II. is a pocket box with folded maps, diagrams, and panoramic photographic plates. Contained within are four segment sheets of the topographical map of THE SELKIRK RANGE (Figure 6). As part of the map legend, it is signed ***E. Deville****, Surveyor General of Dominion Lands.* It illustrates Édouard Deville's achievement in photographic surveying and topographic maps. It is an exquisite example of a contoured and shaded relief lithographic print process on heavy paper.

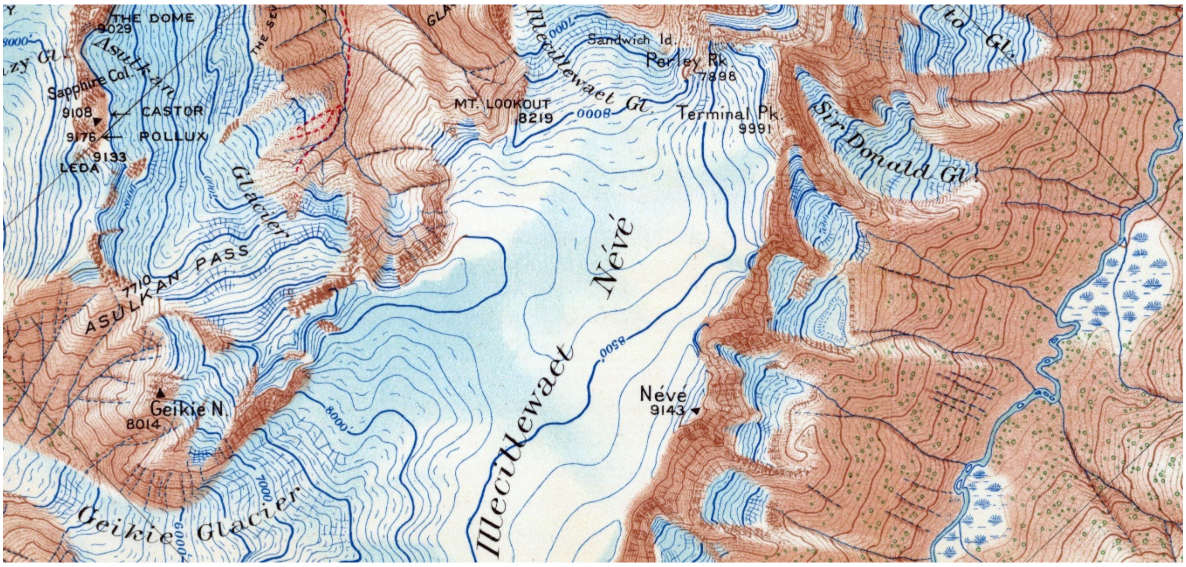

Figure 6: The Selkirk Range – British Columbia – Adjacent to the Canadian Pacific Railway. Topographical Surveys Branch, Ottawa June 15th 1906. E. Deville, Surveyor General of Dominion Lands.

4.3 ALPINE CLUB OF CANADA - DEVILLE & LAUSSEDAT

The Alpine Club of Canada was founded in 1906, with A. O. Wheeler as President and Elizabeth Parker as Secretary. A total of seven honorary memberships were given including Édouard Deville and Aimé Laussedat. Mountaineering involved with the photographic surveys both in the nineteenth and early twentieth century by Dominion Land Surveyors and assistants must be recognized for their historic contribution to Canada's alpine mountaineering. Many first time ascents of mountain peaks were accomplished as a result.

4.4 BOUNDARY BETWEEN THE PROVINCES OF ALBERTA AND BRITISH COLUMBIA

The following text is taken from *Report of the Commission, Appointed to Delimit the Boundary between the Provinces of Alberta and British Columbia, 1913 to 1916* giving a description of the instruments with regards to the *Methods of Topographical Survey*:

"Dr. Deville has given the science much study and has brought it to a high state of precision. The work requires a specially constructed camera and mountain transit - theodolite. It is carried on by climbing to previously selected stations at the summits of the peaks, or to high points on mountain ridges that command a view of the area to be mapped. From these a series of views is taken and their direction established by the use of the transit-theodolite" "The instrumental outfit, adapted by Dr. Deville, weighs about 45 lbs., and is so disposed as to be easily carried, even when the climbing is dangerous." (Cautley, Wallace, and Wheeler 1917: 15)

"The camera is of fixed focus and has a wide-angle lens covering about 52 degrees of arc for one view. It is adapted in two positions to a light, strong tripod with sliding legs, to which are attached levelling screws to bring the plate exposed in the camera to a vertical position, an absolute necessity to obtain suitable views (Figure 7)*. The same tripod fits the transit-theodolite."* (Cautley, Wallace and Wheeler 1917: 15)

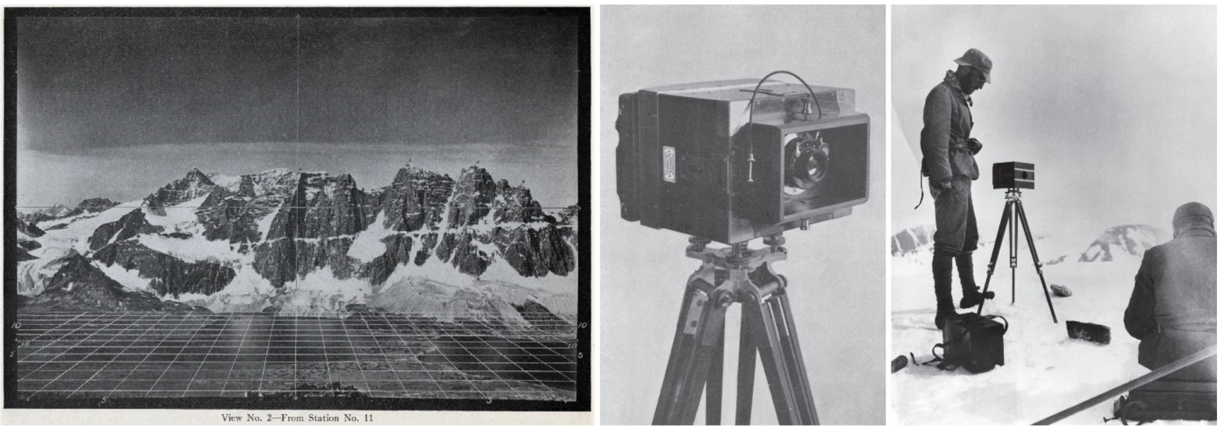

Figure 7: View No. 2 - From Station No. 11. (left). Camera of the Topographical Survey of Canada (centre). Dominion Land Surveyor, on a photo-topographic survey (right).

4.5 MAP OF THE CENTRAL PART OF JASPER PARK, ALBERTA, 1915 – M.P. BRIDGLAND

M.P. Bridgland was a devoted servant or disciple of Édouard Deville and a skilled surveyor, mountaineer and topographer. Bridgland's *map of the central part of Jasper Park, Alberta, 1915* is a fine example of using Deville's photographic survey process (Figure 8). References are shown on the map with regards to camera stations and peaks located by triangulation. The *Jasper Park* map is comprised of six sheets at a scale of 1:62,500 with a 100 feet contour interval. Bridgland's published work *Photographic Surveying* illustrates the use of mathematical perspectives to create topographic maps of the Canadian Rocky Mountains (Figure 9).

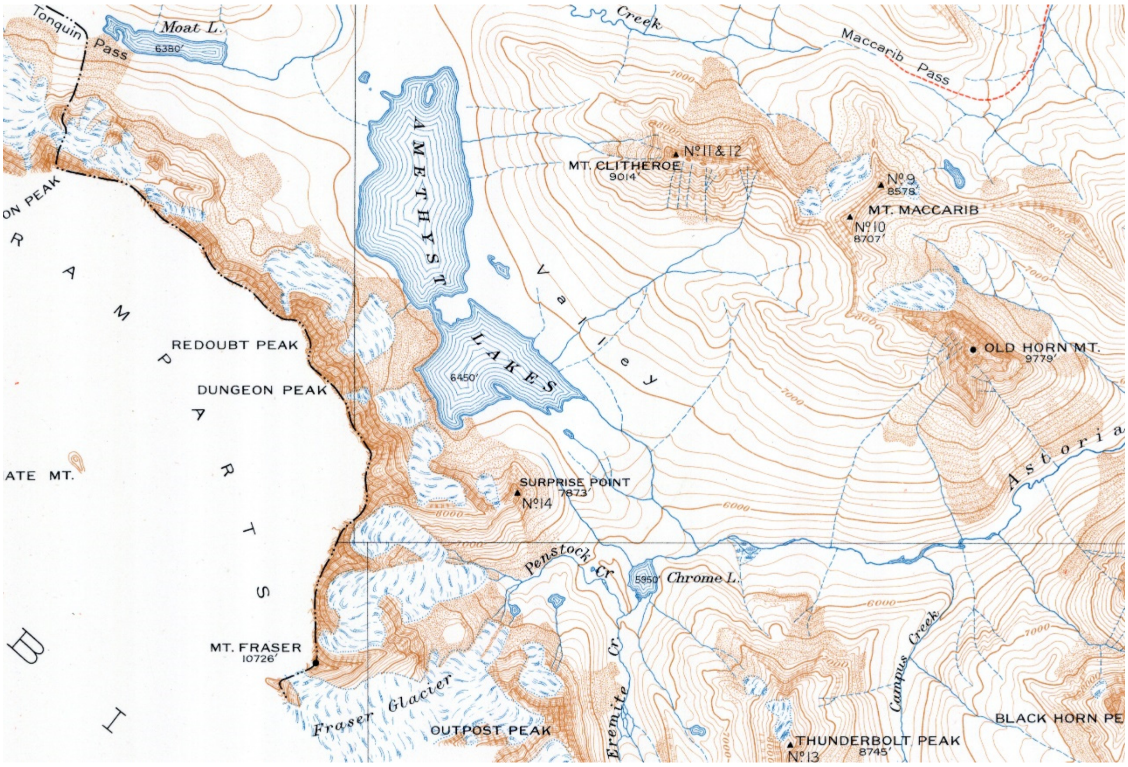

Figure 8: Map of the central part of Jasper Park, Alberta, 1915. Drawn and printed at the Surveyor General's Office, Department of the Interior, Ottawa, Canada.

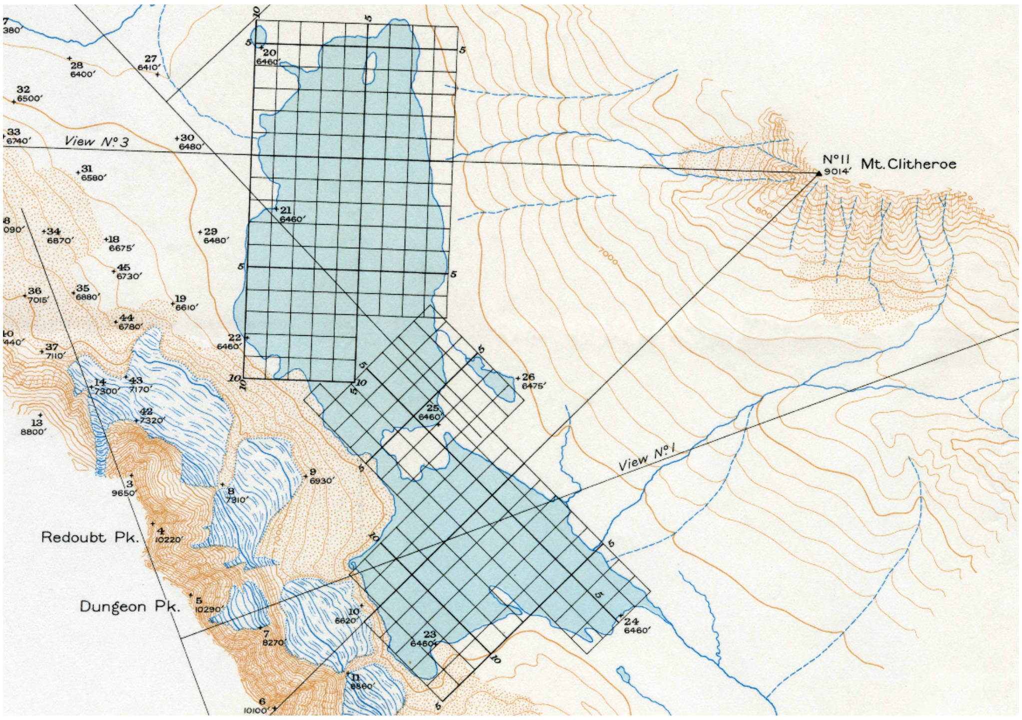

Figure 9: Amethyst Lakes, Alberta to illustrate the methods of photographic surveying. M.P. Bridgland. *Photographic Surveying*, Bulletin No. 56, Department of the Interior, Canada 1924.

5 PHOTOGRAPHIC SURVEYING - BEYOND OUR BORDERS

There have been important accomplishments made by Canadian surveyors and topographers using Deville's methods and equipment. Alpine mountaineering was required in order to ascend mountain peaks in Alaska and the Yukon; some of the most rugged and remote mountains and glaciers were surveyed.

5.1 BOUNDARY BETWEEN THE UNITED STATES AND CANADA – ARCTIC OCEAN TO MOUNT ST. ELIAS

The International Boundary Commission between the United States and His Majesty's Government was formed in 1906. A survey and demarcation of the international boundary between the United States and Canada along the 141st meridian from the Arctic Ocean to Mount St. Elias was completed (Figure 10). A joint report by the International Boundary Commission was published in 1918 by the Department of the Interior, in Washington D.C. Both American and Canadian photographic methods are given recognition in the report, including the following acknowledgement of Édouard Deville:

"For the rough and almost inaccessible region between Mount Natazhat and Mount St. Elias the photo-topographic camera was used, governed, like the plane table, by trigonometric control. In this region the camera proved itself indispensable, as, on account of bad weather conditions and the ruggedness of the country, the mapping probably could not have been done by any other method without serious loss of time. Both the Canadian and the United States patterns of camera were used, following the usual method as laid down in Deville's "Photographic Surveying" and Flemer's "Photographic Methods and Instruments." (Department of the Interior 1918: 193)

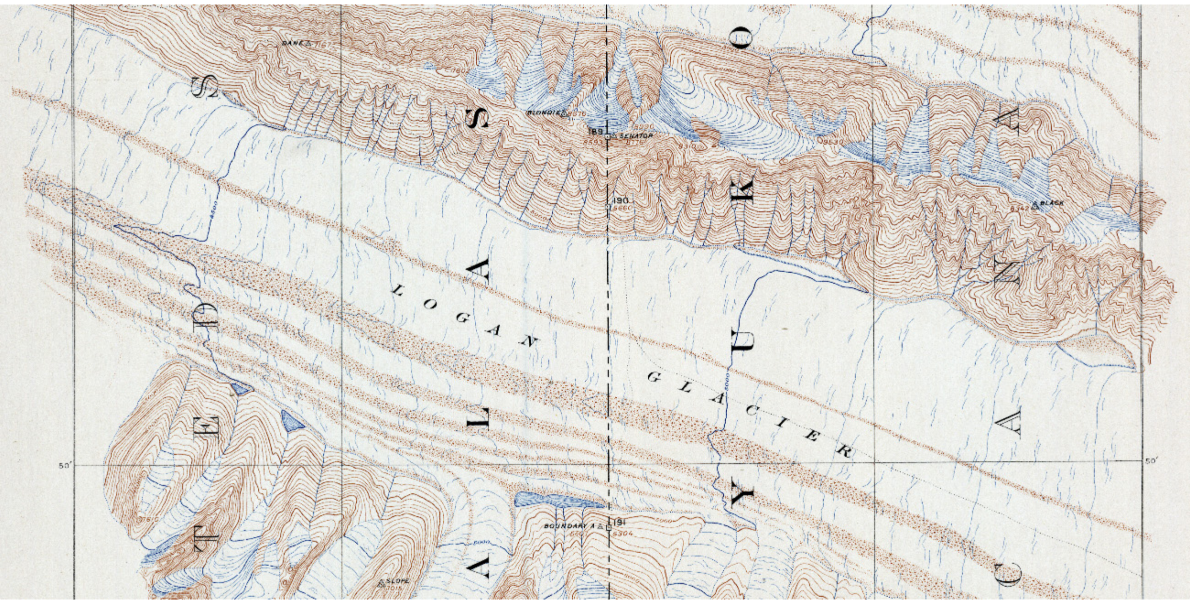

Figure 10: Logan Glacier, Yukon Territory, Alaska - 1:62,500. International Boundary along the 141st meridian, Sheet No. 36 Printed by the U.S. Geological Survey, 1917.

5.2 BAIRD GLACIER, ALASKA & DEVILLE - OTTO J. KLOTZ

Otto J. Klotz, a Dominion Land Surveyor, first visited the Alaska panhandle in 1889 on assignment with the Canadian Topographical Survey under the federal government with regards to a boundary dispute between the American and British governments. Returning in 1894, to conduct work with regards to the Canada - Alaska boundary survey, Klotz conducted a photo-topographic survey of the front of the Baird Glacier in Alaska. Publishing his results in *The Journal of Geology* in 1895, Klotz makes the following statement with regards to Édouard Deville:

"It is believed that the method of photographic surveying, as developed by Mr. E. Deville, surveyor general, Dominion of Canada, will prove of great assistance to those engaged in the study of the motion of glaciers." (Klotz 1895: 512)

Publishing with the prestigious Royal Geographical Society, London, England, Klotz gives this conclusion with the use of photographic surveying:

"Whatever methods of measurement and survey are used, it cannot be too strongly recommended that photographs be taken with a camera of fixed and known focal length from a properly oriented base-line. The study of the motion of glaciers will then be reduced to an exact science." (Klotz 1899: 534)

Even though Klotz does not make a clear reference to Deville in this article, the use of a survey camera for the '*study of the motion of glaciers*', extends the practical application of photogrammetry.

5.3 TOPOGRAPHIC SURVEY OF THE ISLAND OF TUTUILA, SAMOA

In addition to his work in the Canadian cordillera, Deville had conducted extensive hydrographic surveys in the South Pacific beginning in 1868 during his service in the French navy.

James W. Bagley, a topographic engineer of the United States Geological Survey, makes reference to Deville in his publication *The use of the Panoramic Camera in Topographic Surveying*:

"A topographic survey of the island of Tutuila, Samoa, has lately been completed by the Hydrographic Office of the Navy Department. For these surveys a plate camera of Deville's general type was employed to obtain stereoscopic views, and the negatives were worked up in the office at Washington by means of a stereocomparator. It is reported that the method gave satisfactory results." (Bagley 1917: 1)

6 TRIBUTE TO DEVILLE AND LAUSSEDAT - M.P. BRIDGLAND

M.P. (Morrison Parsons) Bridgland's published work *Photographic Surveying, 1924* gives tribute to both Deville and Laussedat. Deville passed away on September 21, 1924 . Bridgland expressed the following words in his written introduction with regards to Édouard Deville:

"The writer wishes to acknowledge his extreme indebtedness to Dr. E. Deville, whose book entitled Photographic Surveying was published in 1895 … From this book the writer has derived the greater part of his knowledge of photographic surveying, and he feels that no apology is necessary for quoting many passages from it verbatim or nearly so."(Bridgland 1924: 2)

Bridgland gives a detailed account of Laussedat's scientific efforts in France. As in Deville's *Photographic Surveying Including the Elements of Descriptive Geometry & Perspective* published in 1895, Bridgland includes the important historical development of photographic surveying. The following is a clear tribute to Laussedat by Bridgland:

"In 1856, Col. A. Laussedat, who was really the founder of photographic surveying, began a study of the subject, using at first a "camera lucida." This consisted of a four-sided prism, mounted over a drawing-board, which, by a double reflection of the rays through an angle of 90°, enabled the operator to see the image as though coming from the board and to make a freehand sketch of it on the paper placed thereon. For some years he continued this work, improving the instruments and elaborating the methods, and, when a suitable lens was obtained, substituted photographs in place of freehand drawings. In 1859, he felt justified in announcing his success to the Academy of Sciences in Paris, and, after a careful and critical examination, a favourable report was given and photographic surveying passed beyond the experimental stage and became a recognized science. A still further impetus was given to its development when dry plates were placed on the market about 1873, and later improvements in lenses and plates, resulting in more perfect images and better negatives, have added much to the value of photography as applied to practical surveying." (Bridgland 1924)

"Since its introduction by Col. Laussedat, the subject has received the attention of many noted scientists in other countries, and many extensive surveys have been made, not only in European countries, but also in many other parts of the world comparatively unknown at that time." (Bridgland 1924)

7 CONCLUSION

The contributions of Édouard-Gaston Deville and Aimé Laussedat in the photographic surveying of the Rocky Mountains are now part of Canadian history. Deville's leadership, practical vision and skills brought photographic surveying or *"Photogrammetry"* to the forefront in Canada's mountain cartography in the nineteenth and early twentieth century. As with Deville and Laussedat, our personal experiences and interaction with colleagues affect the trajectory of our careers. In the case of Deville and Laussedat, their personal learning, leadership skills, and creative vision made a significant and long lasting impact on how we now map mountains.

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HISTORICAL ASPECTS

DESIGN PATTERNS OF NATURALISTIC SHADED RELIEF FOR LARGE-FORMAT MAPS WITH HIGH-RESOLUTION DATA

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ABSTRACT

This article reviews design patterns for naturalistic shaded relief that apply to large-format maps created with high-resolution data. The case involves a large-format, plan-view relief depiction of Santa Cruz Island, California created with lidar and high-resolution imagery data products. Design patterns describe well-established problems of relief depiction and general strategies for solving them. These inform more specific tasks in a workflow. In this case, the workflow incorporates GIS, stand-alone applications, and Photoshop. Large-format depictions of high resolution data enable map reading across scales, making traditional principles of high mountain cartography particularly relevant to their design. The design pattern framework illustrated by this case also helps reveal relationships of principles and steps in a workflow that may be useful in cartographic education.

Keywords: landscape change, Lidar, public education, navigation

1 INTRODUCTION

In 1938, Eduard Imhof produced a large-scale wall map of the Walensee area in Switzerland on a 9.6 square meter canvas based on the "free artistic interpretation of visual impressions gained during long walks through the mountains" (Imhof 2007). He seemed to view this project as an experiment with questionable value to cartographers more generally: "This type of subjective, impressionistic, artistic representation… will seldom serve the purpose of a map, and it does not easily lend itself to the establishment of graphic principles (Imhof 2007: 299). As Patterson (2002) noted, Imhof's pessimism was possibly influenced by the methods that were available in his time, requiring considerable artistic and cartographic expertise and relying heavily on subjective observations of the landscape. In addition, his opinion seems to be rooted in the problem of scale: "Cartographic artistry such as this would lead to confusion at small scales, and would weaken the map's capability to convey information. Here, broad generalizations, both of objects and of colors, are unavoidable" (Imhof 2007: 299).

This article explores this issue largely by flipping the problem around and asking: how do cartographic principles for naturalistic depictions of smaller-scale maps help inform designs of large-scale maps? For small-scale maps, topographic details can create visual noise that disrupts the clear expression of a terrain's major features. Thus the task of generalizing terrain usually occurs quite early in a workflow in order to create what Imhof called "new, condensed forms" (Imhof 2007: 211). As Imhof (2007: 188) described the process, "First to be smoothed out or removed are the gullies, niches, projections, local gentle slopes, erosion terraces, and the small details of alluvial deposits over the ground. Next, whole valleys and mountain ridges are eliminated, and what was a complex mountain group with many valleys becomes what appears to be one mountain only." Though large-scale representations will include these smaller terrain features, the problem for the mapmaker is that the printed map as a physical object may allow the user to change the perceived scale of the representation simply by changing their viewing distance. This is particularly true for large-format maps. Readers will bring their face close to the map to examine details, but they will also step away and consider the geographic context of the location, perceiving the entire map extent in a single view. A key design challenge for large-scale, large-format maps is thus to show detail when close to the map, while still supporting Fridolin Becker's principle at greater viewing distances that "a brief look at the map should be enough to grasp the shape of terrain" (Räber et al. 2009).

While the principles reviewed in this article will likely by familiar to practitioners and academics experienced with terrain representations, the article aims to illustrate a framework to help students and instructors of cartography connect general principles with the more specific methods of mapmaking workflows. To this end, the article frames cartographic principles as design patterns (Howarth 2015) based on a framework originally developed for architectural design (Alexander et al. 1977, Alexander 1979). A design pattern identifies a clear problem that tends to occur over and over again, describes the contexts in which the problem tends to arise, and then outlines general strategies to resolve the conflict. Using this framework, the workflow to produce the map becomes a sequence of conflict resolution, where each step connects to one or more general principles of cartography and helps identifies the situations or contexts where the principle applies.

This article explores these issues through a work in progress to create a large-scale (1:15,000), large format map (printed on four 39” by 26” map sheets) of Santa Cruz Island, California, USA (34° N, 119.7° E). Like Imhof’s earlier experiment, this project aims to present a plan view portrayal of a landscape that appears as natural as possible. The methods differ from Imhof, however, as the project uses computer software rather than watercolors and it blends personal impressions gained from long hikes across the island with high resolution elevation and imagery data.

2 CASE STUDY

Santa Cruz is the largest island in the Channel Islands National Park and is managed by both the National Park Service and The Nature Conservancy, a private land conservation organization. The intended audience for the map includes public visitors to the park, land managers, and researchers and educational groups that access the island through a scientific field station managed by the University of California Natural Reserve System. Although the map will include linework and labels, this article focuses on the depiction of the relief and vegetation patterns.

Santa Cruz Island was selected as a study site for two reasons. First, high-resolution elevation and imagery data are both publically available for the island. The 2010 Channel Islands Lidar Collection is accessible through Open Topography (www.opentopography.org). High-resolution imagery data for Santa Cruz are available from the National Agricultural Imagery Program (NAIP) with a one-meter resolution and accessible through Earth Explorer (http://earthexplorer.usgs.gov/). Since 2007, NAIP products of Santa Cruz Island contain four bands of data (RGB and Near Infrared).

Second, the accurate depiction of small details in the natural terrain, like erosion and vegetation patterns, is particularly meaningful for interpreting and understanding relationships between the island’s recent human history and natural environment. In 1853, sheep were introduced to the island for mutton and wool and quickly reached very high densities. By the 1890s, this had caused severe erosion island-wide, including the creation of entrenched arroyos in valley fills, widespread gullying of hillsides and localized slope failures (Brumbaugh 1980, Perroy et al. 2012). It also altered vegetation patterns on the island, stripping woodlands to bare ground or converting woodlands into open grassland habitat (Junak et al. 1995). Beginning in the 1890s, sheep gradually became excluded from certain kinds of terrain, largely through great efforts of fence-building, in order to convert former sheep range into new purposes (Howarth and Laughrin 2009). As a result of this evolving spatial organization, there is considerable variation across the island with respect to duration of sheep grazing and pathways to becoming sheep-free. Thus a second purpose of the map concerns this thematic story through the accurate depiction of erosion and woodland fragmentation that aims to help elucidate relationships between micro-histories of land use and spatial patterns of island vegetation.

3 DESIGN PATTERNS

This section briefly describes five general design patterns of cartographic relief presentation, drawn largely from Eduard Imhof (2007). The approach is to first briefly describe a general problem or conflict that tends to occur repeatedly in relief mapping. These problem statements appear in italics and are followed by short reviews of the problem's background.

3.1 ILLUMINATION ANGLE

The illusion of shaded relief is most effective when the illumination source comes from the northwest horizon, but if the direction of light is uniform across the entire surface, this creates "a misleading illusion of certain forms" (Imhof 2007: 210).

The illumination angle problem comes up frequently in digital cartography because most automated hillshading methods, beginning with the first effort by Yoëli (1967, 1966), assume a single, uniform illumination angle for the entire relief surface. In manual shading, the solution to the problem was to induce slight variations to the illumination direction depending on the local topography. Imhof (2007: 175-5) advised cartographers to "let the light rays wander about, as it were, along the slopes and around the individual mountain masses" with the goal of removing what he called the "unavoidable expressionless points" that arise should light rays illuminate the surface from a uniform, parallel direction.

Beginning with Kurt Brassel (1974), cartographers have worked on automated methods to mitigate this problem by combining multiple hillshade outputs produced from different illumination angles. Mark (1992) developed a method to combine hillshades from four different azimuths and then create a local combination with weights from a generalized aspect layer. More recently, Veronesi and Hurni (2014, 2015) have developed two methods for automatically changing light direction. The first approach uses a k-means algorithm to cluster the aspect values derived from a DEM and then change the light direction in each cluster. The second approach uses a sine wave equation to adjust lighting azimuth based on slope and aspect values derived from a DEM. This approach also allows for zenith adjustments based on either slope or elevation. Both the Cluster and Sine Wave Lighting methods are available as models for ArcToolbox and can be implemented relatively easily in ArcGIS. Figure 1 compares the output from a traditional analytic hillshade algorithm with northwest illumination angle with an output from the sine wave lighting method.

A very different approach to the same problem assumes that illumination is uniformly distributed throughout the sky so that the amount of light that reaches a location is a function of the amount of sky that is visible to it. This avoids obscuring some features of the landscape because of their orientation. Several different automated methods have been developed to model the amount of sky that is visible at a location based on the elevation values at neighboring locations. These include measures of terrain "openness" (Yokoyama et al. 2002) uniform sky illumination models (Kennelly and Stewart 2006) and models of sky view factor (Zakšek et al. 2011). Štular et al. (2012) found that sky view factor (SVF) was particularly useful to visualize small details of the landscape with high-resolution data in rugged terrain. A model to calculate SVF is available in the Relief Visualization Toolbox (http://iaps.zrc-sazu.si/en/rvt) as an executable package for both Windows and Mac OS. Figure 2 compares a sine wave lighting output to a sky view factor output.

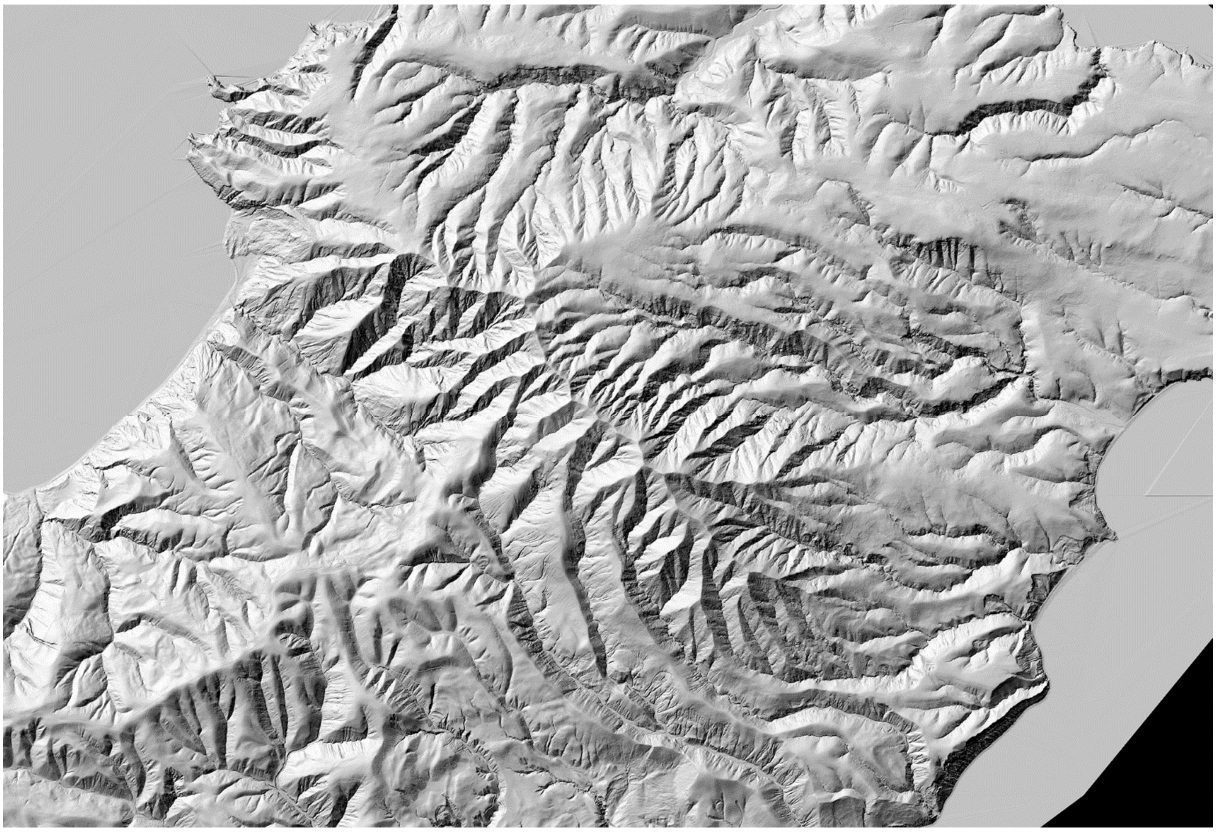

Figure 1: Top: Analytic hillshade with azimuth 315 and altitude 45. Bottom: Sine Wave Lighting with azimuth between 295-315 and altitude 45. Both at 1:50,000.

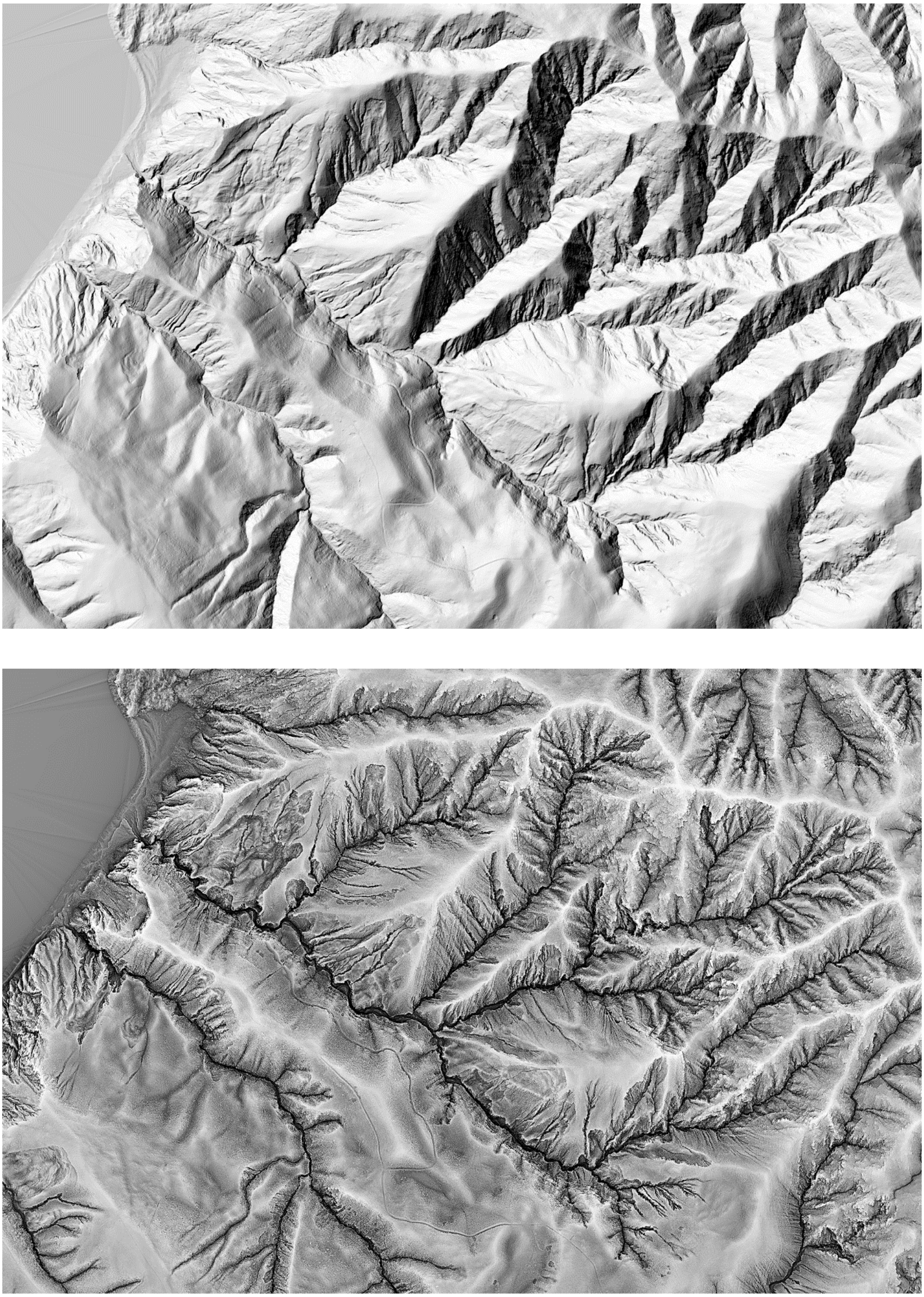

Figure 2: Top: SWL hillshading. Bottom: Sky View Factor with diameter 5. Both at 1:15,000.

3.2 TERRAIN STRUCTURE

In automated hillshades, tones depend only on local slope and aspect. As a result, small terrain details can appear with the same visual emphasis as larger features, making it difficult to quickly recognize the overall structure of the landscape.

In manual shaded relief, cartographers conveyed the structure of landscapes with the help of "skeletal lines," which Imhof (2007: 105) called the "ground plan of watersheds, drainage networks and lines of all types that divide up the terrain." As a first step to shading terrain by hand, Imhof advised mapmakers to lightly sketch in all skeletal lines of the terrain which then provided a framework for all the shading decisions that follow (Imhof 2007: 169).

In digital cartography, one strategy to reveal landscape structure can be found in the work of Leland Brown and Tom Patterson. Brown (2014) developed a method for texture shading DEMs using a fractional Laplacian operator, which is available as the "Terrain Texture Shading" application through Natural Graphics. Applied to DEMs, texture shading shows elevation values that are relative to the surrounding terrain; light areas are higher than the surrounding terrain, while dark areas are lower. This creates an image with some analogy to the skeletal lines and ground plan of a landscape, as the main ridges appear in bright values while the bottoms of main drainages appear in dark values (Figure 3). Patterson (2014) demonstrated methods to composite texture shading outputs with traditional hillshade models to develop visual hierarchy in shaded relief while also helping distinguish smaller landforms and textural details, like sedimentary rock layers.

Figure 3: Terrain Texture Shading with texture 120 and vertical exaggeration 2 at 1:15,000.

3.3 AERIAL PERSPECTIVE

Using high-resolution data with automated hillshading can also make it difficult to quickly discern relative elevations of landforms and to quickly recognize landforms at different scales.

In manual relief shading, cartographers traditionally mimicked the effect of atmospheric haze as a means to communicate differences in the relative elevation of shaded relief. The illusion veils the landscape in a gray-blue haze that progressively reduces the contrast between light and dark with distance. The key components to creating the *distance effect* of aerial perspective involve:

1. Depict highest elevations with brightest tones on illuminated slopes and darkest tones on shadowed sides.
2. Diminish the strength of this shading in lower elevations by reducing the contrast between dark and light tones.
3. Subdue the color of tints in lower elevations by mixing with blue.

Imhof (2007: 187) also pointed to aerial perspective as a means to emphasize extensive terrain forms on maps that also show finer topographic details. This *scale effect* involves blending highlights and shadows of major relief features into the shaded relief developed for the finer terrain details. For example, all local shadows on the light side of a major watershed become lightened, while shadows on the shaded side become strengthened and the local illuminated slopes become slightly subdued by a weak overall shadow.

3.4 SIMPLE, NATURAL PALETTE

"The naturalistic image is attractive and appealing when well executed, but too often it is depicted with too much confusion of color on the one hand, or too great uniformity on the other" Imhof (2007: 297).

Imhof viewed the natural colors of a landscape with the eye of a landscape artist. He explained that the "appearance of colors in a landscape arises from a continuously changing, complex interplay of local surface color, surface structure (smallest features influencing the overall impression), surface conditions, effects of light on color, light intensity and direction of light and shading effects, and also from reflections, contrast effects, aerial perspective, veiling by mist in the air, etc" (Imhof 2007: 297). He argued that maps had purposes to serve that were distinct from landscape paintings which constrained how color could be used. For large scale maps, Imhof (2007: 297) offered the following points of advice:

1. Avoid making the palette too complicated or lively.
2. Subdue hues so that relief and other line symbols remain legible.
3. Present instances of the same class with the same color scheme.
4. Use standardized colors to depict landcover classes.

Each point shows concern for the clarity of the map for the map reader and highlights the function of color as a visual variable in a semiotic system, where different hues stand for different classes of things. Imhof also stressed that the strength of naturalistic impressions is based not solely on the selection of colors, but rather on the "interplay between the various graphic elements corresponding to the impression one gets of the landscape" (Imhof 2007: 299). For him, the three main interacting elements were surface color, shadow details and aerial perspective.

3.5 BLUE SHADOWS

"In daylight, shadows of nearby objects are gray. Landscapes at some distance from the observer, however, possess gray to blue shadows according to the distance and the weather conditions" (Imhof 2007: 190).

This pattern brings tint into both aerial perspective and shaded tones. The bluing of a view with distance will be familiar to anyone who has looked across a mountain range in the late evening. In the Walensee map, Imhof applied the effect by increasing the strength of blue with decreasing vertical elevation. The dark tones of a shaded relief can also appear more naturalistic with blue tint. Imhof (2007: 190) suggested that gray-blue or blue-violet-gray colors were most effective, because pure blue is too bright and diminishes the quality of shaded relief.

3.6 TEXTURE SUBSTITUTION

Digital elevation models usually contain elevations of the ground surface, but some land cover classes, like forests and woodlands and water, are located just above the ground and may have textural qualities that are independent of it.

For naturalistic large-scale maps, Imhof noted that it was essential to include depictions of ground cover: "Omission of the ground cover here would normally detract from the whole sense and purpose of the maps, taking away one of their major natural attributes" (Imhof 2007: 298). In his map of the Walensee, he depicts land cover types with subtle variations of blue-green tints directly to the relief surface. For Tom Patterson (2002: 49) adding texture to a map was a core principle of cartographic realism and efforts to make depictions on maps appear more intuitive to map readers: "Graphical noise and embossed textures give selected area tones, such as cliffs and forests and even raster lines, a tactile appearance that more closely mimics nature." Patterson described a method that substituted textures for land cover types that were cloned from aerial photography, but he did not deem it appropriate for large-scale maps, "because at these scales the generalized textures would be blatantly incorrect replacement for actual detail" (Patterson 2002: 52).

4 WORKFLOW

This section briefly describes the workflow for representing terrain features in the case example map of Santa Cruz Island. Using ArcGIS, a one-meter resolution digital elevation model (DEM) was generated from the lidar point cloud using averages of ground classified values. In addition, a one-meter digital surface model (DSM) was generated using maximums of the first return values of the lidar point cloud. Values in the DEM represents the elevation of the ground surface, while values in the DSM represent the height of the tallest features on the earth's surface, which includes vegetation canopies and buildings. Using the NAIP imagery, normalized difference in vegetation indexes (NDVI) were calculated using ArcGIS software. NDVI values represent the amount of live vegetation at a location. After generating these datasets, the three main tasks in the workflow were (1) develop shading and texture in a grayscale image, (2) create aerial perspective effects in the grayscale image, (3) create landcover and water tints along with additional aerial perspective effects.

4.1 SHADING AND TEXTURE PATTERNS

The initial grayscale shading layer (Figure 4) was generated with three DEM derivatives, one derivative of the DSM, and one derivative of the NDVI product:

1. A hillshade layer from the DEM using the Sine wave lighting method with illumination angle varying between 295-315 and altitude 45.
2. A terrain texture shading layer with texture set to 120 and vertical exaggeration 2.
3. A sky view factor output with search diameter of 5 meters.
4. A hillshade layer from the DSM using the same sine wave lighting method and parameters.
5. A layer representing the presence of woodland habitat created by reclassifying the NDVI using ArcGIS.

The sine wave lighting method was used to produce a hillshade layer and address the illumination angle problem. I then tried to better reveal landscape structure by adopting Patterson’s method of combining the hillshade layer with a terrain texture shading layer. The lidar-based DEM was susceptible to producing salt-and-pepper noise in texture shading outputs. This may have been due to commission errors in the lidar point cloud. The heights of some small island shrubs and wild fennel in former pasture lands seem to be misclassified as ground locations and this fine-level heterogeneity in elevation values may affect outputs from texture shading. Štular et al. (2012) also found that Laplacian filters generate considerable salt-and-pepper noise when used with lidar data. To account for this, I reduced the vertical exaggeration while modestly increasing the texture emphasis in an effort to reveal structural characteristics of major and minor landforms while minimizing noise.

The third step again addressed the illumination angle problem but at a different scale and aimed to enhance the depiction of small topographic features, including rock textures, erosional features (arroyos, gullies, alluvial beds, slope failures, etc), and archaeological features (rock cairns cleared from agricultural features, road-cuts). I generated a sky view factor layer, decreasing the search diameter to five meters in order to better reveal very small terrain features. In the output, lighter tones represent more open locations. I then blended this layer with the terrain texture shading layer used the darken mode with limited opacity. This was done to avoid losing mid-tone in flat areas and to preserve highlights and shading on slopes.

The fourth step addressed the problem of creating texture for features above the ground. In order to create woodland textures that would carry the illumination effects of hillshading, I used the same sine wave lighting method to create a second hillshade from the DSM. I then reclassified the NDVI layer to isolate locations with living vegetation (2 or greater) and then used this reclassified layer as a mask on the DSM hillshade.

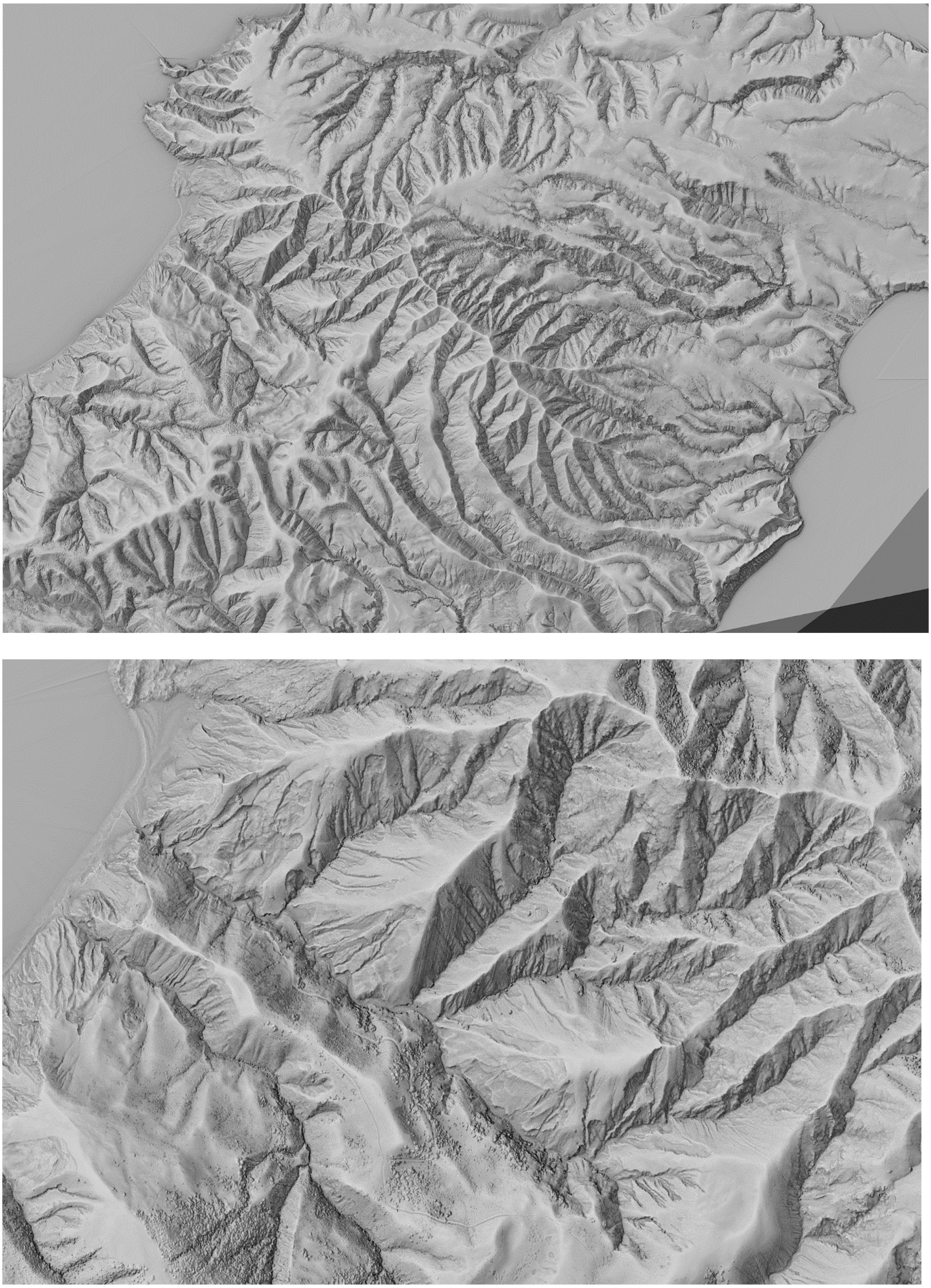

Figure 4: SWL shading of DEM with blended ground textures from TTS and SVF layers and woodland textures from SWL with DSM at 1:50,000 (top) and 1:15,000 (bottom).

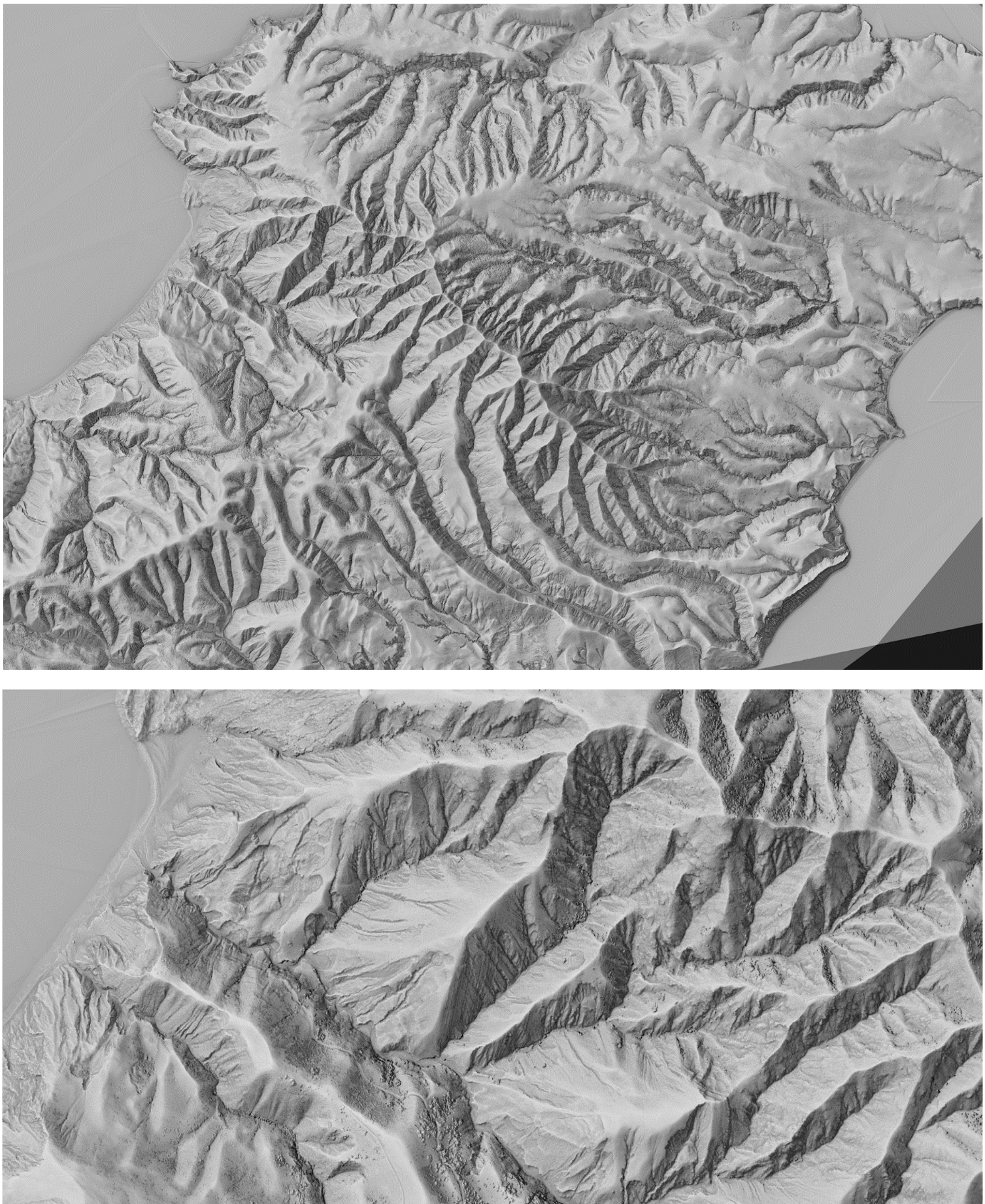

Figure 5: Shaded relief with distance and scale effects of aerial perspective at 1:50,000 (top) and 1:15,000 (bottom).

4.2 AERIAL PERSPECTIVE EFFECTS

The next major task developed both distance and scale effects of aerial perspective (Figure 5). While the difference in island elevation from highest point to sea-level is less than 750 meters (less than half the difference in elevation from the crest of the Churfirsten range to the surface of Lake Walen in Imhof's painting), the insular setting of the island makes low-lying coastal fog and haze a natural component of the landscape.

To create the distance effect, I adapted Photoshop methods developed by Patterson (2001). A key challenge here concerned issues of scale and data resolution. My goal was to help convey the form of major landforms based on elevation and orientation. To do this, I first used a median filter to generalize a copy of the Sine Wave Lighting hillshade. I then multiplied this layer on the shaded relief with an elevation mask in order to diminish the effect with decreasing elevation. To create the scale effect in Photoshop, I used curve adjustments on the generalized hillshade layer to classify the terrain into either illuminated or shaded slopes and then blended this binary illumination layer into the original shaded relief.

4.3 TINTING LANDCOVER, WATER AND AERIAL PERSPECTIVE

The last stage of the workflow concerned colorizing the map. For inspiration regarding the map's palette, I looked to both landscape paintings by the California artist Ray Strong (Figure 6) and personal experience gained from many years of field work on the island.

Figure 6: California Landscape by Ray Strong (1905-2006). Image courtesy of James Main Fine Art, Santa Barbara, California.

Figure 7: Woodland and bare ground tints with masks from NDVI. Blue shadows increase at lower elevations. Ocean texture from NAIP image. 1:50,000 (top) and 1:15,000 (bottom).

The goal was to keep the palette simple by constraining the number of nominal classes based on the map's thematic purpose. For vegetation, I focused on three classes: *woodlands* identify locations that have either been resilient to the impacts of sheep or have since recovered, *grasslands* may have been formerly stripped of vegetation but are now recovering, while *bare ground* may have been stripped and have not recovered. As described above, I derived woodland and bare ground layers by reclassifying the NDVI layer and then used these masks on adjustment layers that added hue and saturation values to the grayscale image. I also tinted grasslands with an adjustment layer below the woodlands and bare ground layers.

Geologically, sedimentary rocks are more susceptible to gullying and small slope failures than volcanic rocks. Rock types also impart different colors to the landscape that are clearly visible when hiking around the island, though not mutually distinguishable. To keep the palette simple, I chose to distinguish between three different classes of rock: reddish-brown for volcanic, pale brown for sedimentary, reddish-orange for metamorphic. Using a scanned image of an island geology map (Weaver et al. 1965), I registered the image to the DEM layer, digitized the rock types, and then used these as masks on separate adjustment layers in Photoshop, each adding hue and saturation values to the appropriate bare ground region of the shaded relief.

The next task concerned depicting the region beyond the island's shoreline. Airborne lidar does not penetrate deeply into water and high-resolution bathymetry data for the island is not currently available. For ocean locations, I chose to substitute color and texture from the NAIP image of the island. This quickly adds many additional features to the map, including kelp, waves, swell, and silt plumes. It also presents an additional challenge of making the photo-realism of the image appear more consistent with the naturalistic but simplified depictions of land features. Using Photoshop, I created a mask of the island's shoreline by adjusting the curves of the DSM and applied this to the NAIP image. To remove the photographic quality of high-resolution image, I applied a dry brush filter to the image layer.

The final task developed blue tint in shaded locations as part of the naturalistic palette. To do this, I use a hue adjustment layer with an elevation mask with diminished opacity to blend increasing amounts of blue with decreasing distance. This influenced the strength of both the land cover and ocean colors. I also added blue tint to the shading in the scale effect of aerial perspective.

5 INTERPLAY OF PATTERNS

Imhof considered surface color, shadow details and aerial perspective to be the three major graphical elements that interact to create the impression of a natural landscape (Imhof 2007: 299). A difficult component of learning how to make naturalistic relief presentations involves being able to recognize these interactions and how they influence a workflow. As graphical elements, shading influences color by contributing luminosity values that interact with hue and saturation values of the tint. Aerial perspective influences both shading and color elements, muting shading contrast and color vibrancy with distance and altering gradations of luminosity with geographic scale. Being able to recognize these interactions will be expressed both in the sequence that tasks are performed in a workflow and the organization of the layer stack in a software package such as Photoshop.

The main challenge is to learning to recognize how more than one design pattern may influence any single step of a workflow or any single layer in a stack. The Santa Cruz Island case illustrates some of these interactions. My decision to substitute woodland texture derived from a DSM recognized that the woodland texture needed to not just represent the canopy texture, but also convey the illusion of illumination and shadow as part of the overall shaded relief. Patterson's (2002) method of "illuminated relief" recognizes the same interaction between principles for texturizing and illuminating relief. The principle of aerial perspective is particularly challenging because of these interactions. In my workflow, I began to develop the distance and scale effects of aerial perspective while developing the grayscale shaded layer because I wanted these shading effects to carry through the landcover tints. But I also revisited the principle towards the end of the workflow, because I wanted the blue tints of atmospheric haze and shadows to carry through both the landcover and ocean tints.

6 CONCLUSION

Creating large format depictions of relief with high resolution data is particularly challenging because map readers will likely think and interact with the static map at multiple scales. Traditional efforts of high mountain cartography can avoid this problem by focusing on representations at one scale or by using symbols to represent features at one scale and shading to represent features at another. Interactive maps similarly avoid this problem by building a series of separate maps at different scales. Alternatively, visualizations of high-resolution data often avoid this problem by constraining the geographic extent of the presentation. But it is perhaps because of scale and the many problems it poses to large-format, high-resolution maps, that many principles of traditional mountain cartography remain essential to their design.

As an academic who practices cartography in order to better understand how to teach it, this case illustrates one method for linking principles to practice. Many students struggle to connect the linear progression of steps in a workflow to general principles, particularly when the influence of these principles can loop and layer through a workflow. While in many places the descriptions of patterns provided here could be improved and in some places re-organized, the design pattern framework helps offer reasons for each step and their sequence in a workflow. It illustrates one approach that brings together timeless principles of map making with the more temporal and technical expertise of making maps with software and data products. By doing so, it draws attention to the problem setting and solving process of map making that is essential to teaching and learning cartography.

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HISTORICAL ASPECTS

UNFOLDING THE MAP

Roger Smith
Geographx, Wellington, New Zealand

Keywords: cartographic exhibition, New Zealand, historical maps

In 2015 I was offered the opportunity to curate a national exhibition on New Zealand cartography. This was a totally new experience for me, I knew it would be challenging but I never anticipated just how much I would enjoy it, nor how much I would learn during the course of the project.

"**Unfolding the Map** – the cartography of New Zealand" opened at the National Library in Wellington in October 2015, and is scheduled to run for a period of 2 years. It is an International Map Year event endorsed by the ICA (Figure 1).

The earliest cartography in the southern Pacific was not printed but oral. The exhibition acknowledges the feats of early Polynesian navigators who criss-crossed the world's largest ocean in double-hulled canoes more than 200 years before Columbus ventured across the Atlantic.

My favourite part of the exhibition though is a chronology of selected print maps. These date from the time of first European contacts in 1642 through to the present day. With tens of thousands of maps to choose from yet limited exhibition space, a lot of time went into selecting representative works that illustrate advances in cartographic technique and style, but which reflect also the progressive social, political, economic, and environmental development of New Zealand as an emerging nation.

Figure 1: Welcome wall introducing the visitor to the exhibition. The five coloured panels to the right expand on the five key genres covering most of the printed maps on display.

The maps chosen for display mostly fall into one of five genres or themes:

1. Coastal Charting
2. Surveying and the Cadastre
3. Resources and Environment
4. Topographic Mapping
5. Tourism and Recreation.

I suspect most "new world" countries that underwent colonisation by European powers could categorise their cartographic resources in similar fashion (Figure 2).

In addition the exhibition looks at the impacts of technological developments on map-making, the transition over the past 30 or more years from print to digital mapping, and the current state of cartography in New Zealand. There is also a more whimsical section devoted to New Zealand place names, and a section on the role of the NZ Geographic Board in developing protocols for dual language place names.

Lastly but not least, an educational outreach programme for schools has been developed to run in parallel with the exhibition, and there is an ongoing related public lecture series running at the library with a focus on cartographic and map-related topics.

Figure 2: Entrance to the ground floor exhibition space at the National Library. The walk-on map of New Zealand in the entrance foyer is at a scale of 1: 215,000 and is printed on felt.

The NZ Cartographic Society has taken the opportunity to capitalise on the exhibition by adopting the “Unfolding the Map” title for the 8th National Cartographic Conference (Geocart'2016) to be held at the National Library in September 2016. This event will also double as the 4th ICA Regional Symposium on Cartography for Australasia and Oceania.

ORIENTEERING MAPS

COMPARISON OF THE CURRENT AND NEW INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

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ABSTRACT

This paper gives an overview of changes that occurred between the old and new version of International Specifications for Orienteering Maps (ISOM). In addition, we provide several examples on how the new ISOM would affect existing orienteering maps and what would that changes bring to most of orienteering map owners and users.

On several maps we transformed symbols from ISOM 2000 according to new ISOM 201x, and used that maps for test comparison purposes. The analysis conducted on complex terrain models, showed that ISOM 201x would cause reduction of legibility on detailed maps. On such maps, due to enlargement of minimum symbol size, mapmakers should use new, more generalized approach of mapping. Some symbols (such as cliffs) will become larger, and therefore the overlapping of symbols might occur. On the other hand, some symbols will become thinner (form lines) and that might lead to bad visibility in case of low quality printing, when organizers of orienteering events can't use offset printing. The analysis of new ISOM draft, that was conducted on simple terrain models and in urban areas, showed better legibility compared to ISOM 2000 due to thicker line symbols (such as roads, streams and fences).

Because of miscellaneous uncertainty with ISOM draft regarding the influence on legibility, further discussion with all orienteering federations should be made and the detailed research focusing on ISOM development should be considered.

Keywords: International Specifications for Orienteering Maps (ISOM), orienteering maps, map symbols

1 INTRODUCTION

Orienteering began in late nineteenth century in Scandinavia as a military exercise (Boga 1997). Orienteering running is a sport where athletes, with aid of orienteering map need to visit different control points as fast as possible using only compass and their own navigation skills. Orienteering maps are maps, specially designed for orienteering sports disciplines (Petrovič 2014). Orienteering maps are drawn according to International Specifications for Orienteering Maps (ISOM) declared by International Orienteering Federation (IOF). Since 2008 IOF is working on ISOM 2000 revision and in 2015 new ISOM draft was published.

The International Orienteering Federation (IOF) is the international governing body of the sport of orienteering. The IOF was founded in 1961 and recognized by the International Olympic Committee (IOC) in 1977. At the moment, the IOF has 79 member countries. (URL 1).

Four main orienteering sport disciplines are foot-orienteering, ski orienteering, mountain-bike-orienteering and trail-orienteering. Besides them, there are also some other variations and types, which often serve for trainings, for fun or as a part of other complex events, like adventure races (Petrovič 2007). It should be also mentioned that most of the foot-orienteering disciplines (middle distance, long distance and relay) are organized in forested area – often in the mountains, while sprint discipline is mainly placed in urban area.

It is very important that the organizers or trainers select the terrain that is suitable for specific purpose, according to orienteering discipline, skill and expectation of competitors, their age, and available time to spend for orienteering (Petrovič 2009). However, no matter where on the Earth map is, each competitor should be able to know what to expect on the terrain just by reading the map – that should be ensured with International Specifications for Orienteering Maps (ISOM). The legibility issue of orienteering maps was part of the standardisation process of the sport (Zentai 2011). Specifications for map symbols and their printed colors are strictly defined for the competitive map by the IOF (Brown 1985).

Since its beginning, ISOM should enable use of the same map legend in all countries. Also, the orienteering maps must show the actual situation, including all visible features that are easily identifiable and useful for the competitors. The legibility of orienteering maps is also important: all unnecessary features should be left out.

During the history, ISOM was changed and adapted to requirements of competitors, mapmakers, new technologies, available new source data, and development of sport.

2 INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS 1969-1990

First International Specifications for Orienteering Maps (ISOM) was published in 1969 on German, English, French and Swedish language and was consisted of general instructions for mapping – among other that maps of the international events have to use the same legend in all countries (Zentai 2007). Since then, ISOM had several editions in following years; 1975, 1982, 1990 and 2000 (URL 2) adding more symbols for orienteering maps.

ISOM 1969 was a 2-page sheet with specified dimensions of orienteering symbols which should be presented in map legend. Black, brown, blue and yellow color was used for 52 symbols that might occur on map. In upcoming years, this version of ISOM was translated into several European languages and used as a mapping standard for orienteering maps.

ISOM 1975 provided more detailed and specific rules regards orienteering map symbols. To already existing 4 colors, green and violet were added into specifications. Edition consisted of 28 pages was approved by the VII IOF Congress at Sweden and contained Introduction, General requirements for O-maps, Map symbols, Explanations of symbols and Course symbols. Number of symbols almost doubled compared to 1969 edition and were now 100 symbols in total. Symbols were also divided into 3 classes; "A" – symbols obligatory for maps for international events and world championships, "B" – symbols which can be used for certain special types of terrain and "C" – symbols acceptable only for non-international events.

Third edition, ISOM 1982 consisted of 24 pages and was based on developed ISOM 1975 with goal of improvement and eliminating weaknesses. The main adjustment were made in representation of vegetation (runnability) for which green stripes occurred. This edition consisted of 98 symbols. Also combination of green and yellow were allowed.

ISOM 1990 added 7 new symbols making it in total 105. It was appropriate to discontinue the distinction between "A" and "B" symbols and to abandon the "C" symbols dating from the early, experimental phase. The established "B" symbols were incorporated into the list of definitive symbols. At that time the IOF had 32 member countries. (URL 3).

Desktop mapping enabled production of orienteering maps with digital methods. The relatively small number of symbols in orienteering maps made it relatively easy to make formerly hand drawn orienteering maps by computer (Zentai 2014). Nowadays, orienteering maps are drawn by CAD software.

3 INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS 2000

ISOM 2000 didn´t bring big differences in map standardization, however, it got adjusted to computer mapping and use of CAD software. ISOM 2000 is current standard used for foot orienteering maps. The scale for an orienteering map is 1:15,000. Maps at 1:10,000 must be drawn with lines, line screens and symbol dimensions 50% greater than those used for 1:15,000 maps (URL 4).

It is important to mention that ISOM 2000 is fundament for specifications for maps used in other disciplines of orienteering sport; park orienteering (sprint), ski, mountain bike and trail orienteering resulting with International Specifications for Mountain Bike Orienteering Maps (ISMTBOM), International Specification for Sprint Orienteering Maps (ISSOM) and International Specification for Ski Orienteering Maps (ISSkiOM). In the autumn of 2008, all national federations were invited to provide the first input to the ISOM revision (URL 5).

After 15 years of ISOM 2000 use, final draft of new ISOM is published by IOF.

4 ISOM 201X FINAL DRAFT

In 2015 the IOF Mapping Commission sent the ISOM 201x Final Draft (URL 6) to the national federations and new symbol set is already available online (URL 7) enabling conversion between „old" and new ISOM.

When compared to existing ISOM 2000, it is obvious that almost 30 symbols will change size, color or shape also adding some new symbols not used in previous editions of ISOM. Maybe most significant change is made with form line thickness which is reduced to 0.1 mm (0.14 mm in ISOM 2000). Although this change will improve legibility of maps on PC screen and enable mapmakers to draw fine relief details more precisely, this might cause problems in case if map is not printed with use of offset printing resulting with hard-to-see symbol, as well with offset printing 0.1 mm in extreme outdoor condition is badly visible, especially for older competitors.

Furthermore, minimum length of cliff symbol changed from 0.6 mm into 0.7 mm (outside measure) resulting with 0.1 mm longer symbol. This might be a problem in detailed terrains where cliffs occur. Mapmakers will need to redraw most of areas where cliff symbols will overlap and will have to either draw more generalized maps, or to move overlapped symbols so they become legible. Watercourses in new ISOM 201x draft are thicker than it was the case with ISOM 2000. Crossable watercourse is now 0.3 mm (0.25 mm in ISOM 2000) wide, while small crossable watercourse is 0.18 mm (0.14 mm in ISOM 2000) thick. Selected symbols with significant changes compared to ISOM 2000 are presented on Figure 1 and Figure 2.

When analyzing changes presented on Figure 2, four vegetation symbols will change drastically; open and rough open land with scattered treed and undergrowth symbol. This change might improve legibility and provide extra information about runnability in such areas.

As for vegetation boundary, green line is introduced with intention to be used in stony area but it can not be used as boundary around and within full green area symbol (410).

When it comes to man-made features, major road symbol (502) is renamed into wide road and will be 0.2 mm thinner when compared to ISOM 2000. Also symbol 503 – minor road from ISOM 2000 should also be presented with symbol 502 in ISOM 201X. This will improve legibility in urban area. However, high stone wall almost doubled the size and it is now 0.3 mm thick (0.18 mm in ISOM 2000). Analysis made with this symbol proved that this symbol should be revised and considered to be thinner. New symbol for distinct vegetation boundary is added and will be possible to present not only with black line (solid or dotted), but also with green line 0.12 mm thick.

ISOM 201x will also add some new symbols not used in previous editions of ISOM, such as trench, prominent water feature – square, prominent vegetation feature – triangle, prominent man-made feature – asterix) presented on Figure 3.

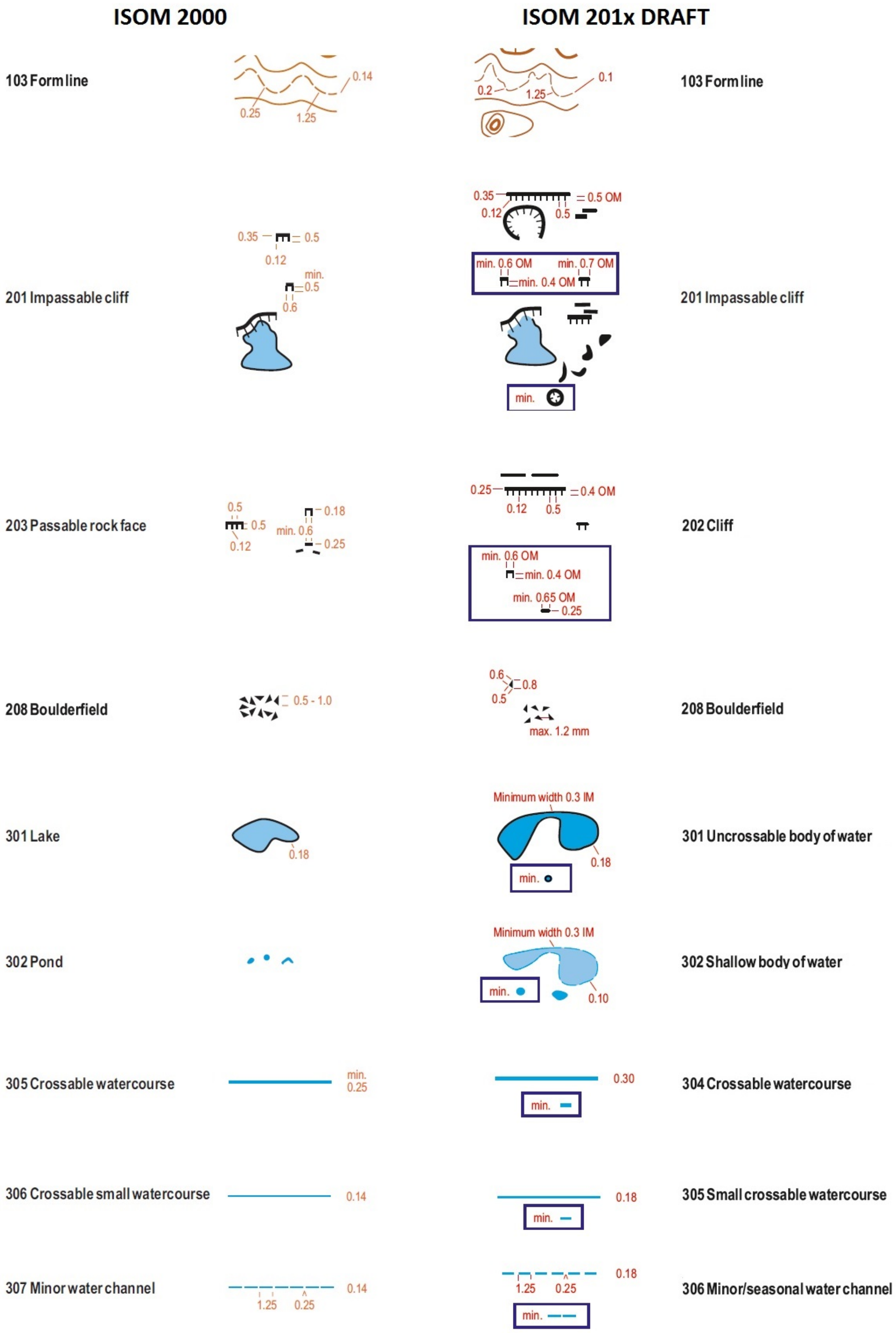

Figure 1: Selected landform, rock and water symbols in new ISOM 201X draft (right) compared to ISOM 2000 (left) with significant changes.

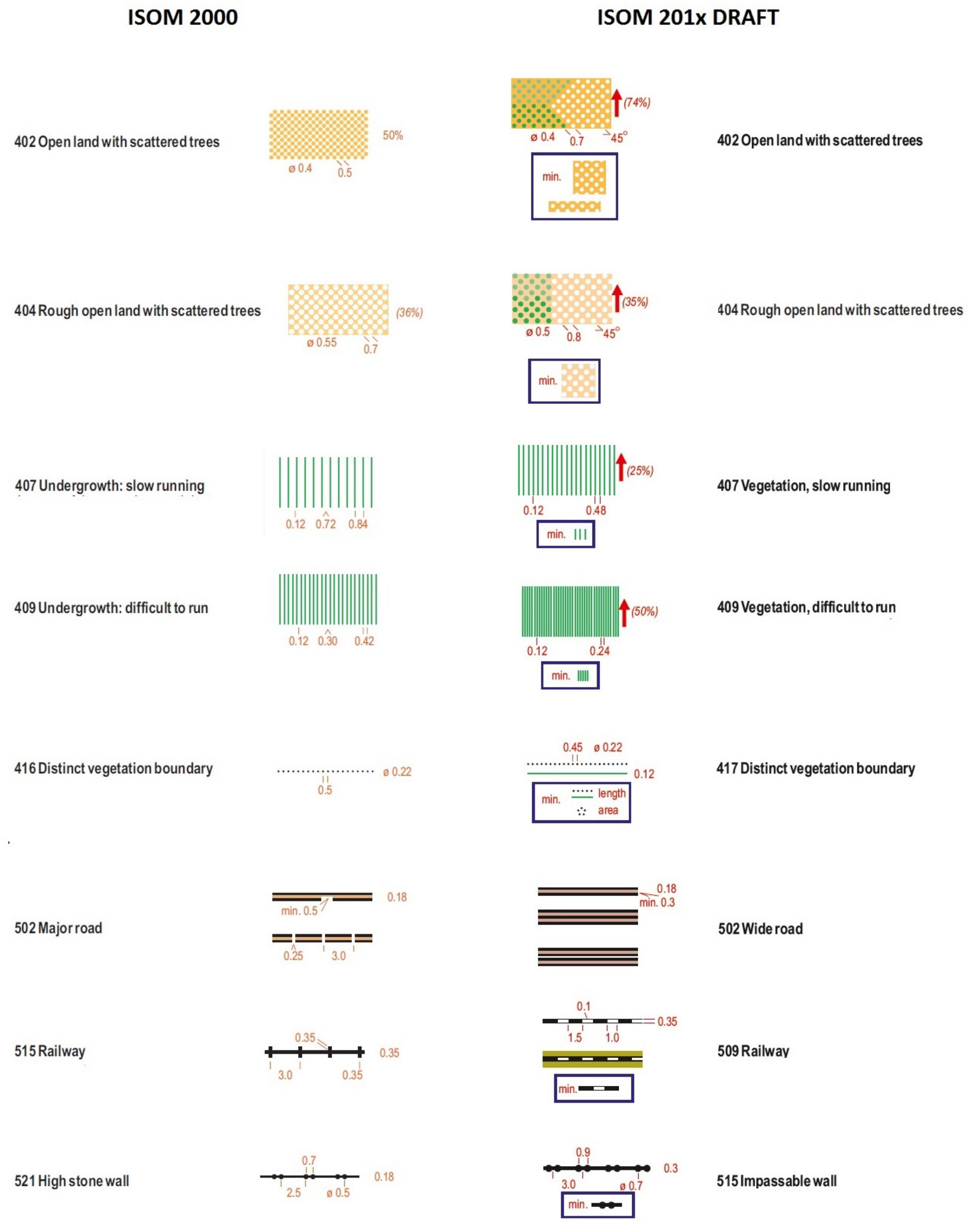

Figure 2: Selected symbols of vegetation and man-made features in new ISOM 201X draft (right) compared to ISOM 2000 (left) with significant changes.

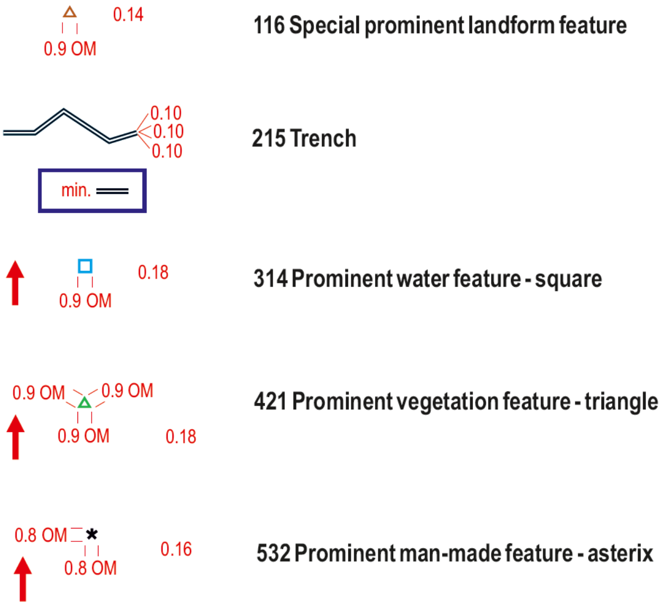

Figure 3: New point and line symbols in ISOM 201x draft not existing in ISOM 2000.

For most of existing maps it is expected that new ISOM will make maps more legible. For example, rivers and streams will be thicker making them easier to notice on the map. Some opposite effect will be made on detailed areas – especially with plenty of cliff symbols used on the map with minimum size.

5 ISOM 201X APPLIED ON EXISTING MAPS

When applied and analyzed on existing maps, new ISOM 201x might have bad result causing maps to be overcrowded with thick details covering each other. Such example might be seen on Figure 4 where typical Iberian Mediterranean terrain will require map revision or even complete map redrawing.

Figure 4: ISOM 2000 (left) and new ISOM 201x draft (right) comparison on Mediterranean terrain, cartographer: Cèsar Roca (URL 8).

When applied in urban area (Figure 5) it is obvious that new ISOM is making maps more legible with thicker fence symbol – impossible to pass, and thicker road symbol. We can also notice that water bodies are darker (also classified as uncrossable body of water, not lake like in ISOM 2000) while light blue (ex. pond) now represents shallow body of water. Undergrowth (vertical green stripes) is now more obvious due to smaller gap between the lines; reduced from 0,84 mm to 0,48 mm for vegetation providing slow running but good visibility (such as branches on the ground, low bushes etc.).

Figure 5: ISOM 2000 (left) and new ISOM (right) in urban area – map of Byråsen, Sweden, drawn by Matjaž Štanfel.

Next comparison was made in karst area. It is most common that in karst a lot of stone details occur (boulders, cliffs, caves etc.) usually making that kind of terrain one of most detailed one for orienteering. When new ISOM is applied on karst maps (Figure 6), due to enlargement of minimum cliff symbol size it often causes overlapping, making map harder to understand, especially while running.

Figure 6: stony area drawn by ISOM 2000 (left), map directly converted into new ISOM 201x (center), and manual correction and adaptation of the map by ISOM 201x draft (right) – map of Kalce, Slovenia, drawn by Matjaž Štanfel.

Correction of overlapping will require a lot of interaction of mapmakers with purpose of making distances between details bigger and in some area, new generalization will be necessary so maps could stay legible and usable for orienteering. Also, new ISOM draft have three stony ground symbols (Figure 7) instead of only "black dot" point symbol used in ISOM 2000.

So this areas will need to be completely redrawn and will require field control to define the proper symbol that could be used. It is noticeable that form lines are thinner in new ISOM proposal (from 0.14 they are now reduced to 0.1 mm) and further printing test should be made for evaluation.

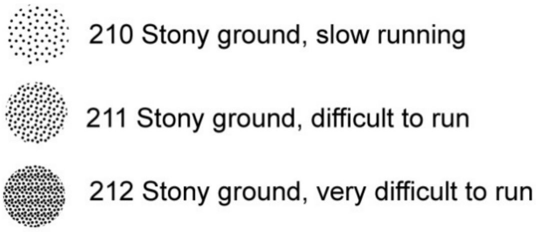

Figure 7: Three different symbols used for stony ground according to ISOM 201x draft.

Meanwhile, most of orienteering maps in Europe don´t have such big number of stone details and in that kind of terrain new ISOM might give better solution making streams and rivers thicker and more legible. Symbol used for rough open land with scattered trees (35% yellow with regular pattern of white dots) is now more obvious due to enlargement of gap between white dots, while color of dots now also vary from white to dark green depending on runability. Example of simple terrain is shown on Figure 8.

Figure 8: ISOM 2000 (left) and new ISOM (right) in flat area – map of Byråsen, Sweden, drawn by Matjaž Štanfel.

Analysis of new vegetation boundary symbol (green line) proved that it is very good solution where terrain is stony and a lot of black details occur in close vicinity making it to be a good step towards improvement of legibility of orienteering maps.

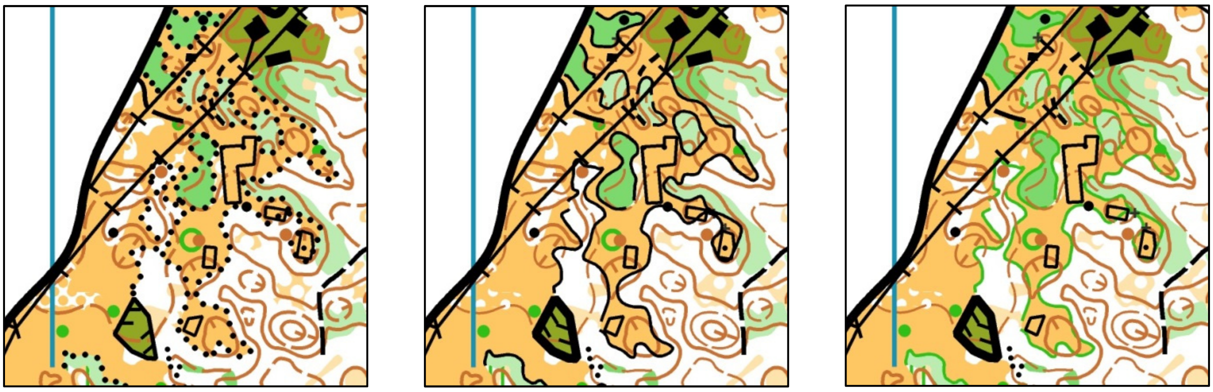

Figure 9: Three possible symbols for distinct vegetation boundary in ISOM 201x draft – map of Kalce, Slovenia, drawn by Matjaž Štanfel.

6 CONCLUSION

New ISOM 201x draft will improve legibility of orienteering maps where terrain is not extremely detailed with stony objects. However, on detailed terrains it will probably cause deprecation due to significant enlargement of some stone symbols causing maps to be overcrowded with details. This will for sure lead to hard-labouring corrections of map (adjustment of symbols and field revision) and consequently causing big expenses for map owners (mainly orienteering clubs), especially in countries with mapped karst terrains (Croatia, France, Slovenia, Switzerland, Italy, Austria etc.). Some federations have already sent their comments on proposed draft. One of them is Swedish, mentioning a clear need for guidelines and practical examples, especially for contouring in complex areas (URL 9). Also, form lines might be too thin for laser printers and testing with both offset and laser printing should be done before final conclusion. On the other hand, the improvements in legibility in less detailed terrains and addition of new symbols for vegetation such as open land with scattered tree which will contain detailed information regards runability will provide athletes important information for route planning. Further discussion about new ISOM should be made with goal of eliminating weaknesses of new symbols. Instead of adding and altering the size of symbols it is logical that better visibility and legibility couldn´t be reached without further generalization process implying that mapper´s experience is essential for high-quality orienteering map.

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EMOTIONAL MAPS

EMOTIONAL MOUNTAINS - VISUALISATION OF GEOREFERENCED EMOTIONS IN THE BERCHTESGADEN ALPS

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Keywords: emotional cartography, User-Generated Content

In recent years emotion-related applications like smartphone apps that document and analyse the emotions of the user, have become very popular. The classical map, on the other hand, mainly provides objective information and collections of facts but subjective components such as emotions or opinions can provide additional information. Space and emotions are fundamentally connected. Locations have an atmosphere which can evoke strong and diverse emotions. Thus, places can be sensed as boring, attractive, calming, scary or dangerous.

Research on capturing and analysing georeferenced emotions from user-generated content was carried out and an algorithm for extracting location-based emotions from the written language in the metadata of georeferenced Flickr photos (i.e. from their titles, descriptions and tags) has been developed. Within this extraction approach various grammatical issues were considered, like negations of words or amplifications (Hauthal and Burghardt 2016). The extracted emotions combined with the coordinates of a photo result in a georeferenced emotion. The obtained emotions are documented in emotional maps as well as in valence-arousal-space originating from psychology. The two dimensions valence and arousal proposed by Russell (1980) can be described as ranging from negative to positive and from unarousing to arousing (Figure 1).

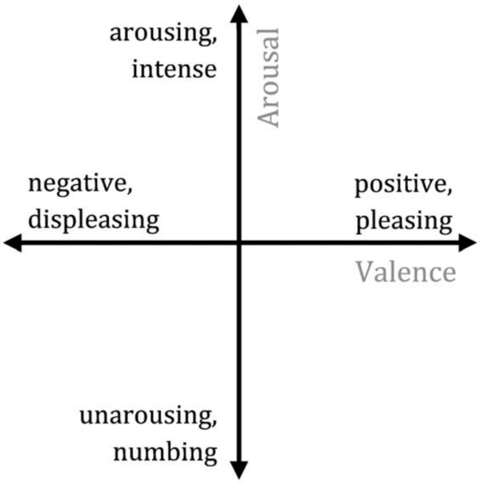

Figure 1: Two-dimensional structure of emotions by Russell (1980).

These two dimensions allow to locate emotions intuitively within valence-arousal-space. For instance joy is a very positive emotion with high arousal whereas anger also has a high arousal but a negative valence.

The algorithm was originally applied to the city of Dresden, Germany and is now for the first time adopted to a non-urban, mountainous environment – the Berchtesgaden Alps (Figure 2).

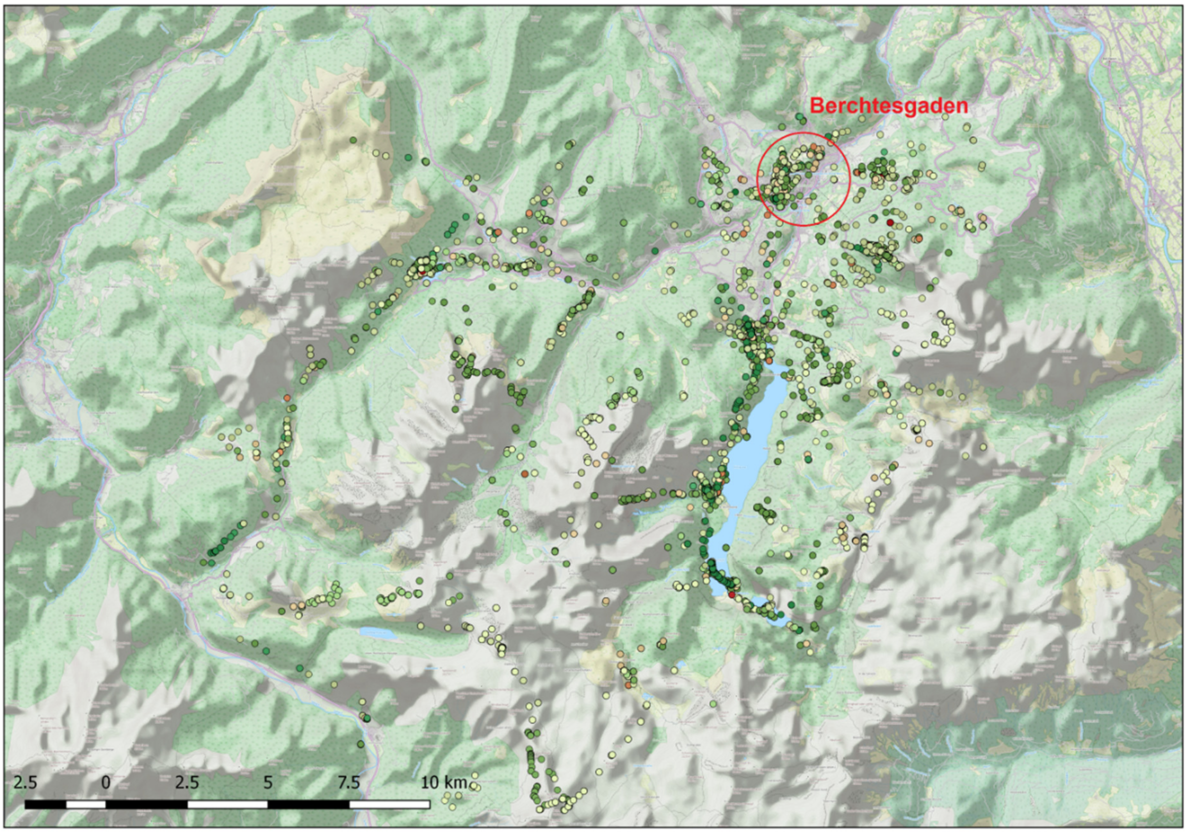

Figure 2: Point map of the investigation area showing all emotions (the greener, the more positive / the redder, the more negative / the darker, the more arousing / the brighter, the less arousing), (Base map: Open Street Map – Open Database Commons Open Database License (ODbL) 1.0)

Major differences between these two study areas include that expectedly more nature-related terms were assigned by the users for describing the photos of Berchtesgaden and its surroundings. In addition, more positively exciting emotions were detected in the alpine environment due to the impressive mountain scenery. Extracted negative emotions in this area mostly hint at the Nazi past of the Kehlsteinhaus mountain lodge and other structures that can be related to that time.

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ABSTRACTS

GENERALIZING RELIEF SHADING IN VECTOR SPACE

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As digital terrain data becomes available at finer spatial resolution, the need to create generalized shaded relief maps suitable for display at smaller scales becomes more prevalent. To date, efforts to generalize shaded relief maps have focused on two methods. The first approach involves filtering or modifying the original terrain data to make a more generalized elevation model. The second approach involves filtering or generalizing the values of gray on the shaded relief map itself. An alternative approach presented here is to use surface normal vectors that are first resolved into x, y, and z components and then summed using vector addition within the kernel of a low-pass filter. In this manner, the orientations of the vectors and associated surfaces are adjusted independently of the elevation value. Results appear less blurred than generalized terrain models that are shaded or generalized shaded relief maps when a kernel of the same dimension is used to calculate mean values.

Keywords: cartographic generalization, multi-scale mapping, relief shading, vector analysis

3D MAPPING OF MOUNT RUSHMORE NATIONAL MONUMENT: VIRTUAL VIEWS, AIR PHOTOS AND LIDAR DATA

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Oblique 3D map views provide an effective means to portray a natural or historic landscape to a general audience. International Mapping has worked with the United States National Park Service to create a virtual bird's eye view of Mount Rushmore National Monument that alters reality to present a clearer picture of a park's features and points of interest. This presentation will look at the 3D modeling and rendering process and how trimming and removing trees, moving buildings, sculpting terrain, and other manipulations can help a reader see the park more clearly than in an air photo. It will also examine the process of integrating LIDAR data with traditional DEM data in a virtual view.

Keywords: 3D map, 3D model, DEM, LIDAR

AUTOMATIC SWISS STYLE ROCK DEPICTION

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Whereas automation thrives in many cartographic disciplines, topographical rock depiction has stubbornly resisted this trend. This is no surprise, however, since it is a niche product, and it requires proficiency in a range of diverse skills like generalization, relief shading and illustrative composition to make the rendering readable as well as aesthetically pleasing.

In this contribution, a fully automatic method to derive Swiss style rock depictions from raster elevation data is presented. In Swiss style, rocky terrain is charted using monochrome hachures. They are modulated in thickness and interspacing according to the same illumination model as applied in relief shading. The twofold role of the illumination model provides the rationale for the workflow of the method.

First, the elevation data is smoothed and skeletal lines are emphasized, in order to generalize the terrain according to the map scale. Instead of deriving hachures from the generalized terrain right away, a shaded relief image is created in an intermediate step. The shaded relief has a much simpler structure than the hachures, i.e. regular pixels as opposed to vector lines, and it represents the amount of illumination to be used for the modulation of every hachure. The hachures come in three varieties, fill hachures for rock faces, ridge and form hachures for depicting terrain edges and major morphology. The fill hachures are traced orthogonally to the surface gradient along jittered paths to create the impression of manually drawn lines, taking the width of each path segment from the underlying shaded relief. The ridge and form hachures are created by offsetting edges in the shaded relief along gradient lines.

Regarding the implementation of the method, Line Integral Convolution (LIC), originally a vector field rendering technique, is used in both generalizing the raster and creating the shaded relief, where a variant here dubbed as "Rotational LIC" is used for the latter. Poisson Editing provides the means to smoothly combine multiple light directions, as it is the case in manually shaded reliefs. Finally, the rendering of hachures with equidistant gaps is accomplished by a streamline visualization technique.

Keywords: automation, generalization, relief shading, rock depiction

ESTIMATING THE EFFECT OF DIFFERENT INFLUENCING FACTORS ON THE SPATIAL DISTRIBUTION OF ROCK GLACIERS IN THE SWISS ALPS

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Rock glaciers are characteristic features of mountain permafrost. Their occurrence indicates the presence of permanently frozen ground but is highly heterogeneous in size, frequency, shape and environment. There is little knowledge on factors controlling this heterogeneity; however modelling and mapping of the permafrost distribution as well as predictions on climate related changes rely on this information. Our study uses a GIS based approach to estimate the effect of different influencing factors on rock glacier characteristics. Potential influencing factors to be tested were precipitation, mean annual air temperature, erosion, glaciers, lithology, slope, aspect, altitude and snow cover. The factors were analysed using a rock glacier cadastre of two partially contrasting regions in the Swiss Alps: the Albula Alps and the Glarner Alps. The spatial characteristics within the mountain regions were identified by adding topographical, geological and meteorological data to the GIS. Taking into account the interaction of these different influences, the effect of each factor on rock glacier occurrence and characteristic was determined. The particular significance of the influencing factors precipitation, lithology and erosion on rock glacier distribution became evident; the interaction of the factors precipitation and lithology seems to play a key role. Snow distribution was shown to cause a different rock glacier frequency in different aspects. Rock glaciers interact with all of the factors analysed and are shown to have complex relations with their regional environments.

Keywords: rock glaciers, Swiss Alps, GIS

TREKKING, LIMINALITY AND CARTOGRAPHY

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Every serious journey, pilgrimage or trek into nature depends for their success on the participant fully engaging with his surroundings. Technology in the shape of GPS and Google Earth, and modern social attitudes toward outdoor experience, are making engagement with the outdoors on an intimate level more difficult for the current and new generations.

Engagement with landscape is vital for all of us - when we are engaged, we cannot be indifferent. Cartography is a tool to foster this engagement, and there may well be new ways in the use of this tool to encourage this.

Liminality - a 'threshold of change'is the desired state of a successful hike, trek or pilgrimage.

The opportunity to attain this is reduced by the use of GPS, but can be enhanced with suitable cartography.

When we find our way in the world, we rely on one of two strategies. One is spatial strategy, in which we build cognitive maps using relationships between landmarks. The other one is a stimulus response strategy - which is kind of an autopilot mode. When you use a GPS you don't necessarily use your spatial strategy.

Use of GPS has not only meant a loss of map-reading skills, but spatial skills.

We examine the changes happening since the advent of GPS technology, and suggest ways of using paper maps to counter these changes. One of the outcomes in studies of this appears that the use of the GPS disrupts something in the human brain that we are supposed to do well.

Keywords: GPS, spatial skills, wayfinding, printed maps, liminality

REPRESENTING THE COMPLEXITIES OF WILDLIFE MIGRATION IN WESTERN WYOMING

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New wildlife GPS-collar technology is providing wildlife ecologists the opportunity to collect an immense amount of location and time-stamped data, giving new insight into animal migration and ecology that was not possible before. Mapping and visualizing complex wildlife migration data in meaningful ways presents many design challenges. This paper focuses on the spatiotemporal data and cartographic design challenges encountered in the creation of thematic maps and data graphics for the in-production *Atlas of Wildlife Migration: Wyoming's Ungulates* and associated scientific and conservation reports. This paper will discuss the process of developing map products from initial primary field data collection, to data processing and analysis, to the collaborative design stage and the outreach efforts of the project. The recent discovery of the longest land mammal migration in the contiguous United States, the 150-mile "Red Desert to Hoback" mule deer seasonal migration is featured. Other topics covered include visualization of ungulate ecology topics of migration timing of moose, phenology and nutrition, and migration and snowpack. This project is a collaborative effort among University of Oregon cartographers and wildlife researchers at the University of Wyoming and the Wyoming Migration Initiative.

Keywords: wildlife migration, cartographic design, atlas, Wyoming, ungulate ecology

GLACIER SURFACE AND SUBMERGED GLACIER FOREFIELD MAPPING AT ECOLOGY GLACIER (KING GEORGE ISLAND, ANTARCTICA) USING PLÉIADES SATELLITE IMAGERY AND BATHYMETRIC DATA

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Glaciers on the South Shetland Islands of Antarctica Peninsula have been exhibiting a striking retreat since the 1970s. On King George Island, several studies have been undertaken to map the retreat and volume change of the Warzawa Ice Field, the largest ice field in the island range. However, due to almost permanent cloud cover, the large outlet glacier, Ecology Glacier, has been largely excluded from analysis. The Ecology Glacier is located in the southern quadrant of the island, and has retreated approximately 600 m since 1979. Determining the scale of volume change is important here, because the glacier is converting from being marine-terminating to land-based, and there is currently an invasion of plantlife beginning to take over the glacier forefield. The aim of this study is to develop a new digital elevation model of the glacier, and to tie this together with recently acquired bathymetry data to provide a detailed mapping framework for understanding glacier dynamics. We processed sub-metre tri-stereo imagery from the Pleiades satellite system to derive a digital elevation model (DEM) for the Ecology Glacier. Ground control points acquired with a differential GPS system have been collected off glacier during two field campaigns. In addition, bathymetric data collected from a recent survey in December 2015, was used to map the recent glacier forefield area that has been filled with seawater. This mapping effort represents a new dataset that will be used as a baseline to understand current glacier changes in the area.

Keywords: ecology, glacier, remote sensing, Antarctica, bathymetry

MOUNTAIN MAPPING AND OLD TOPONYMY OF MARAMURES AS PRETEXT FOR FIELD WORK WITH TOURISM GEOGRAPHY STUDENTS

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This paper presents a cartography endeavor for non-cartographer students, a pretext for rigorous field research, data retrieval and map design. It has the structure of a case study, focusing on mapping the old toponymy in Maramures (Romania). The trigger was the weak understanding of the local place-names by the cartographers who worked after the WWII in the area; a great number of items were misspelled or distorted if not invented on topomaps. Old land property documents speak about places that are hard to identify because of this kind of error. Nowadays, this subject is challenging also for its stories. Tourism geography students have a study program that involves mainly vocational disciplines. In order to enhance their understanding of the territory we managed to introduce subjects related to cartography. This year will be the third year they could participate in a data retrieval project, initiated as Diploma work. Technically, they will retrieve old toponymy data, with phonetic transcript on a given surface, mainly mountain areas and villages around Maramures. This data is then transformed into a map, useful for tourism (the story behind the name of the place), for cadastral and agricultural issues (it solves the" mystery" with the official toponymy and the old, popular place-names) and as archive, as the old place-names are slowly forgotten. This is a very interesting research topic for the students, they are getting in touch with various stakeholders, local people and landowners, and they imagine and design their map. Then, the design is tested and finally the map is published.

Keywords: old toponymy, mountain mapping

THE CENOTE CAVE PROJECT: MONITORING GLACIER DEPOSITS WITH TERRESTRIAL LASER SCANNING IN THE HEART OF DOLOMITES, ITALY

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Abyss of Cenote is an impressive ice cave which hosts one of the most voluminous cave glaciers of the Dolomites. The exploration of this abyss had already begun in 1994 by the Speleological Group Proteo of Vicenza, after the discovery of the entrance as a results of the emptying of a lake then known as "Lake of Two Forks" at 2,940 m a.s.l. in the Regional Park of Fanes, Sennes and Braies. Finding the way down through the ice was not easy and in the following years the explorations were interrupted at about 70 meters depth due to difficult conditions for the summer melting of ice mass. Only in 2010, taking advantage of the first cold of autumn, it was possible to descend a huge inner shaft of 165 m deep that lead into a dome occupied by a cave rock glacier with typical terminal tongue embankments at depth of 280 m.

A research project was launched to monitor long-term movements and volume changes of this ice deposit as well as to understand the cave microclimate and the potential for future palaeoclimate studies.

In October 2015 was organized a first expedition to perform a complete survey of the final chamber using a Leica HDS7000, a phase difference laser scanner with a dual axis compensator and flow rate of 187 m. This survey has provided the detailed volume of the chamber (420,000 m^3) as well as a first record of the position of the ice masses hanging on the ceiling and of the rock glacier at the bottom. The laser scanner measure of the final room provided a maximum width of 120x36 m with a base area of 2,734 m^2 and a total height of the abyss that exceeds 200 m, confirming that this is the largest underground room explored in the Italian Dolomites.

Moreover, barometric, temperature and humidity dataloggers have been installed in the cave to record the microclimate, while pollen traps have been installed to study the present flux of pollen at the surface and inside the cave.

The Cenote ice cave research project aims to shed light on the climate evolution of the Dolomites during the last hundreds or possibly thousands of years, as well as on the more recent environmental changes that lead to the upward melting of the cave glacier and the consequent opening of the cave to the surface.

Keywords: TLS, ice cave, Dolomites

Between April 26 and 30 2016 a group of mountain cartographers met for the 10th ICA Mountain Cartography Workshop held at the Carl-von-Stahl-Haus directly situated at the Austro-German border at the rim of Berchtesgaden National Park. This “Jubilee” Workshop was the tenth in a series of workshops which are being held every two years, alternating with the International Cartographic Conferences. The Institute of Cartography of the Technische Universität Dresden was host to the meeting which gathered 48 mountain cartographers from 18 countries. This publication is the record of the workshop, containing 21 papers and 9 abstracts covering topics including relief aspects, mountain and hiking cartography, ecology-related aspects, glacier-related aspects, snow- and ski-related aspects as well as historical aspects, apart from miscellanea.