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MASTERARBEIT

Titel der Masterarbeit

Creating new touristic maps of high mountainous areas which have not been mapped either for touristic purposes or at all

Methods, challenges and cost-efficient solutions in the workflow

Verfasser

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Contents

1. Introduction

1. Choosing the topic and motivation

Over the next few paragraphs I would like to describe briefly what has led me to the decision to choose a topic related to making of touristic maps. As it was influenced by my free time interests and my personality as well, let me introduce shortly the origins of it.

As the end of my master studies approached, I began thinking of what my thesis would be about. Just like when choosing the topic for my bachelor thesis in Budapest, my goal was to come up with a very practical topic which shows up not only the theoretical aspects but the applied one, too. It was also important to find a topic which is close enough to me. I grew up in Miskolc, Hungary. I went to school there as well. From a young age on the nature, especially the mountains and the weather attracted my interest. From a very early age we usually did trips to the High Tatras which is only 180 kilometers away from my home town. There I got used to the high mountainous scenery which did not get out of my mind. Step by step, I did longer and more serious trekking tours there. The navigation, the sometimes rapidly changing weather conditions all amazed me. I have learnt how to use maps, compass. After purchasing a watch equipped with altimeter, map-reading made more sense. Even with the use of GPS, mountaineering has remained an interesting challenge for me. Exploring new sceneries and adventurous mountain ranges is what attracts my interest, especially if those areas are not affected from mass-tourism. Doing there everything on my own is also necessary for the feeling: preparing the food in the sunset is worth much more than eating a meal inside the restaurant of the refuge. Experiencing the untouched nature during mountaineering is priceless.

In 2009, a topic for my bachelor thesis had to be found. Creating something new and deferent was my goal. I decided to look for a region which is attractive for tourists but of which a touristic map had not been made, yet. A mate – László Lukácsa – preferred this idea, too, so we began the search for a place which could be ideal for this propose. We had been negotiating about what to choose: the Alps of Albania or the first National Park of Bosnia and Herzegovina. Finally we chose the highest mountain range in Bosnia which we later visited as well. With the use of GPS and old Yugoslavian Topographic Maps we recorded the routes and trails. Then we created a simple but useful map for tourists using the old yet precise Yugoslavian 1:25 000 sheets as a base. The Sutjeska National Park – the oldest protected treasure of the nature in the territory of Bosnia and Herzegovina – has it all what a mountaineer can wish: remote landscape full of beautiful limestone formations, overhanging cliffs, great viewpoints and a lot of snow in the winter time which allows ski-touring from December until May.

As I mentioned above, mountains are essential in my life. Therefore the topic of this thesis is also focusing on them. I think that new paper maps still have a bright future. I don't think that new technologies have to rule the world in ways of sending to the background every traditional predecessor. Furthermore, I think cartography has still an important mission towards mountaineers and tourists – and not just in the Alps. And as we may know it for sure, cartography and mountains have a special relation to each other which has been improving and getting more and more intense since the last dozens of decades, especially since high mountain tourism became so popular. This popularity helped the improvement of the cartographical products as well. To serve a growing market is always a special challenge. And this popularity can be dedicated to the mountain clubs of the alpine countries, too, which made enormous efforts to get mountaineering popular and to create cartographical products of alpine regions.

2. Structure of the work

The Master thesis '*Creating new touristic maps of high mountainous areas which have not been mapped either for touristic purposes or at all – methods, challenges and cost-efficient solutions in the workflow'* focuses on those relevant high mountain ranges, which haven't been mapped for touristic purposes, yet.

Generally, one can find remote mountain ranges in every continent. What makes them special and interesting for travelers? The answer for this question is very complex. Some mountains attract people because of their height, others because of the spectacular natural treasures. Many of them have challenging mountain faces while others are well known destinations due to the lush forests and nice view points. What is the common in them? The fact that they are today considered as remote high mountains. The reason for that is various. Partly the difficult access made many mountains less-visited in the past decades. Another reason however is the political situation. For these reasons, some mountains had simply been unknown for mountaineers. The target areas of this work are those of the above mentioned mountains that have not been mapped for touristic purposes in large scales.

The thesis would like to show methods how new cartographic products can be created of mainly remote, yet even more popular high mountain ranges. I would like to put the emphasis on cost-efficiency in every segment of the workflow when creating a new product. Therefore I do not wish to deal with techniques or solutions which can only be maintained in the theory and are not proper for real-life use.

In the Alps, all of the mountains and their walls have been climbed. The playground for adventurers is not the Alps anymore. There are several regions on the Earth, which are still remote and not captured by mass tourism. Some of these mountainous territories are new even for cartography. The trend of discovering far-away places has been becoming wide-spread. The continuously improving civil aviation opened up new horizons. The growing mobility is the key for new discoveries, even for the every-day-people. Most importantly, non-mass-touristic destinations are even more popular. This means, that the market of cartographic products might be affected from that as well.

The three research questions of this Master thesis are the following:

1. Which are those high mountain areas that can be considered as target areas of a new hiking map?
2. The use of which techniques and solutions can help cost-efficiently create the first high mountain map of an area?
3. How can Collaborative Mapping contribute to a cartographic product of a remote high mountain range?

All the above mentioned three points are key elements of my thesis. However, I have to ask a lot more questions. Yet, these are one of the most essential ones.

Some areas have still not been mapped in a large scale. It means, that new maps have to be created, which are designed for tourists and mountaineers. I would like to find cost-efficient methods and techniques which enable the cartographer to create high quality products for the target group.

As for the structure of the Master thesis, the chapters are dealing with different aspects of the topic. The introduction is followed by the chapter *Maps of high mountainous areas.* It contains several sub-chapters, of which one is dealing with a short historical background of high mountain maps, another one with the mapping situation of relevant mountain ranges at a glance.

In the third chapter, the target areas, in other words some of those remote mountain ranges are introduced which have not been mapped in large scale for tourists or at all. Mountain ranges will be introduced with a short description and will be grouped as for their location.

Another chapter is dealing with the data collection needed for creating new map contents in general: good quality, cost-efficient and easy-to-get data have to be produced and processed. Remote sensing, field surveying are among the key methods needed to get geospatial data which can then be processed and analyzed.

Collaborative mapping is a new aspect of cartography. It is based on user-generated data and of course the growing number of enthusiasts who are willing to spend some of their free time in order to build a community of amateur map makers. It is interesting to study how this new direction can help for new hiking map projects. This work therefore deals with this new aspect as well which includes even remote sensing and not just the basic field surveying activities. A whole chapter is dedicated to the research of how collaborative mapping can contribute to a mapping project of a remote mountain range.

The sixth chapter is dealing with map production. I listed those processes which are important before the project or after the desktop-mapping processes. Pre-calculations and scheduling, color management, printing, the used material and paper folding are among these topics.

In the seventh chapter I listed some cost-aspects of a hiking map project. Obviously, some processes and costs are common in almost every mapping project. The way of data acquisition is one very important issue when calculating costs. It can greatly influence the budget of the whole project. Other than that, selecting the right software for data evaluation and map making is equally important. Printing and material costs are also influencing the final unit price, just like the product marketing.

Last but not least, the Synopsis sums up briefly the essence of this thesis, focusing on the research fields. It is answering for a number of questions. There is also a list of the target areas which best fit the problem statement of this thesis.

2. Maps of high mountainous areas

1. From the beginnings: the first maps and map-like drawings of mountains, purposes of maps, user need changes over the change of time

The first map-like drawings of mountains were made between 2400-2200 B.C., and originated from Mesopotamia. The hills and mountains are shown from a side-view. This type of the depiction was widely used during the following ages as well, even in the Middle Ages and in the early New Ages. Renaissance was a major age for cartography. The first maps of several European countries were drawn in those times. This cultural movement also affected map-like drawings of mountains. The observation of nature related phenomena gained popularity. This was the case for cartography, too.

The more accurate depiction of mountains can be connected to the tourism: the improving of travelling, the reduction of working hours and the human curiosity had led to new activities. During the 18th and 19th centuries, travelling already served other needs than working, but at first only for some of the richest and adventurous people. But after a while travelling has been becoming more and more flexible, faster and cheaper. Yet it was not until the 20th century, that tourism and travelling became popular and available for almost everybody. Hence, discovering of high mountains was attractive for young people. At first it was only done by the local inhabitants. Later on, tourists from farther lands came also to discover the mountains. It was good for both sides: the tourists visited and discovered another area and the locals got good money for the accommodation and the other services they offered for these strangers. One of these services was and is the guiding in the mountains. Who else would know better the terrain than somebody who lives and works in the same area? Detailed maps and route descriptions are the other important aids in a foreign area. These products are equally useful for the tourist and his/her accompanying guide. Therefore it was not a coincidence, that following the foundation of the alpine clubs of Switzerland and Austria, accurate high mountain maps were produced. It took several decades, until the most popular mountain ranges of the Alps had been depicted.

User needs are an important issue within high mountain cartography as well. At one side, new technologies are always important in the implementation and production processes. On the other hand, the real needs of users must be in focus for map makers. Especially because nowadays a lot of small cartographic companies try to break into the touristic map market and these companies do not have spare money for risky researches. But who are and who were the users of these maps?

In the ancient times, trade routes led through the various mountains and valleys in Europe and in Asia. Let's just think of the Silk Route. With its tremendous length, this old trade route led through several mountain ranges. Sometimes even the easiest way did not avoid the mountains. The real discovery however remained for the upcoming ages. As mentioned before, local people were the other human beings who tried to cut long routes with ascending high to ridges then descending on the other side. In most cases, mountain ranges made it very difficult to get from one valley to the other, especially if there was no mountain path leading to the other side. Other than that it isolated one inhabited region from the other. This affected the people, the culture and the language in various ways as well.

Mountain paths and routes were first created and used by locals in order to fulfill their needs: to ensure grass for the animals, to hunt or simply to cut routes leading to other valleys around the ranges. These routes were more or less documented which helped the navigation there. But in the beginnings, climbing up to the very top was rare. In most countries, locals thought that monsters and mystical creatures live among the mountains. Religious purposes gave reasons for such activities. In most countries, locals thought that monsters and mystical creatures live among the mountains. Most interestingly in some cultures this was the purpose for not summiting a mountain as well. On the other hand the terrain and the lack of equipment made ascents to higher peaks impossible. In some cases there were ascents to mountain tops from royal order: in 1492, Charles VIII ordered to defeat the Aiguille in the Vercors range [GAR-05]. He did not want to have any unreachable area in his kingdom. Yet until the mountain tourism, lots of peaks remained undefeated – and routes undocumented. By the end of the 18th century, the first 4000 meter peaks were reached. This was the time for the first national map series in several European countries as well. But during these decades, the produced maps were not detailed enough to use them for mountaineering.

One of the new reason for reaching high mountain regions and peaks was the science. The unknown world of the high altitudes was very attractive for dozens of scientists. Astronomers wanted to get higher and higher, too, in order to get a better night view of the sky: after long decades of the first ascent to the Mont Blanc in 1783, a small observatory was placed to the very top of the highest summit of the Alps. By the mid-19th century, almost every main peak was climbed in the Alps, which is the real cradle of mountaineering itself.

The real accurate mapping of the high mountains had begun in the second half of the 19th century. To fulfill the needs of mountaineers and to make this new activity more popular, firstly the Austrian (1862), then the Swiss Alpine Club (1863) was founded. In 1865, just after 3 years of its founding, the first map was published by the Austrian Alpine Club. These associations were important map makers, too. Other than that, route descriptions and year books were also essential products of them. The leaders of these mountain clubs knew how important it was to create accurate depictions of the most popular mountain ranges.

The user need for maps and route descriptions were growing steadily: with the modern mountaineering the before inaccessible summits were climbed, too. This meant a new challenge for the cartographers: the cliff depiction. It gave a chance for mountain climbers to testify and navigate better among the ridges, rock pillars and other rock formations. At the end of the 19th century, the so called Swiss style rock representation was produced by means of shaded hachuring, whereas the lighting came from the Northwestern direction. This type of representation is still being used as the method with the vertical light source gives back the characteristic and morphology of the rocks on a high level. These maps were not only an accurate source of information for the growing number of mountaineers. They are more than that: esthetic artworks, which were created with a high level of professional know-how. These products fulfilled the needs of skiers, climbers and high mountain tourists. The only disadvantage was the enormous amount of time, which was needed to create a single sheet.

Several maps produced by the Austrian Alpine Club are still in use with smaller modifications. During the 20th century, every range of the Alps was mapped professionally. National map series, high detailed trekking and touristic maps are available either in the original paper-map form, or in a digital way. The last century was the most important period for the 3D reliefs as well. Numerous mountains and big walls were depicted in scaled artworks – mainly of the Alps. Moreover, route planning applications began to play an important role in helping mountaineers.

It is not an excess to state, that the Alps has remained the playground for mountaineers in many ways. But not just for them: the newest applications, methods and techniques are tested there, too by supplier systems, warning services, transportation, outdoor-clothing companies and even by cartography. Of course this has many reasons: the proximity to engineering centers of Europe, the high level of living standards, the accessibility and the infrastructure. But what about the other high mountain ranges of Europe or the world?

Air transport of passengers						
	2007	*2008*	*2009*	*2010*	*2011*	*2012*
EU-27	792 700 448	798 330 585	751 060 420	776 851 750	821 265 790	826 463 402
Euro area	547 987 073	551 909 511	523 390 838	546 835 220	579 358 303	582 495 724

Tab. 1: Air transport of passengers (2007-2012): an indicator of growing tourism of EU-27 countries and the Euro area, summarizing departures and arrivals within the given period

Nowadays, the relatively easy and comfortable ways of travelling enable to discover the before hidden and far away regions. But not just the technological advances provide new possibilities. Political situation of many remote regions have changed a lot during the last half century, too. The significance of tourism has become a major source of money for several countries of the Third World. With these changes, new possibilities and markets opened up for cartography and cartographic products. I would consider one other reason which has made mountain maps more popular: the growing number of mountaineers who do not want to hire a guide for the tour. They need map products and tend to use them more likely as well.

2. High mountain maps at a glance: where is what?

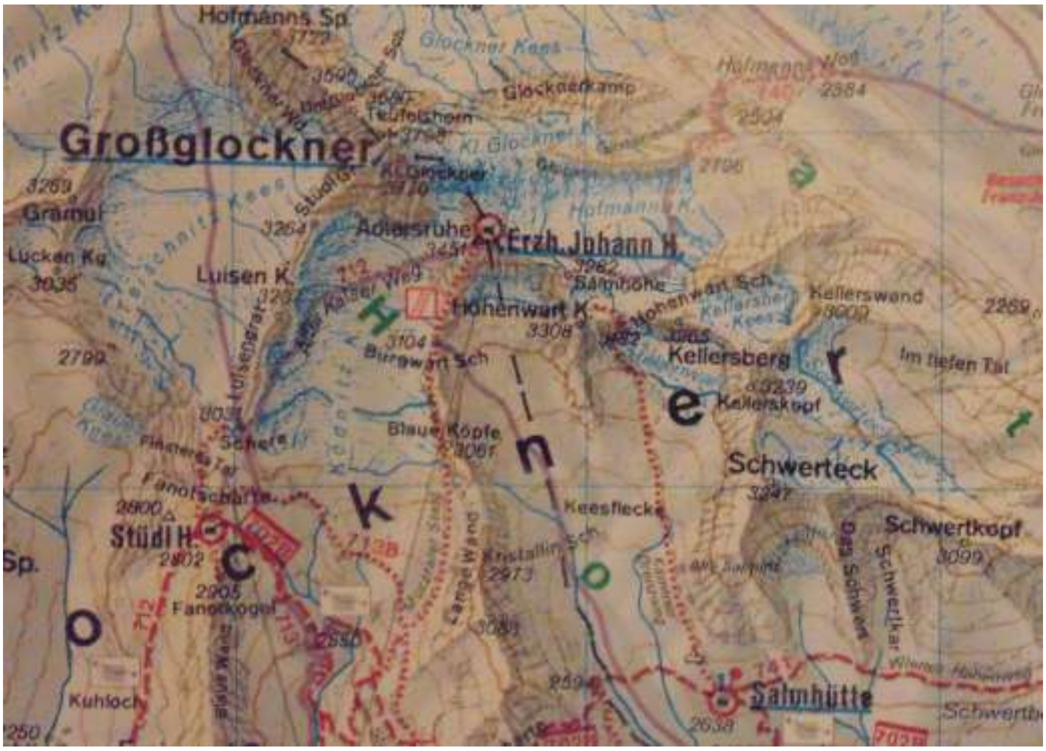
In this sub chapter I listed those mountain ranges of the continents which are already popular with mountaineers. At the same time I also felt the need for showing those mountains and high mountain ranges which can be more popular in the next few decades thanks to amongst the improvement of air traffic and road networks. But travelling is just about taking tourists somewhere. Finding the real purposes for the fact, why people like to discover foreign regions and landscapes could be the topic of research of another interesting study or thesis. I am absolutely sure that among other techniques, cartographic visualization is a good way of showing and making popular an interesting mountainous area for those who are willing to visit new places, regions and mainly mountain ranges.

It is necessary to make a summary of what we have in terms of cartographic products. A short description will represent each of the listed mountain ranges and some relevant cartographic products will be mentioned as well. The intention with this chapter is not exactly the showing of how many different guide books were produced about the mountain ranges. It would like to give a brief description and a short introduction on each selected mountain ranges. This short summary on mountain ranges on Earth is divided into seven parts as each one consists of one continent.

A. Europe

In Europe, the time of mountain adventurers has come to an end in many ways. Its most famous mountain chain is the Alps. It is a result of the continental plate collision between the African and Eurasian plates. Since it is located in the middle of Europe, it has been a popular destination of tourists and mountaineers since the 18th century. By the time of the golden age of the alpinism, during the 1850's and 1860's, almost every mountain peak has been climbed for the first time in this 800 km long mountain range. Its highest elevation is at 4810 meters on Mont Blanc which is located in the Western Alps. The highest point of the lower Eastern Alps is Biz Bernina at 4049 meters, respectively. Every of the 82 more than 4000 meters high peaks of the Alps are heavily glaciated while the hundreds of lower, still more than 3000 meters tall peaks can also often be approached just on a mixed snow/ice and rock climb. It is not a coincidence that the Alps are considered to be the cradle of mountaineering. Not just new climbing techniques have been found out and practiced here but many of the new climbing equipments have been found out, first-used and produced in the alpine countries. Therefore the Alps have undisputedly become the most important high mountain range in the world's mountaineering.

Not far from the Alps, the Pyrenees are another well known high mountain range. A great number of Frenchmen and Spanish climbers visit the mountain range as it forms a border region of the two countries. Therefore national and private map series are available in various scales depicting this mountain range. The French Institut Géographique National sells national maps in a scale of 1:25 000. Multi lingual guidebooks of the Pyrenees and the nearby regions have been published, too.



Ill. 1: Part of a current hiking map of Grossglockner, the highest mountain in Austria

The Carpathian Mountains are a 1500 kilometers long mountain range. It is the second longest among the high mountain ranges of Europe. Its flora and fauna is quite unique as it is still a home to a great number of bears and wolves. Yet, their living environment has changed a lot during the last few decades. The highest point of this long mountain range is the Gerlachovsky stit at 2655 meters, located in the High Tatras sub-range. A wide range of touristic maps and guide books are available for every relevant high mountain range of the Carpathian Mountains. The most popular one is the above mentioned High Tatras which is the smallest high mountain range in the world with an area of only 371 square kilometers. Its 26 km long ridge reaches everywhere at least 2000 meters.

Rila and Pirin are two high mountains located in Bulgaria. Despite their relatively small area, Rila is the highest one, Pirin is the third highest mountain range in the Balkans both reaching an elevation of more than 2900 meters, respectively. Both one can be found in national parks named after the mountain ranges. These mainly granite mountains have been popular destinations of tourists for the last dozen decades. Therefore touristic maps of these regions can be bought as well. Balkan Mountains are another and much bigger mountain range in area. This vast mountain chain stretches along Serbia and Bulgaria. For mountaineers is it less attractive than the above mentioned two higher ranges. Its highest point, the Botev Peak at 2376 meters has a topographic prominence of more than 1500 meters.

The other cradle of the mountaineering – mainly for ice and mixed climbing – is the mountains of Scotland. The high mountainous terrain, the extreme weather conditions made these ranges of the Scottish Highlands attractive for mountaineers, especially for the British. A detailed map series of this territory and a wide range of guidebooks are available on the market.

The Scandinavian Mountains is the longest mountain range of Europe with more than 1700 kilometers, as Caucasus Mountains cannot be found entirely in Europe. It consists of several sub-ranges with an altitude of at least 2000 meters. It stretches through the whole Norway, Sweden and some parts of Finland. Its highest peak, Galdhøpiggen is 2469 meters tall. Numerous mountain ranges have quite the same morphology than the Scotch Mountains but they are much better glaciated. Some of their ranges are very remote. Despite, national map series and touristic maps are available for the most relevant parts of the mountain range.

High mountains of Greece are also frequently visited. The Olympus range and its summit, Mytikas at 2911 meters is the third highest peak in the Balkans. This mountain range is best known from the Greek mythology, as it was said to be the home of the gods. Several guide books and maps are dealing with this high mountain range. Tourists, climbers and even skiers like to visit Olympus National Park. Pindus is a less known mountain range situated about 100 kilometers to the west from Mount Olympus. Its highest elevation is at 2637 meters. Mountain tourism is relevant here as well but this range is popular mainly with locals. This range stretches about 180 kilometers long in a north-south direction starting from southern Albania until the Peloponnese. Mount Taygetus is also known from the Greek mythology. It forms the southernmost areas of the continental Greece. Its highest peak is only about 2407 meters tall, but more notable is the fact that its topographic prominence is about the same (2350 meters) as of Mount Olympus, respectively. More to the south, the isle of Crete has two record holder mountain ranges. Lefka Ori is the southernmost mountain range in Europe with many peaks over 2000 meters. The most prominent peak in Greece can be found here, too: Mount Ida’s height equals to its clean prominence of 2456 meters. These two ranges mean a popular one-day destination for many tourists who spend their holidays in the isle as these peaks can be reached easily in paths mostly without any technical difficulties. Touristic maps, map-like drawings and digital terrain models are sold for these areas.

The only regions where the last wild and untouched ranges of Europe can be found are the Balkans. However, the former military maps of Yugoslavia with scales up to 1:25 000 offer accurate base maps for most of the popular ranges, the lack of guidebooks and the need for modernizing make the Dinaric Alps attractive for both adventurers and the map makers. Moreover, Albania had not been mapped in the similar way like the countries of the former Yugoslavia. Prokletije is the highest mountain range within the Dinaric Alps. Its other name is Albanian Alps as these mountains are located mainly but not entirely in Albania. It covers an area of more than 2000 square kilometers in the territory of Albania, Kosovo, Macedonia and Montenegro. The southernmost glaciers in Europe can be found here (Ill. 7). They were first observed by researchers as late as 2008, respectively. They are situated at relatively low elevations between 2000 and 2400 meters. Probably 5 active glaciers remained here. The highest point of the range and the Dinaric Alps is the summit of Maja Jezercë at 2694 meters. It was first climbed in 1929 by a British team. A private company published hiking and biking maps of the Albanian Alps in 1:50 000 scale not too long ago. Several other, less popular but ranges with a possibly high touristic potential of the Dinaric Alps have not been mapped for touristic purposes.

Ill. 2: A typical mountain path just beneath Mount Olympus in Greece

The Korab and Shar Mountains lie next to each other at the border of Albania and Macedonia and partly in Kosovo. Both ranges reach a height of 2700 meters, and consist of dozens of peaks reaching 2500 meters. Yugoslavian topographic maps are available for the area even with a scale of 1:25 000, but relevant hiking maps have not been produced.

B. Asia

Perhaps the most diverse continent is Asia. With its vast North-South and East-West measures it is home to many ethnic groups, countries, thousands of species and dozens of high mountain ranges as well. Many parts of Asia were already known to Western people by 1498, when a young Portuguese discoverer, Vasco da Gama made the first ever sailing from Europe to India. This expedition was a milestone in the history. No one could sail around Africa before. More than that, this journey opened up an important sailing route for traders, who were previously forced to use the diverse routes leading to Asia from Europe through high mountains.

The most wonderful is the fact, that even after more than 500 years of this first sailing to Asia, some regions and mountain ranges are still not well-known to foreigners. This is partly because of the huge distances and difficult terrain, but the political situation of many regions and countries made the mountaineering limited as well. Even today, mountaineering is still affected from politics but not like before. Many borders opened up in Asia, yet Bhutan for example only accepts a limited number of tourists who have to fulfill strict requirements. Recently, it makes the situation even more difficult that some countries like Afghanistan or regions like Jammu and Kashmir are not safe for tourism.

In South Asia, there are mountain ranges which exceed 4000 meters in height, but in most cases those cannot be considered to be popular destinations for mountaineers. This is mainly because of their location on Earth. The lush tropical vegetation and at some cases the almost endless rainfalls make uncomfortable conditions to do outdoor activities high up on the mountain. The other drawback is the hard access for many of these regions. Despite, some of these areas can be perfect choice for trekking tours. Indonesia and Malaysia have several mountainous islands, which can be perfect for a vacation at the sea as well. Although the main sights in these countries are well known, the highlands and the national parks are still not discovered by tourism or at least not for foreigners. Such places can be found in the Crocker Range in Malaysia or in the Barisan Mountains of Indonesia. In the Philippines, the country high point Mt Apo at 2954 meters has a growing popularity with tourists.

In Western Asia, several 5000+ meters high mountain ranges attract the adventurers. The most important of them is the Caucasus. Although one part of the mountain belongs to Europe – its highest summit, the top of Europe the 5642 meters high Mount Elbrus as well - several of its ranges belong to Asia. Most importantly, the northern ranges are easily accessible from Russia. Unfortunately, no road connections from the Northern Caucasus to the southern, Georgian ranges are possible as the border is closed for foreigners between Russia and Georgia. Russia's highest mountain was first climbed in 1874 by a British climbing team. The lower, eastern summit of Elbrus was reached already in 1829. This range had remained a popular destination for explorers of the following decades, too. Its mapping began quite early, especially for the northern ranges. Several touristic maps were published over the 1990's. Until today, every relevant mountaineering area has been mapped and most of them are available with Latin scripts. Of course by now, many of them should be updated. Next to maps a wide range of travel books are also available which are partly or in whole dealing with the Caucasus.

Elburz is another important mountain range in Northern Iran, just to the south from the Caspian Sea. Its highest point, the Mount Damavand is a country high point as well. The volcano is a popular destination for mainly local trekkers, as it is situated pretty close to the capital Teheran. Map-like depictions in 2D and 3D had been produced of Damavand, which aimed at showing mainly the normal route leading to the mountain. A comprehensive, detailed touristic map with Latin scripts is still to be produced.

Central Asia has been attractive for mountain climbers for a long time. In its southern part, all of the 8000 meters high peaks on Earth can be found. Mainly over its western parts, several mountain ranges stretch with 7000 meter high summits. Many of them are still hard to climb. The famous five 7000 meters high peaks of the former Soviet Union are located there as well. These summits were one of the most popular and most difficult peaks to reach for many Easterners during the 20th century. Still today, if a climber successfully summits every 7000 meter peak of the former USSR then receives the Snow Leopard award. After the collapse of the Soviet Union, political situation became instable in many regions. Yet, former Soviet countries soon recognized that tourism is an important source of money. Several high mountain ranges of this area attract mountaineers and tourists from all over the world.

The Himalayas are perhaps the most well-known mountain range out of the Alps. This range is the result of the plate tectonic processes of Indo-Australian Plate. It crosses five countries with a length of almost 2500 kilometers: Pakistan, India, China, Nepal and Bhutan. It contains 10 of the 14 8000er peaks. Every of these peaks were first climbed either in the 1950's or the 1960's, respectively. Still, some of their faces are amongst the physically and technically most challenging routes. As for its mapping situation, several cartographic products were published during the last few decades which are mainly focusing on the highest summits. This mountain range is also the scene of many famous books and movies. Compared to the fellow Central or Inner Asian mountain areas, the Himalayas have better improved areas as for tourism, especially the regions around the highest mountain in the world, the 8850 meters high Mount Everest. A trekking map of the world's highest mountain was published in the series of the expedition maps of the Austrian Alpine Club. Langtang Himalayas were also mapped by the alpine club, all in 1:50 000 scale.

Ill. 3: Google Earth image depicting the central ranges of the Himalayas

The Karakorum is the other highest mountain range with 4 of the total 14 8000er peaks. This is one of the most popular range for expedition mountaineering. Several of its mountain tops reach 7000 meters. Even more peaks in Karakorum rise above 6000 meters, dozens of them are unclimbed. The world's second highest peak, the K2 is located there as well. It was first climbed in 1954 by an Italian team. This mountain has the technically most challenging normal route of the 8000er peaks. Tourism is growing as the infrastructure has been modernized over the last few decades but still the long way of improvements has just begun.

Cartographic products are well-known, at least for the most popular areas of the highest peaks. The Austrian Alpine Club contributed a lot to it, as some parts of the Karakorum including the Nanga Parbat mountain and its surrounding has been mapped n 1:50 000 scale already in 1936, respectively.

Hindu Kush is one of the great ranges in Central Asia, which stretches more than 800 km long in Afghanistan and Pakistan. Its highest peak is the about 7700 meters high Tirich Mir. Along the mountain range there are almost 40 7000ers, of which some has been very rarely climbed until now. There is a lack of cartographic products for the region. Guidebooks and maps are hard to find and not accurate sometimes.

The Pamir Mountains are another famous range with three peaks over 7000 meters and several over a height of 6000 meters. It is located mainly in Tajikistan and Kyrgyzstan. It features 3 out of the 5 former Soviet 7000 meters peaks. Here are some of the world's most difficult climbing routes which lead in high altitudes above sea level. Its severe weather also makes mountaineers' life harder. Two map sheets in scales of 1:50 000 depicting this area have already been created by the Austrian Alpine Club. Because of the lack of relevant cartographic products and the high potential of future improvement of the region, this area will also be studied in the thesis.

Hindu Raj is a less known high mountain range located in Pakistan, right between Hindu Kush and the Karakorum. Its highest elevation is at 6872 meters. As the political situation is not stable in the region, it also affects mountaineering in this mountain range.

The Tien Shan is a more than 2500 kilometers long high mountain range. Perhaps it has the most remote regions amongst the Central Asian ranges. This is the northernmost 7000er mountain range in the world with peaks like Pobeda – 7439 meters and Khan Tegri – 7010 meters. In spite of its remoteness, this range has been popular with adventurers and expeditions since the 1960's. However, one can still find unclimbed mountains there as well. The severe weather makes the touristic season very short: climbing and trekking tours usually take place in late summer. Maps and guidebooks are hard to get but the above mentioned peaks are mapped. A 1:100 000 scale map of Inylchek region of the Tien Shan is the part of the expedition map series of the Austrian Alpine Club.

Kunlun Mountains are perhaps the longest range in Asia. Its ranges stretch almost 3000 kilometers long through Tibet and China. Its highest peaks rise above 7000 meters. It rises at the northern edge of the Tibetan Plateau. Despite its vast size, access to the mountains is very complicated as transportation is limited due to lack of roads. Often it is considered as the toughest mountain ranges of the world. Cartographic products of the area are hard to find, many parts of this enormous range have not been mapped in big scales.

The Altai Mountains are in the very north of Inner Asia, right where Russia, China, Mongolia and Kazakhstan come together. The highest peaks don't even reach the 5000 meters height but their morphology and the surrounding areas make them respectable. The severe weather conditions are typical for this range, too as it stretches at the 50th latitude. Mainly Russian topographic maps can be used for navigation, which are quite precise but old.

A number of high mountain ranges can be found in or near the Tibetan Plateau which would be popular destination of mountaineers almost everywhere in the world, but somehow they are more likely in the background. Such a mountain range is the Transhimalaya. It stretches parallel to the Himalayas at its northern side in Tibet. Its highest peak is the sacred Mount Kailash at 6638 meters. Just next to it to the west, Nyenchen Tanglha Mountains are a 700 kilometers long high mountain range with four peaks reaching 7000 meters. Its highest peaks were climbed first only in the late 1980's and in the 1990's. Altyn-Tagh is another less famous mountain range in the Tibetan Plateau. It consists of mainly 4000 and 5000 meters tall peaks, but its highest elevation is at 6245 meters. Tanggula Mountains are one of the highest mountain ranges of the Tibetan Plateau. About two dozens of its peaks reach 6000 meters in height. The highest one is Geladaindong Peak at 6621 meters. The source of the Yangtze River can be found here as well. Mountaineering began only in the 1980's here. There are several 5000 and 6000 meters high peaks in the Central Tibetan Plateau as well, but most of them are not easily accessible. However, both mountaineering and cartography can find here interesting mountains.

In East Asia there are almost no relevant mountainous areas, at least compared to Central or West Asia. Yet, one almost unknown mountain range rises to the east of the Himalayas: the Hengduan Shan. Its highest peak is more than 7500 meters high. As for cartographic products, this area cannot come up with anything real useful for mountaineers. This is not true for the other popular and one of the better known mountains of Asia: the Fuji. This Japanese volcano is a myth of which several publications, books and maps have been published.

In North Asia there aren't any important high mountains which would be interesting for mountain climbers unless Altai Mountains are is considered to be a part of it. Although it would be challenging to climb a 7000 meters high peak over the Arctic Circle. But in Northeastern Asia, the Kamchatka Peninsula has some interesting high volcanoes to climb. The highest among them, Klyuchevskaya Sopka is 4750 meters tall. It is the highest volcano in Asia. This and the other volcanoes of Kamchatka are the part of the UNESCO World Heritage Site.

C. Africa

Africa is a special continent with a wide scaled variety of natural treasures and mountainous landscapes. In each corner of this magnificent continent is something breathtaking natural sight. This continent is very attractive for mountaineers and outdoor tourists as well. Some of the high mountains reach a height of more than 5000 meters. The accessibility of some regions is difficult but the rewarding environment compensates for it.

North Africa is home to the world's biggest hot desert, the Sahara. With its size of over 9 400 000 square kilometers it stretches through the Maghreb countries and the Nile Valley. The Atlas Mountains is the highest mountain range in this area. Its highest peak is Toubkal at an elevation of 4167 meters. Tourism has a long tradition here, especially in the mountains of Morocco where even ski resorts can be found. At first French climbers began alpine activities in Atlas back in the 1920's when Toubkal was first climbed, too. Still under French ruling, Club Alpin Français opened its first refuge there in 1938, which has been in use since then as well. Over the last decades, several guide books and maps were produced of the High Atlas, which is the most popular touristic destination of the Atlas Mountains. Its great accessibility is a huge advantage for the tourism.

In North Africa, deep in the Sahara there are other high mountains as well. Compared to Atlas Mountains these ranges are remote and less known but may be worth for a visit. The Hoggar Mountains are located in south Algeria. Although its highest peak has an elevation of about 3000 meters, the thousands of cliff formations are ideal for rock climbing or bouldering. Tibesti is a mountain range in Chad that stretches to its northernmost borders to Libya. This volcanic range consists of five volcanoes of which the highest is Emi Koussi with its 3415 meters. The huge craters of these shield volcanoes are clearly visible from the space, too. Furthermore, this mountain range has the country high points for both Chad and Libya. Last but not least, high mountainous areas can be found in Egypt, too. On the Sinai Peninsula and along the Red Sea one can find wild cliff formations peaking at 2642 meters. Mount Sinai is said to be the biblical place were Moses received the Ten Commandments, respectively. This area is well documented but also often visited. A number of guide books are available for the area in many languages. Topographic maps with a scale of a 1:250 000, and for some areas even in 1:50 000 have been published.

Canary Islands are a special peace of Africa and Europe. They belong to Spain but geographically they are considered to be a part of Africa. The seven bigger volcanic isles are all mountainous with high points ranging from 817 to 3718 meters, respectively. The highest mountain itself is an active stratovolcano. Teide makes the isle of Tenerife the tenth highest isle on Earth. This is the 40th most prominent mountain on Earth as its topographic prominence equals to its height. It can be climbed within two days but the more comfortable tourists can use a cable car until about 3500 meters. This volcano is usually climbed through the normal route. A wide range of guide books and maps are available for tourists.

Sub-Saharan Africa disposes of more several high mountainous areas of which some are touristic destinations for decades, while others are completely forgotten or simply not yet discovered. The most famous mountain of Africa, the Kilimanjaro is located in Tanzania. The Kibo has an elevation of 5895 meters and this makes it the highest mountain of the continent. It was first climbed in 1889 by an Austrian-German team. Nowadays, guided tours lead to its very top, where thousands of tourists get to from year to year. This famous volcano is well depicted and documented in maps and guide books. Not far from the Kilimanjaro, another peak with a height of more than 5000 meters is located: the Mount Kenya. At 5200, this is the highest point of Kenya. It was first climbed by the Englishman Halford Mackinder. This region is also well mapped in order to fulfill the needs of those more than 15 000 tourists, who visit the Mount Kenya National Park each year.

There are other mountainous regions in Africa, which are by far not so frequently visited like those mentioned above. Mount Cameroon with its 4040 meters is the highest mountain in Western Africa. It was first climbed in 1840, but tourism has pretty much avoided this volcano. Although this is an active volcano, ascents can be made throughout the year. Small scale topographic maps are available for the area. Large scale touristic maps haven't been published, yet.

Another attractive destination for adventurers is the Ethiopian Highlands. Ras Dashan is the highest mountain of the range with an elevation of 4550 meters. This is the highest point of Ethiopia as well. Bale Mountains are another high mountain range just south to Ras Dashan, located in southeast Ethiopia. Its highest point is at 4377 meters. Both of these mountain ranges have good chances to become touristic destinations in the future but thus far just a small number of travelers accessed to these mountains. Ethiopian Mapping Authority has been creating among others 1:50 000 topographic maps for the whole country but it is unknown when they can provide map sheets for the entire country.

Beside Kilimanjaro and Mount Kenya, Rwenzori Mountains is the only other high mountain range with 5000er peaks in Africa. Five out of the ten highest peaks of Africa are located in the Rwenzori range. Its highest point is at 5109 meters on Mount Stanley. It is a country high point for both Uganda and the Democratic Republic of the Congo and part of the Rwenzori Mountains National Park, a UNESCO world Heritage Site. This is a well known area of the Equatorial Africa, thus a lot fewer tourists visit the national park than for example the Kilimanjaro. Cartographic products of this area are not wide ranged but once 1:50 000 scaled topographic maps were made by Ordnance Survey International.

Last but not least, The Drakensberg of South Africa and Lesotho is a more than 1000 kilometers long mountain range reaching up to almost 3500 meters. Its basalt and sandstone cliffs make it a popular place for rock climbers. On the other hand, hikers also like this vast mountain range. Over the last decades, a wide range of cartographic products and guide books have been published and available for this area.

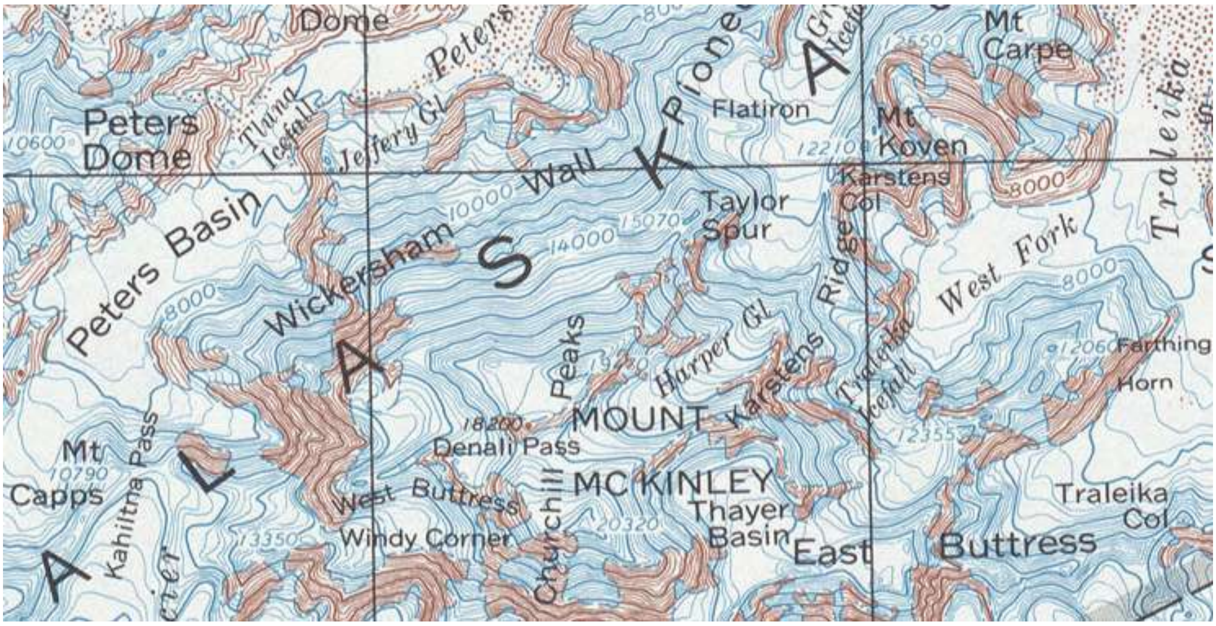
D. North America

North America is the home to the Rocky Mountains, an almost 5000 kilometers long high mountain range stretching through the United States and Canada. Its highest peak, Mount Elbert reaches above 4400 meters. Out of that, more than 60 mountains have an elevation of minimum 4000 meters. Just like the Alps in Europe, Rocky Mountains are the most popular high mountain range for tourists in North America. Several national parks and ski resorts offer a wide range of outdoor activities. The mountaineering began here in the second half of the 19th century. Since then, numerous publications, books, maps have been produced about Rocky Mountains. National and private map series offer map sheets for the area – without rock depiction.

Sierra Nevada is another popular high mountain range located to the southwest from Rocky Mountains. It stretches through the US states California and Nevada. Its highest peak is Mount Whitney, at 4421 meters. This is the highest point of the continental United States. The famous rock climbing area in Yosemite National Park is located in Sierra Nevada as well.

The U.S. Geological Survey and several private companies published maps and guide books of this mountain range. In this thesis I would not like to deal with these already popular and from many aspects documented high mountainous areas.

Alaska Range is the highest mountain range in North America. Its highest peak is Mount McKinley with an elevation of 6168 meters. It was first climbed 100 years ago, in 1913 by a British-American team. It is the northernmost 6000er on Earth. The mountain is part of the Denali National Park, which was established in 1917. Since then, several guide books and maps have been created.



Ill. 4: US Topographic map of Mount McKinley – original scale is 1:250 000

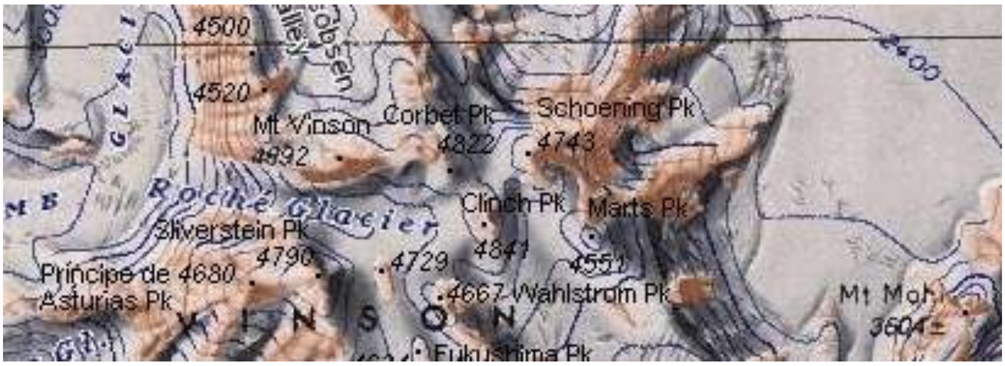
In the arctic territories of Canada, a wild, vast yet remote mountain range has been becoming popular with mountaineers: the Arctic Cordillera. These mountains are not extremely high but have other extreme features: the severe weather is the most important enemy of the climbers. These mountain ranges are situated in the northernmost islands of Canada. The highest summit is Barbeau Peak at 2616 meters. Several dozens of peaks reach an elevation of 1000 till 2000 meters. Some of them are still unclimbed. Many of them have huge walls and faces are ideal for rock, ice and mixed climbing. Yet, maps and guide books to help the visitors have not been published in a sufficient number.

Another arctic mountain range of North America is the Watkins Range. It is located in the eastern part of the world's biggest island, Greenland. Its highest point is Gunnbjørn Fjeld at 3694 meters [URL-8]. This is the highest mountain of the Arctic. What would prove its remoteness better if not the number of the rare summit ascents. These completely ice covered mountains are preferable for ski-mountaineers, since most of the peaks can be reached with skis. A limited number of maps are available for the area. The most detailed ones are scaled at 1:200 000.

Far to the south from the Arctic areas, several high mountain ranges can be found in Central America. Most of them are of volcanic origin. The American Cordillera consists of many high mountain ranges from which some can be found in Northern and Central America. One of them is the Trans-Mexican Volcanic Belt. Its high volcanoes like Citlaltépetl, Popocatépetl are the main attractions for the tourists. Mexico's whole territory is covered with 1:50 000 scale national topographic maps. Moreover, important areas of the tourism have already been mapped for those purposes as well.

E. Antarctica

Antarctica is the biggest desert on Earth. This remote continent has become a major touristic attraction over the very last decades. However, out of the researchers, nobody can reside on the surface of the continent, not even for a single night. Only one day visits are allowed, Therefore tour agencies regularly operate ships on which accommodation is offered and compulsory even if it is right at the land. This regulation do not allows the multi day tours and therefore strongly limits the mountaineering activities. Yet, several mountains rise above 3 and 4000 meters. Even one 5000 meters high peak can be found here: the Mount Vinson. Special permits have to be obtained in order to maintain mountaineering activities in Antarctica. Yet, all of the major peaks have been climbed over the last decades. Because of this strict situation, currently there is no sense in making mountain maps for those tourists who would like to do mountaineering in Antarctica.



Ill. 5: Part of a USGS map of the Vinson Massif

F. Australia and Oceania

As there are only some mountainous areas, Oceania is an important and popular destination mainly for those tourists, who would primarily like to enjoy a sea-side holiday. Yet, mountaineering has not been unknown there at all. For example the first ascender to Mount Everest, Edmund Hillary himself was a New-Zealander.

Although it is not the highest range of Oceania, the Southern Alps became a popular and first-line mountaineering area not just for locals. Mount Cook, the highest peak of the range was first climbed in 1895. Out of that, 16 peaks rise above 3000 meters. Every corner of this heavily glaciated mountain range has been mapped already. Moreover, a number of guide books have been published as well.

New Guinea, the second biggest island on Earth is home to the other relevant mountainous areas in Oceania. The highest peak can be found in the Sudirnam Range, named as Puncak Jaya. This mountain with its 4884 meters is the highest island peak in the world. Other than that, it is part of the Seven Summits as well because no taller mountain can be found in Oceania. In New Guinea there are other 4000 meters tall peaks too, which offer great adventures for hikers and rock climbers. Cartography has done not much so far to provide maps for the tourists about these tropical high mountains. The Indonesian national topographic map series offer sheets in 1:50 000 scale depicting also the mountainous areas of the island.

G. South America

South America is the home to the world’s longest continental mountain range, the Andes [URL-4]. The subduction of oceanic crust at the South American plate is the reason why this volcanic mountain range stretches mostly parallel to the whole western coast of South America. This is nearly the only relevant mountain range for mountaineers in the continent. However, a mountain range called Sierra Nevada de Santa Marta is located in this continent as well and it is considered to be the highest coastal range on Earth. It is not far from the Andes but it is completely isolated from that. The highest peaks, Pico Cristóbal Colón and Pico Simón Bolívar top the peaks of the Andes in that region with both reaching 5700 meters.

The cartographic works done in the Andes cannot be described homogenously. This high mountain range stretches over 7000 kilometers through 7 countries. Its highest elevation is at 6962 meters on the summit of Aconcagua. The Andes can be divided into several sub-ranges. However, I would like to introduce its highest and most relevant peaks depending on which countries they are situated in as it makes more sense if we consider that the seven countries have different mapping practices and products from each other.

At its northernmost ranges in Colombia and Venezuela, the Andes already reach up to 5000 meters. Its highest peak is Nevado del Huila at approximately 5370 meters. This is an active volcano which is climbed very rarely. There are 4 more at least 5000 meters high peak in Colombia of which neither is climbed frequently. Moreover, Colombia is the only Andean country, which has its highest point outside of the Andes. As mentioned above, Pico Cristóbal Colón is the country high point there. As for maps, the whole territory of Colombia is covered with 1:50 000 national topographic map sheets. In some cases, touristic maps are available as well.

Venezuela is the only one of the Andean countries where the highest peak does not exceed a height of 5000 meters. The country high point, Pico Bolívar is suspected to be about 4978 meters high, whilst some older sources estimated a height of 5007 meters. Venezuela has a national topographic map series with 1:100 000 scale which is accessible for tourists as well. Special mountain maps for touristic purposes have not been created by known publishers.

Ecuador is the only one of the Andean countries, where 1:25 000 scale maps were published for the whole territory of the country. Therefore its popular high volcanoes can be well accessed if one can purchase these map sheets. Some guide books have been dealing with these popular high mountains. The 6268 meters tall country high point, Mount Chimborazo is also the subject of guide books. Moreover, the famous British mountaineer Edward Whymper, who reached the summit of Chimborazo wrote a book about his journeys with the title Travels amongst the Great Andes of the Equator. Chimborazo and its neighboring peaks are easily accessible as the capital Quito is just some hours away. Despite, no hiking maps were created by well-known international publishers.

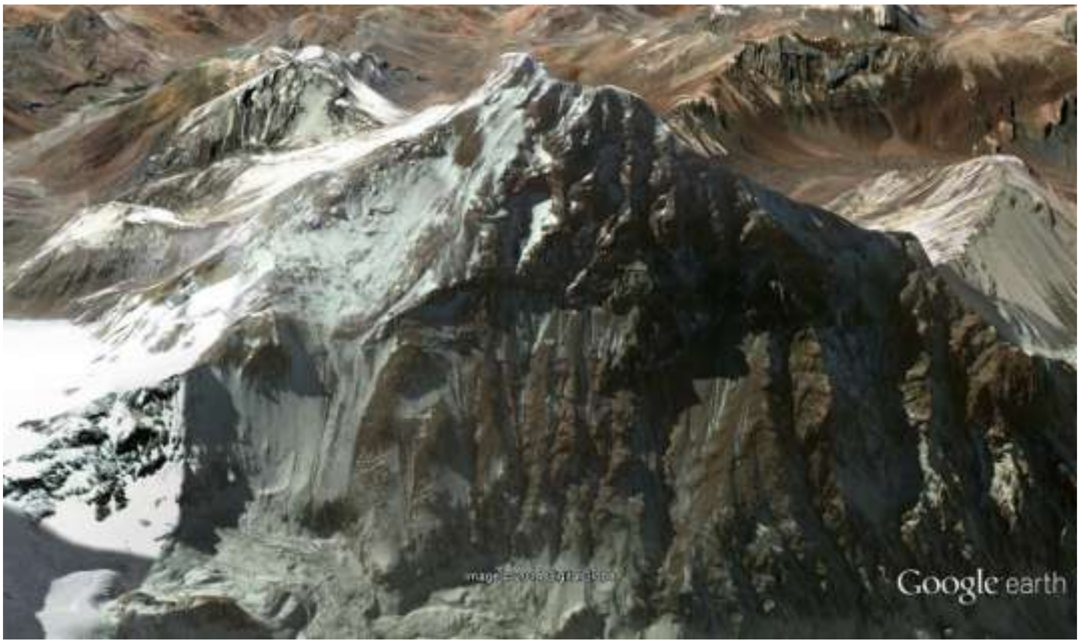
Ecuador's southern neighbor, Peru is home to the Cordillera Blanca within the Central Andes with several 5000 and 6000 meters high mountain peaks. One of them is the Alpamayo, which was selected for the most beautiful mountain in the world. Huascarán is the highest peak of the country at 6768 meters. The technically most difficult high peaks of the Andes are located there, like the Yerupaja or the Siula Grande. Both of them are peaks of the Waywash mountain range. This range is a bit different in its morphology compared to the most ranges of the Andes. The steep and exposed faces, highly glaciated slopes and the remote peaks make it a very desirable destination for trekkers and climbers as well. The National Institute for Geography offers a map series with the scale 1:100 000. These sheets cover the whole country. The Austrian Alpine Club also produced three maps depicting the Cordillera Blanca in scales of 1:50 000 and 1:100 000, respectively.

Bolivia is the country with the highest capital in the world. La Paz is located in the heart of the ranges of the Andes, at an elevation from 3200 up to 4100 meters. The country high point, Nevado Sajama has an elevation of 6542 meters. But the almost same high Illimani at 6438 meters can be seen from the city as well, making that an easily accessible over 6000 meters high mountain. But Cordillera Real has other 6000 meters high peaks as well. Every of them are located close to the capital La Paz. The Military Geographic Institute of Bolivia created 1:50 000 scale maps for the whole territory of the country which is accessible for tourists as well. Austrian Alpine Club created two touristic maps of the Cordillera Real in scales of 1:50 000, too. Moreover, guide books and route descriptions are also on hand for tourists.

Chile is the longest yet narrowest country in South America. It has continental borders to Bolivia and Argentina. The country is located almost everywhere high above the sea surface mostly within the mountain ranges of the Andes. The national 1:50 000 scale map series cover the whole territory of Chile. It makes navigation easier in the area. The Chilean Andes is home to some of the highest mountains in South America, also to the 6891 meters tall

Ojos del Salado, which is the highest volcano on Earth. This mountain was mapped by the Austrian Alpine Club in a scale of 1:100 000. Other than that, about 35 peaks reach an elevation of 6000 meters in Chile. Just like in Bolivia, most of these high peaks can be well accessed.

The Andes in Argentina stretch only on a small territory compared to the size of the country. The highest peak of the mountain range however called Aconcagua is located there. This is the highest mountain of the whole Americas as well and the tallest one in the Western and Southern Hemispheres, respectively. As for topographic prominence, this mountain is the second highest on Earth after Mount Everest. As this mountain can be well accessed and considered to be one of the easiest one to climb around 7000 meters, several touristic maps and guide books have been produced of that. It is no coincidence that thousands of tourists try to climb Aconcagua each year but just about 30% of them are able to get to the very top of it. This means about 1000 climbers each year. But not Aconcagua is the only high mountain in the country: nine out of the ten highest peaks of the Andes are located partly or fully there. The Military Geographic Institute of Argentina offers maps in various scales beginning from 1:500 000 until 1:50 000.



Ill. 6: West face of Aconcagua viewed in Google Earth

Patagonia is another important region for mountaineers with several big walls and steep mountain faces. The area is shared by Argentina and Chile. Its high mountainous areas consist of the southernmost ranges of the Andes. The morphology of these mountains is different from those which are located more to the north. The much higher erosion created unique cliff formations. Although these southern ranges are not so high than the ones to the north, they are at least as challenging for mountaineers as the others. The southernmost, mountainous archipelago consisting of dozens of islands is called Tierra del Fuego. This is one of the very few places on Earth, where mountainous glaciers can reach the sea level thanks to the unique climate of the area.

Last but not least, Guiana Shield is a craton located in the territory of Venezuela, Guyana, Suriname, French Guiana and Brazil. As I mentioned above, Pico da Neblina and the Cerro Marahuaca are two of the few more or less relevant peaks of this highland. Pico da Neblina is the country high point for Brazil. It is 2994 meters high and lies on the border to Venezuela.

3. Target areas

1. Listing of target areas

I believe that creating maps of mountain ranges previously not mapped for tourists, locals and mountaineers, is still a challenge of cartography. In the previous chapter the emphasis was put on listing the most significant mountain ranges of the seven continents regardless of how thoroughly mapped they are. In this chapter these areas are going to be mentioned and described in greater detail.

First and foremost I will focus on mountains higher than 2500 meters that fit the purpose of my thesis. I will provide short descriptions of them, dividing them into groups according to continents. The available cartographic products of these mountain ranges will be discussed more extensively as well. I will also attempt to answer one of the questions raised in my thesis of which areas on Earth can be considered as target areas for this thesis. I would like to name and shortly introduce these areas.

A. Europe

Where can it happen that researchers find unknown glaciers in a mountain range of Europe where no one suspected that ice cover still exists? The answer is the Balkans and within that the Dinaric Alps**.** That is the only high mountain range in Europe which is more or less not well mapped and documented. However, most of its relevant mountain ranges have already been famous destination of the tourists. The reason why these mountains are so magnificent lies perhaps behind the fact that some of its hidden ranges are far from holiday resorts, health care facilities and good infrastructure. The untouched nature still dominates there. The most popular and known mountain range within the Dinaric Alps is the Durmitor in Montenegro. However various other sub-ranges are still relatively unknown in the western world.

Less known is the range of the Maglić. Its highest peak, Maglić is the highest mountain in Bosnia and Herzegovina. This mainly limestone mountain group can be found at the border to Montenegro in the southeastern part of the country. It reaches an elevation of 2386 meters. This range is just the second highest one in the region, but dominates its surrounding with its steep walls and faces. The whole territory of this mountain lies in the Sutjeska National Park, the oldest protected area of Bosnia and Herzegovina. It is famous for one of the oldest primeval forests of Europe.

Ill. 7: Newly discovered glaciers in the 'Cursed Mountains' of Albania

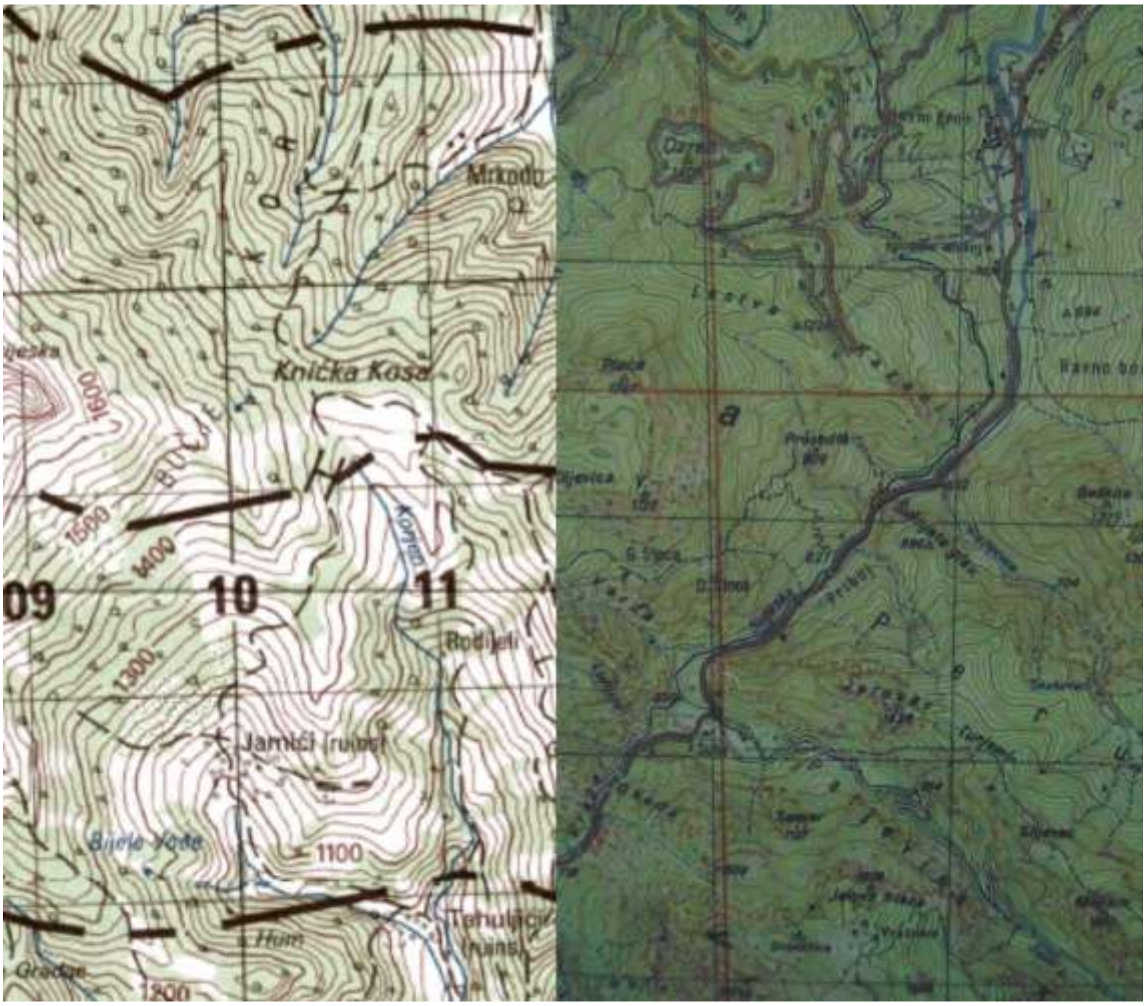
Luckily, this area is not affected heavily from land mine fields and was not in frontal zone in the Bosnian war. Tourism has safety gateway in this way. A touristic map of the area has not been published officially. Yet, me and a colleague made basic touristic route drawings and depiction of points of interests digitally to a former 1:25 000 Yugoslavian topographic map after simple measurements with handheld GPS devices. This paper map was featured in my Bachelor thesis “A Maglić turisztikai térképe- boszniai oldal” (Touristic map of Maglić) in 2010. Since then, this map had been completely redesigned in the Master thesis of László Lukácsa. This map is available in digital version as well. However, the map is not available for commercial use.

Over the early 1990’s, the Defense Mapping Agency – since 1997 the National Imagery and Mapping Agency (NIMA) of the United States of America added new layers and extra features to the Yugoslavian topographic maps produced in the late 1970’s and early 1980’s by the Military Geographical Institute (Vojnogeografski Institut). The main reason for that was the political threat of the escalading situation of the former Yugoslavian countries from the early 1990’s which - after several armed conflicts - finally resulted in the breakup of Yugoslavia. Some modifications were made with the old map series, which was produced for the whole territory of the former Yugoslavia between 1971 and 1990. The old Gauss-Kruger projection was transformed to Transverse Mercator and to the WGS 84 datum. Not every map sheet of the Yugoslavian 1:50 000 map series were remade, just those which were the part of the most important conflict zones. As these maps are accessible, they mean an important tool for navigation in many sub ranges like the nearby high mountain ranges Bioč Volujak, Zelengora and others of the Dinaric Alps. However, displaying of touristic relevant objects and trails are essential.

The original Yugoslavian topographic maps were made to be used strictly by military personnel and only for governmental purposes. Their reproduction or communal use was prohibited. For tourists only route descriptions, some guide books and bad quality topographic maps with modified content were available. The Military Geographical Institute was the producer and provider of these map sheets. Between 1971 and 1990, more map series in scales of 1:500 000, 1:300 000, 1:200 000, 1:100 000, 1:50 000 and even 1:25 000 were made which covered the whole territory of Yugoslavia. The smaller scaled maps covered partly or fully the neighboring countries as well.

Ill. 8: A part of the 1:25 000 paper map Maglić

The most detailed and biggest scaled, 1:25 000 maps were similar to the 1:50 000 maps but they differed from that in many ways. The 1:25 000 maps represented about 140 square kilometers on a map sheet of 50x70 cm. A 1:50 000 scaled map covered about 555 square kilometers [URL-16]. These maps were very accurate. The layers have a clear classification and they are displayed well. The language of these maps is Serbian, therefore a good alternative for these original maps is the American reedited map series which contains a small glossary of frequently used landscape forms translated from Serbian to English. In fact, Rock depiction almost not existed at all but in many cases the large scale enabled the use of contour lines in steep areas as well. They were marked with brown and have 20 meters in interval. These 1:25 000 scaled topographic maps are high quality analogue maps for hikers. However, cliff depiction would be a useful element to be added to these maps. What are certainly missing for tourists are the points of interests - POI. Most importantly, these are view points, resting areas and defining of the route type more accurately. Commercial services like shopping areas or the places for accommodation and other notable tourist services are of a great importance in these rarely inhabited areas, too. Other than that, administrative boundaries and related offices should be displayed for sure. The user of these maps should not forget that the map information on the 1:50 000 maps produced for the high mountainous regions of the higher Dinaric Alps is as of the early 1980’s. It means that certain, if not all of the layers have to be upgraded and revised. The more detailed 1:25 000 map series for these areas is about 10 years older than the 1:50 000 versions. Therefore a number of changes could have happened in most of the map information like the populated area, road types, railroads, bridges. But also many important facilities and objects important for tourists like cultural features, obstructions have to be remade. Ground cover can change a lot within 3-4 years as well. Its area and the type of vegetation are important, too.



Ill. 9: Re-edited (left side) and original (right side) Yugoslavian topographic maps (1: 50 000)

Thanks partly to the low number of tourists and the lack of guide books and hiking maps, over the recent years several open source edits were made by tourists. One can find GPS tracks of mountain paths in the Internet. They can be displayed in a number of applications, including Google Earth. This is a real example of the nowadays frequently mentioned fact how Web 2.0 influences many aspects of cartography as well. For areas where no relevant cartographic works are available in the market, this is certainly the case. Digital maps for GPS use containing the hiking trails and the necessary information mentioned above have not been produced, either. But collaborative mapping can open up new horizons here.

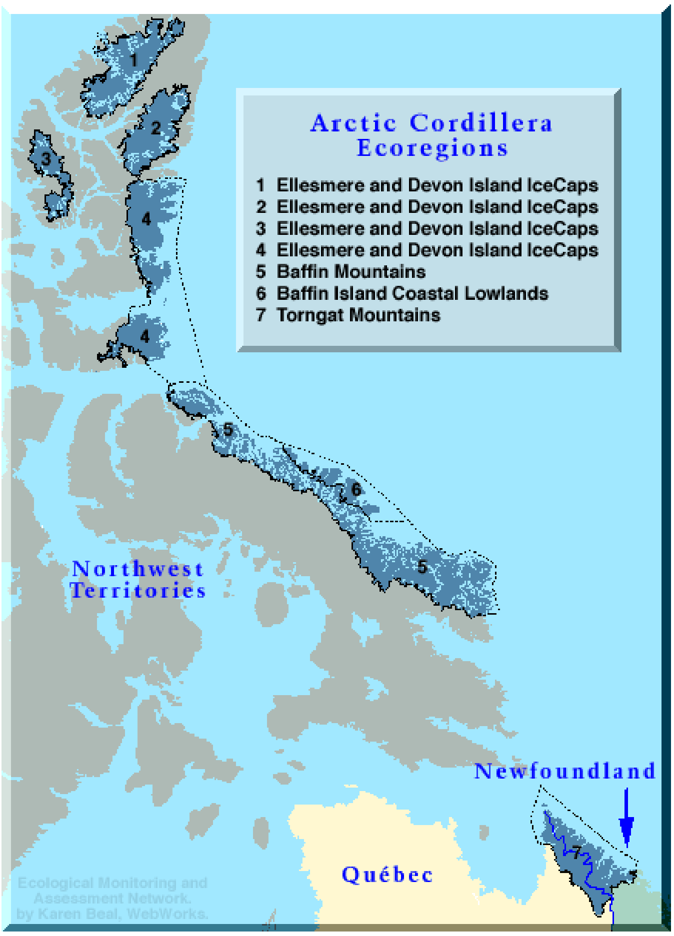
B. North America

North America is home to several magnificent high mountain ranges in which everybody can find an outdoor activity like ski mountaineering, alpine skiing, bouldering, rock or ice climbing, hiking or simply just walking in the beautiful nature. The most of the high mountain ranges are easily accessible and are more or less safe to visit from the national parks, even in the far Alaska.

In spite of this, some ranges are completely remote, not easily accessible and lie far away from any inhabited areas. One of the last ones is stretching in the northernmost isles of Canada. The Arctic Cordillera is a relatively low mountain range with hard terrain for mountaineers. Thanks to its northern location, the whole mountain range is heavily glaciated. It is situated in the Arctic Archipelago mainly on the Baffin and Ellesmere Island. Seven out of its numerous peaks and cliff towers reach an elevation of 2000 meters. But not that is the reason why it is so popular with mainly ice and rock climbers. The steep terrain, the remote mountain faces are real challenges even for extreme mountaineers. This is one of the last mountains on Earth, where still many mountains did not see their first ascenders. Mountains with such walls like Polar Sun Spire with its 1300 vertical meters high north face are not rare in the Arctic Archipelago. On the other hand, during the short summer months tourist ships visit more and more these beautiful and almost non-inhabited islands.

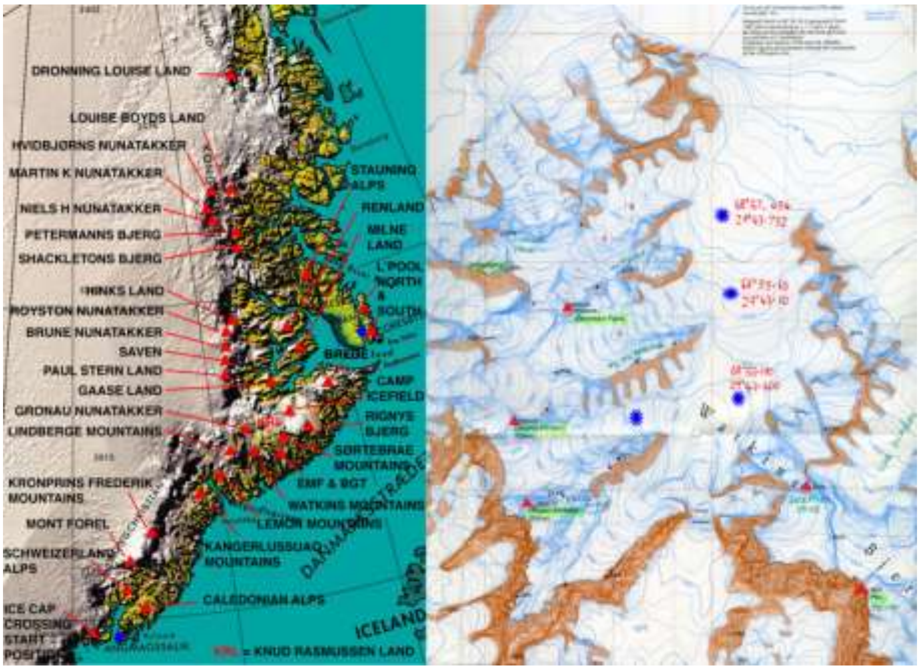
The whole territory of Canada had been covered with the 1:50 000 national topographic map series. Therefore useful help for the navigation can be bought relatively easily. However, a slightly modified version of these maps would be an important contribution for tourists. Nevertheless, collaborative mapping might have a bright future in these remote territories of Canada as well.

One other and maybe even more hidden area is Greenland and its continental areas. In fact, it is the second highest island on Earth which belongs to Denmark. It is considered to be a part of North America and not Europe. Large scale maps have not been produced for its entire area, yet. However, some map sheets in 1:250 000 scale are available which only cover some inhabited coastal areas of the island. Out of that, only small scaled maps have been produced.



Ill. 10: An illustration showing the Arctic Cordillera and its parts

Watkins Range is the highest mountain range of Greenland. It consists of not just many peaks higher than 3000 meters but is also the home to the highest peak of the Arctic. Gunnbjørn Fjeld is the tallest mountain with 3694 meters. Two of its highest neighbors reach above 3600 meters as well. Heavily glaciated surface is what the climber awaits here. Most of the peaks can be ascended on skis. Yet, exposed terrain in iced or mixed terrain is also not hard to find. Over the recent years, more companies dealing with mountain expeditions have been organizing trips to the mountains of Greenland. Respectably, some of them also contribute to open source mapping. Yet, it would be useful to create the first ever big scaled hiking map series depicting some areas of this long mountain range stretching mainly along the eastern coast of the island. Out of the basic map information like contour lines, ground cover and reliefs, ski routes and camp sites should be displayed.



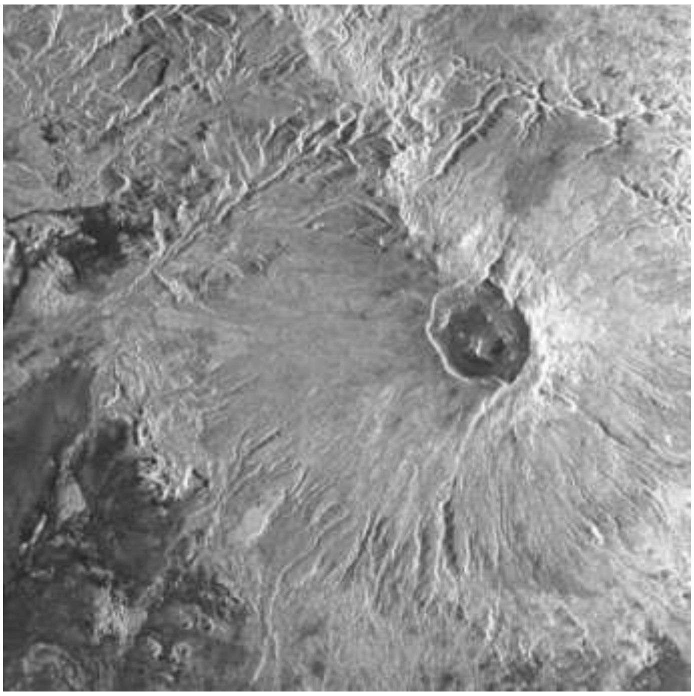
Ill. 11: East Greenland: Notable mountains and a map used by mountain expeditions

C. Africa

In the previous chapter, I have listed some areas of Africa where mountain ranges are not well documented. Hoggar Mountains is a high mountain range situated in southern Algeria. These mountains are a part of a highland from which the volcanic hills and rocks of various sizes rise up. This highland is located in the central Sahara. The highest mountain at 2908 meters is called Mount Tahat. As this region is dry and lies at the Tropic of Cancer, snow cover is rare even in the higher altitudes. Therefore limited activities are possible in the mountain range. But wind erosion created unique rock formations which are popular with rock climbers. The situation of mapping is just on an elementary level. The most detailed topographic maps available for the public is a 1:200 000 scaled map sheet from the national map series of Algeria published by the Cartographic Organization of Algeria. This map can be a good base map for a touristic map as it is being updated over the time. Paths, tourist information and a short guidance are desired to be added to a touristic map. Thanks to the good base map, no additional aerial surveys or remote sensing are necessary but might be done if that is more cost-efficient.

Tibesti Mountains can be found mainly in the northernmost corner of Chad, but a smaller part stretches over the border to Libya. The structure of this mountain range is similar to Hoggar Mountains. Highlands are the base for the erosion formed, completely vegetation free rock creations. The limited number of flora and fauna is a consequence of the dry and hot climate and the volcanic soil. These highlands cover an area of 100 000 square kilometers. The highest peak within that is the Emi Koussi at 3415 meters . This volcano is also the highest point of the Sahara and a country high point in Chad as well. According to some sources, not more than a hundred tourists have climbed this mountain top so far. This has many reasons. Firstly, this is one of the most isolated regions of Africa. Its accessibility is very difficult. No international airports or cities with any kind of public transportation can be found in this area. Paved road network cannot be found at all. Furthermore, the border crossing between Libya and Chad is said to be difficult, too. Most of the few western tourists who finally successfully visited this mountain range could however cross the border after arriving from Libya. Coming from the southern regions of Chad is almost impossible. The other reason for that is the unstable political situation in the region.

The mountains of the Tibesti are primarily may not be in focus due to its high peaks. Though, some mountains reach an elevation of 3000 meters, but technically most of them could easily be climbed. On the other hand, this region could be a paradise for rock climbers. Thousands of smaller and bigger walls and faces are unclimbed, yet. Many of them are probably quite challenging to climb. Even above 3000 meters, snowfall is very rare and it does not accumulate for many days.



Ill. 12: Emi Koussi (3415m), the highest mountain in the Sahara pictured from the space

Maps covering the whole or certain parts of this area are rare. There are no available national map sheets of Chad. However, US Army offers topographic maps covering the territory of Chad in 1:250 000 scale with Transverse Mercator projections. These sheets available for public use were created during the 1960's. Interestingly, Soviet Military maps offer the most detailed maps available today at a scale of 1:200 000 which are a bit newer as for the map information since they are from the 1980's, respectively. As usual for this maps series, Gauss Kruger projection and the Pulkovo 1942 datum is used. Contour lines are displayed after every 40 meters of vertical rise. As mostly only Cyrillic letters are used on the map, this is obviously a disadvantage of this map series affecting many users.

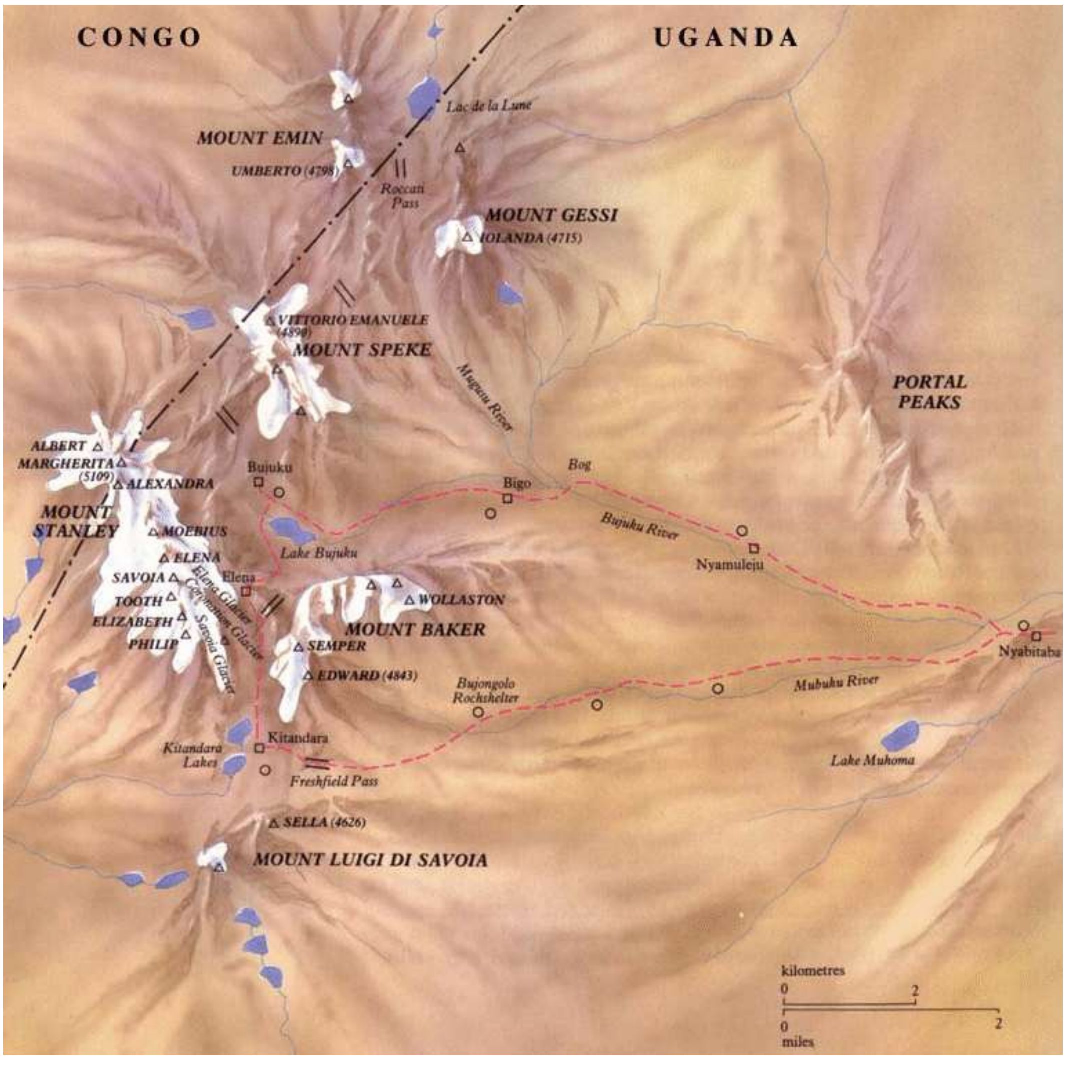
Moving about 2000 kilometers to east-southeast, Ethiopian Highlands is a well known, vast mountainous area situated in East Africa. It is also called the Roof of Africa as the average height of this region is between 1500 and 2000 meters above the sea level. Several mountain ranges dominate this highland, of which some rise to heights even above 4000 meters. Despite this elevation, no glaciated areas can be found within these mountain chains. The reason for that is the tropical climate of this area and the low annual precipitation. There are a number of high mountains in these highlands which are high enough to be considered to be a destination for mountaineers. The accessibility of this mountain range is limited, not to mention the possible security risks.

The Simien Mountains is the highest mountain range in Ethiopia. Its tallest mountain is Ras Dashan. Previously, its height has been measured at 4620 meters but more recent measurements showed that it reaches only about 4550 meters. Next to it, dozens of peaks reach 4000 meters. Thanks to the country’s better political situation and the easier accessibility, this peak has been more and more popular over the last decades. According to sources, local tour guides also organize tips to this technically not challenging mountain peak which is by the way an ultra prominent peak with about 4 kilometers of topographic prominence.

Bale Mountains are a range of high mountains with many peaks reaching to 4000 meters and more. These mountains are situated in southeast Ethiopia. The landscape is a bit different from the Simien Mountains. Here the dominant mountain faces and walls are more frequent. The flora and the fauna are richer as well. This mountain range might be an extraordinary destination for those, who like trekking tours and multi-day trips to tropical high mountainous areas. There have been less visitors of the Bale Mountains National Park than the northern Ras Dashan, yet.

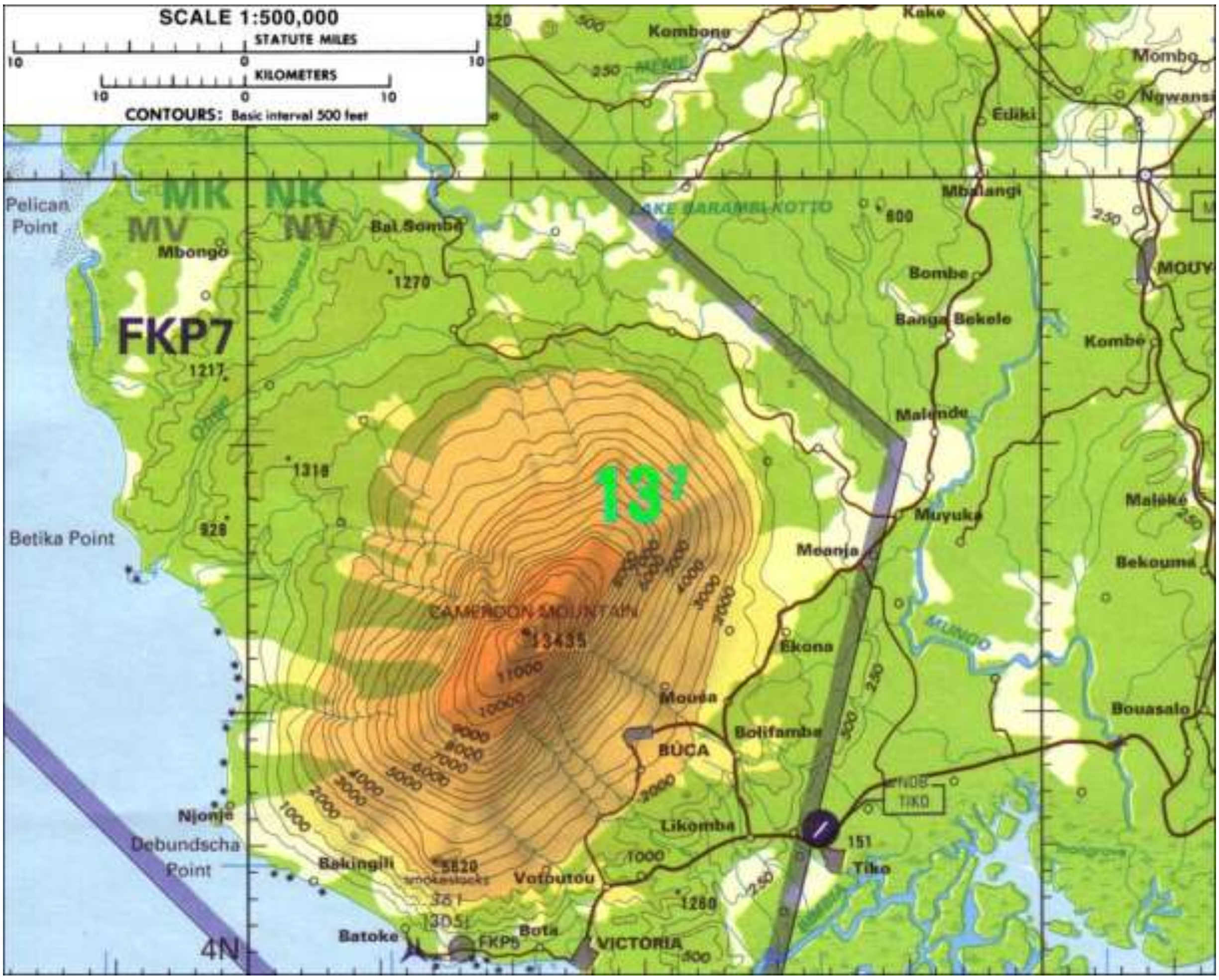
Ethiopian Mapping Authority has already published large scale, 1:50 000 scaled topographic map series for these mountain ranges as well. These maps have a Transverse Mercator projection. The map information has not been updated recently – it is from the 1990’s. Even though, these maps can serve as a base map for a future touristic map of the area. A map of the Simien Mountains is also available online, provided by the local national park. It is a very simple application without search function. But this is a good sign of the improvements from the locals in order to boost the tourism.

The Rwenzori Mountains is a mountain range located in Equatorial Africa. It is situated in the border region of Uganda and the Democratic Republic of the Congo. Its highest point is Margherita Peak of Mount Stanley at 5109 meters. It is a country high point for both neighboring countries. It is an ultra prominent peak with about 3950 meters of clean topographic prominence. This is the one of three 5000 meters tall peaks here but several one rises up to 4000 meters, respectively. Just like the other few glaciers in Africa, the snowcaps on Rwenzori have been melting heavily over the last few decades. It is therefore not a coincidence that in the middle of the last century the size of the glaciated area was 6 square kilometers, by now it is only about one. Rwenzori Mountains is a popular touristic destination of Uganda. Yet, much less tourists visit this natural heritage than the Kilimanjaro, located not that far away. Despite, Africa's third highest mountain range has a lot to offer: organized multi-day treks and rock climbing are just some of them. There are a surprisingly low number of maps and guide books published on this area. The Rwenzori Mountains National Park created a map showing the main attractions for tourists along with accommodations and transportation facilities within or near the park. Department of Lands and Surveys of Uganda published 1:250 000 scaled topographic maps of the country which entirely cover the Rwenzori Mountains as well. Created in the 1970's, these map sheets are using the UTM system but are not very relevant to use. A more detailed and newer 1:50 000 scaled topographic map is available, created by the Surveys and Mapping Department of Uganda. This map series has a Transverse Mercator projection. Nevertheless, either a touristic map or a downloadable map for GPS use would be essential.



Ill. 13: A sketch of Rwenzori, created decades ago but still used today

In Western Africa, Mount Cameroon is the highest active volcano of Africa and the ninth highest in the world. It is a stratovolcano reaching an elevation of 4040 meters. Its prominence is 3900 meters, making it the 31rd on the list of peaks by prominence. The mountain was first ascended in 1840. Thanks to the big amount of precipitation, its summit area is sometimes covered with snow. This volcano is considered to be technically not challenging. The very final parts can sometimes be done with skis as well. This is a popular mountain, where even trail running competitions take place each year. An experienced hiker can reach the summit without difficulties in two days. Moreover, local guides or porters can be hired as well.



Ill. 14: Mount Cameroon (original scale: 1:500 000)

Mapping of Mount Cameroon for touristic purposes have not been done, yet. As a target area of this work, it had been selected to be mapped as the low cost hiking map created in the context of this work. There are however some map series that cover Cameroon available on the market. The 1:200 000 scaled Soviet military topographic map series is the most detailed one. This is also the youngest of the available maps regarding the map information. The US military maps with a scale of 1:250 000 have been produced over the 1960's. In the same scale, maps of Joint Operations Graphic are also covering these areas. National mapping of Cameroon has not yet been done.

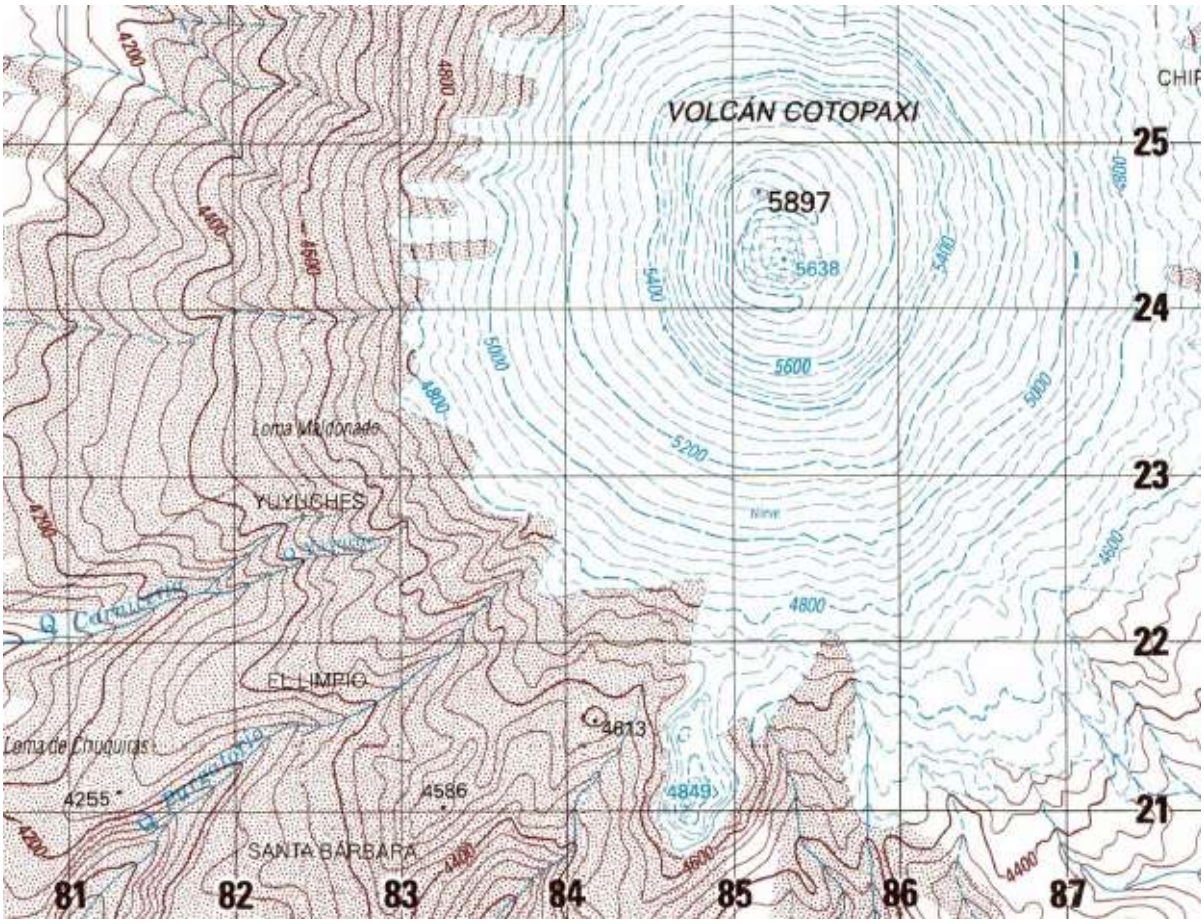
D. South America

The Andes, as it was shown in the last chapter, have some untouched yet relevant areas for hikers, trekkers and mountain climbers. Here I would only mention some areas which have not been in the focus of the tourists so far. As it was described before, the Andean countries are well documented on topographic maps. Other than that, hiking and touristic maps have been produced of many ranges of the Andes as well.

Cordillera de Mérida is one of the northernmost high mountain ranges of the Andes. It is located in northwestern Venezuela. Sierra Nevada de Mérida is the highest range within these mountains. The country high point Pico Bolívar is located there as well. It is a popular destination for tourists even for shorter trips as the world's highest cable car station is located on one of the high peaks in this range, located approximately at 4780 meters above sea level. Therefore the area together with the Sierra Nevada National Park seems to be a good subject for a hiking map. Interestingly, the glacial retreat has been so severe over the last decades that it seems to be obvious that Venezuela will be the first Andean country without glaciated areas. The third highest mountain, Pico Bonpland has already lost its glaciers by 2011 [URL-4].

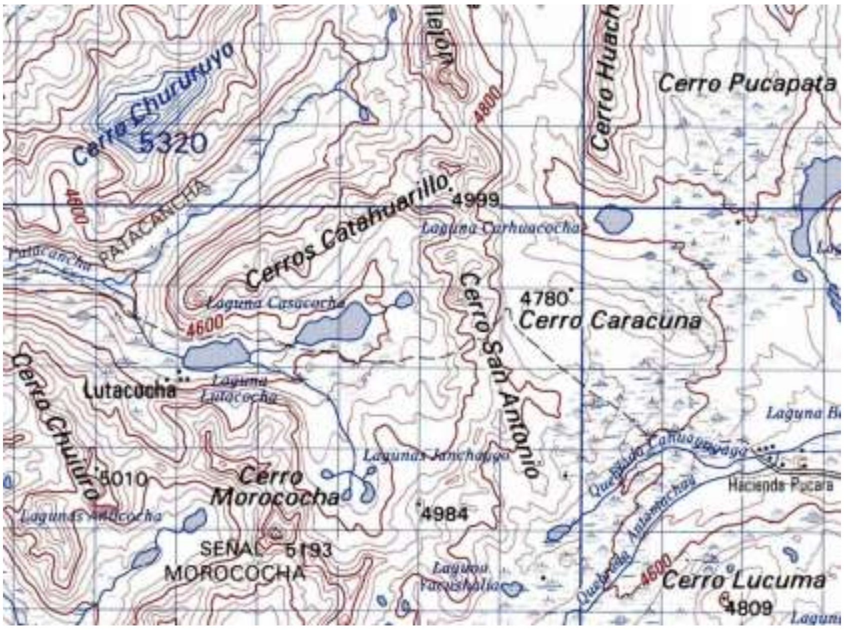
Another less known range of the Andes is the Cordillera Oriental or East Andes. This is mainly because it does not have any country high points or notable volcanoes. Despite, its accessibility and the short distance to the capital Bogotá makes this high mountain range a good choice for adventurers. The highest peak, Ritacuba Blanco reaches an elevation of 5410 meters and it is located within El Cocuy National Park where a dozen of 5000er peaks can be found. Its mountain top is completely glaciated, making it one of the few permanent ice-capped mountains of the East Andes. However, researchers are estimating the total melting of the ice cap until 2025. As Columbia already produced a detailed, 1:50 000 scaled map series for its whole territory, it can serve as a proper base map for future touristic maps. According to the national park, only about 4500 tourists visit the park annually. It is an unbelievable low number compared to the beauty of the landscape and the good accessibility.

A number of interesting volcanoes arise from highlands in the territory of Ecuador. Chimborazo is the highest of them, but almost ten of those reach an elevation of 5000 meters. Topographic maps are available in a scale of 1:25 000, which is unique in South America. However, peaks like Chimborazo or Cotopaxi are so popular destination for climbers from all over the world that a hiking map specially redesigned for mountaineers would be essential. As the highest peaks are not located very close to each other, one detailed, 1:25 000 scaled map sheets cannot display many of them. But a map could contain more pieces of smaller maps with the cut of the areas between them. In this case when only one peak and not a long mountain ridges have to be displayed, this might be a good solution. The base map for the hiking maps may be the national topographic map sheets in scale 1:25 000 with Transverse Mercator projection. The map information of these maps was added during the early 1980's.



Ill. 15: Topographic map of Cotopaxi (5897m) – original scale is 1:50 000

Perhaps the most rarely visited ranges of the Andes are located in Peru, right within Altiplano. This is a vast highland with an average height of nearly 3800 meters [URL-4]. It stretches from south Peru through the western areas of Bolivia until Argentina about parallel to the Pacific Ocean. This plateau is home to more sub-ranges of the Andes with several dozens of peaks over 5000 meters and many even above 6000 meters, respectively. This area forms the central parts of the Andes. Several volcanoes and mountain ranges stretch here, making it one of the most fascinating areas for mountaineers in the Andean countries. Despite, these mountains are not so popular like the huge volcanoes in the neighboring Andean countries or like the area of Cordillera Blanca.



Ill. 16: Topographic map of Peru – original scale is 1:50 000

The Willkanuta mountain range is a vast mountainous area. Within its territory, there are 5 mountains reaching 6000 meters and dozens of other mountain tops are over 5000 meters as well. This mountain range is the most glaciated within the Central Andes. This is a quite well accessible region of the Andes. It is a real paradise either for a trekker or a mountain climber. In some mountains, ski mountaineering is also possible as this is a relatively wet and therefore greatly snow covered area of the Andes.

The Coropuna is a big stratovolcano which rises from a volcanic highland in southern Chile about 100 kilometers from the Pacific Ocean. This is the highest volcano in Chile. It is the part of the Central Volcanic Zone of the Andes, which theoretically borders the Altiplano from the west along its entire length. There is a vast ice cap on the mountain extending to as low as 5300 meters. It stretches on a surface of about 130 square kilometers. Its first ascenders were probably the Incas as some findings were found not far from the summit, recently.

Another less known high mountains in the nearby is the Kallawaya mountain range. It is located in the Carabaya Province of Peru. It does not have peaks higher than 6000 meters but as for technical difficulty, these glaciated peaks are mostly featured with steep walls and crevassed glaciers. It is very rarely visited as long walks are necessary just for getting to the base camps of many of its mountains where the real adventures in fact are just about to begin.

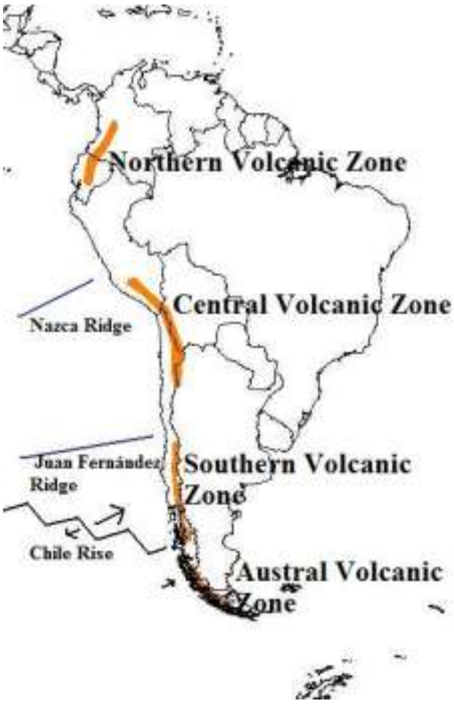
Cordillera Apolobamba can also be found right in the borderland of Peru and Bolivia. Just like its neighbor, it has many fascinating peaks. Dozens of them rise from the high plateau where the highest navigable lake itself, Lake Titicaca is also located. The highest one is Chaupi Orco which is 6044 meters tall [URL-5]. The area of these mountains is rarely inhabited. According to descriptions, long walks lead even to the base camps of many mountains. Even today, first ascents can be made in many of these mountain faces. Unfortunately, no accurate navigational tool has been made, yet. A British Expedition reported after their climbs in the area in 2005 that they used a map which was based on a 1913 British survey.

Cordillera Kimsa Cruz located entirely within Bolivia. It is less popular range like its northern neighbor, the Cordillera Real. Yet, it has some stunning landscapes and high mountains. It has about 30 peaks over an elevation of 5000 meters. As the main ridge is only 35 kilometers long, a single 1:50 000 scale hiking map might contain the whole area of that. Its accessibility is also good, as the capital of Bolivia La Paz lies only about hundred kilometers from that. Interestingly, La Paz has the highest elevation among the capitals, ranging from about 3200 meters until 4100 meters, respectively. It is the biggest city of the Altiplano as well.

As a part of the Central Volcanic Zone of the Andes, several high stratovolcanoes rise in the border region of Chile with Bolivia and with Argentina. There are numerous 4000 and 5000 meters tall mountains here which are very rarely climbed [URL-4]. It is thanks to the remote location, as the Atacama Desert and several minor and major salt lakes make human life impossible there. The few inhabited places are usually home to the miners who work in extreme conditions high above the vegetation. Snow line can only be found at 6000 meters or even higher, above 6500 meters. This is the highest in the world, topping every other place. It is because of the lack of precipitation and the lots of sunshine. The highest and most popular mountains of this border area are Ojos del Salado at 6893 meters and Llullaillaco at 6739 meters. These two are the highest active volcanoes on Earth. There are a number of other volcanoes above or near a height of 6000 meters within the Central Volcanic Zone of the Andes which stretches about 1500 kilometers long. As this is not a guide book, all of the notable volcanoes of the area cannot be listed. One of the better solutions would probably be the individual displaying of these mountains so that the huge and less important surrounding areas could be eliminated from the map.

To the west from the southern part of the Central Volcanic Zone, not too many notable mountains can be found. One of them is Nevado de Cachi at 6380 meters. It is located about 150 kilometers from the high volcanic area, entirely in Argentina. It is a rarely visited mountain. As a non-volcano, this is one of the easiest 6000er in the Andes. It is also easily accessible. This can be a popular destination in the future even for trekkers. Due to the relatively small area, a detailed touristic map can cover its whole area.

The Southern Volcanic Zone consists of some even less popular mountains. One of the reason for that is the fact that the highest peak of the Andes, Aconcagua can be found in the nearby as well, catching a lot more interests. However, some of these volcanoes also reach 5000 and even 6000 meters [URL-4]. Although, peaks getting lower as we go farther to the south from the Chilean capital, Santiago.



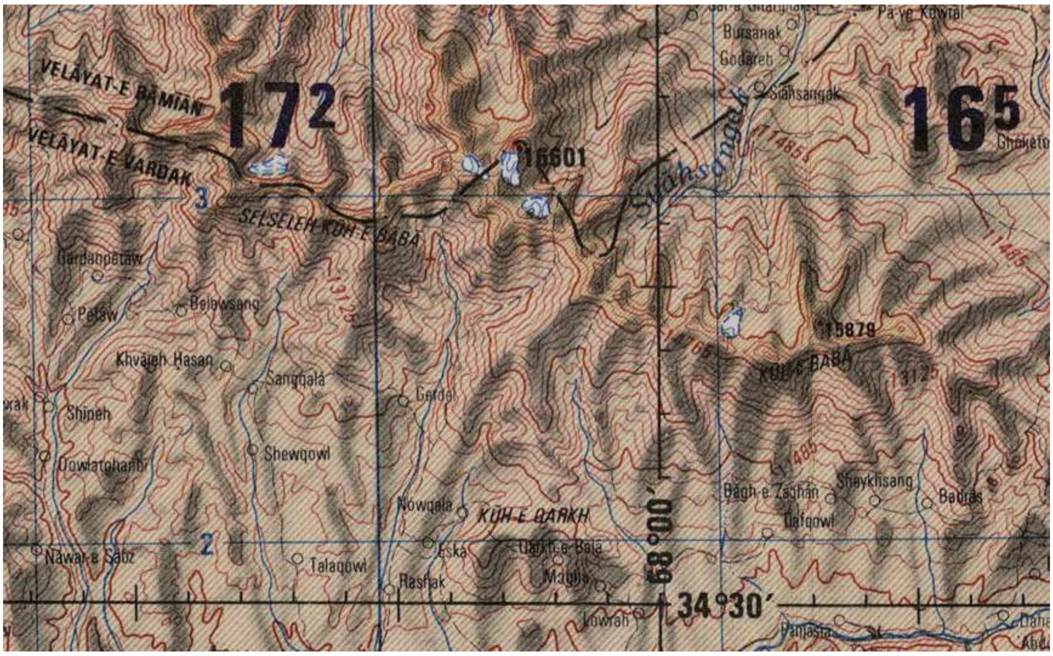
Ill. 17: Volcanic zones of the Andes

Patagonia is a popular place for mountaineers. Here also the Chilean border and near its vicinity the most famous destinations are located. The rapid growth of the precipitation can be observed as we move to the south. At its southernmost mountains, snow line descends to about 1000 meters. Comparing to the 6500 meters at Atacama Desert, this is the highest variation in these values within one mountain range. The morphology of the mountains is different from the northern and central ranges as well. Unique rock formations, steep mountain faces, hard accessibility, great distances and severe weather: these are the most important features which are typical for this area. Several high volcanoes and mountains are reachable without climbing equipment in the Andes. Yet, Patagonia is home to much lower mountains which are technically more difficult than their northern neighbors. Several mountains were first climbed just during the second half of the last century. The vast area of glaciated surface also makes the reaching of many peaks difficult. Touristic maps of Patagonia are available for the most visited national parks and mountains up to about 1:80 000 scale. Yet, some interesting mountainous areas can be found in this 800 000 sq km area which has not been mapped for touristic purposes.

Another mountainous area is Guiana Shield, which has some prominent peaks as well, like the almost 3000 meters high Pico da Neblina or the Cerro Marahuaca in the heart of the rain forests of Amazonia. Due to its remote location, very few tourists visit the highest mountain of Brazil. This is also because of the lack of guide books and cartographic products which are provided from the mountains of Amazonia.

E. Asia

No other continent than Asia has mountains above 7000 meters, respectively. But here there are several, as I listed them in the previous chapter. Some of them are more or less known for expeditions, some of them also known for trekkers. Yet, numerous ranges and sub-ranges have still not been visited too often by Westerners.



Ill. 18: Hindu Kush Mountains near Kabul - JOG topographic map, original scale is 1: 250 000

Hindu Kush is the westernmost mountain range with peaks reaching 7000 meters. It has many remote chains which despite their steep terrains have not been popular destinations for mountain climbers so far. The highest part of the Hindu Kush is definitely its eastern range. For mountaineers, the central and eastern ranges are the most relevant. Some hiking maps have already been made on this the area but only the highest peaks were captured. As Afghanistan is politically still an unstable country, no improvement of the tourism is to be expected in the next years. However, many technically difficult routes are leading in big heights could be done in the area between Kabul and the Wakhan corridor where the essence of this mountain range lies. Despite the lack of hiking maps, some good and also detailed map series are available for the whole territory of the country, like the Soviet 1:50 000 maps, and the one published by East View Geospatial with the same scale. Topographic maps of the Joint Operations Graphic – JOG are available at 1:250 000 scale.

Pamir Mountains is the northern neighbor of Hindu Kush. It spreads in a smaller area, but it has more well known peaks. Perhaps all of the most famous 7000er peaks can be found here: the former Peak Lenin, the former Peak Communism. The most climbs lead to these two mountains in this region. Accordingly, Peak Lenin – now Ibn Sina Peak is considered to be the easiest mountain above 7000 meters. Therefore it is the most frequently attempted climb in the Pamir. Other than that, Peak Korzhenevskaya is the third and last peak here above 7000 m. The Pamir does not have so many notable mountains like the Hindu Kush but the steep and highly glaciated walls and faces make it a real challenge even for expedition style climbs. Kyrgyzstan produced some maps in a scale of 1:200 000 which cover the central Pamir but Soviet maps are available for this area as well. Anyway, these Kyrgyz maps are only some kind of modernizations of the Soviet maps.

Tien Shan has many chains which are unknown even for most of those who have already been participating in Central-Asian mountain climbs. This is not a coincidence, as this mountain chain stretches from the Pamir through northeast China almost until the Mongolian border. Even only kilometers from the well known area around its two summits reaching 7000 m, lots of peaks are awaiting the mountaineers. Some of these glaciated mountains have very steep relieves and were first climbed during the 1980's and the 1990's, but still today one can find unclimbed peaks among them. As an addition to the 1:100 000 expedition maps produced by the Austrian Alpine Club, at least two more map sheets specially designed for mountaineers could be created for the area. Through the central and eastern ranges, one can find more mountain chains with various elevations. The highest are definitely the western areas with about 30 peaks over 6000 meters. Although, Bogda Shan in the eastern range has numerous peaks above 5000 meters as well. Interestingly, mountaineering has begun there only in the early 1990's. Since 2013, the eastern part of the mountain range is classified as a World Heritage Site and protected by UNESCO.

Kunlun Shan is one of the longest and perhaps the remotest mountain range stretching through Northern Tibet. Therefore a number of its peaks are unclimbed, yet. The most important reason for that is the fact that the only road connection to the vast Central Kunlun is the Xinjiang Highway. Other than this, no good quality paved road have been built in the area which has almost no inhabitants due to the extreme weather and big elevation. The world's second highest non-arctic desert, the Taklamakan is located to the north from that as well. The so much isolated central areas of this mountain range can be the last places on Earth that will be visited by great number of mountaineers. Despite it is relatively hard to get to the area the several non-technical 6000 high mountains are awaiting the mountain adventurers from all over the world. Mountains here are not featured with huge walls or not with extraordinary prominence, but they may certainly be challenging to climb and all before just to find them, too. Probably, a 1:100 000 map series of the most relevant peaks would be the best solution for the users. The approach of the mountains needs to be displayed on maps with smaller scales in a range of 1:200 000 to 1:500 000. The reason for that is the vast areas which has to be covered and the not too various terrain which is typical for these plateaus. What would and has to make a Kunlun hiking map special is the basic identification of the soil types around the mountains as even off-road vehicles deal hardly with some of the local soil types. In the lack of routes, this is what can make navigation and route planning possible. The other reason for the smaller scale is the low number of map elements. In this moon surface-like area, no vegetation can be found. Human settlements are extremely rare; therefore no buildings or man built objects can be found. This makes the job of the cartographer easier. Also, cliff depiction should not be made here as the morphology and the high level of glaciations don't require the use of that. Nevertheless, updating of maps too frequently would also not be of a great importance.

Ill. 19: Target areas shown on a Google Earth image

Hengduan Shan is perhaps the least known 7000 m high mountain range on Earth. It is located in Sichuan province of China but its sub-range continues in Myanmar. Only some parts of that rise above the vegetation zones at about 5000 meters. The highest peaks are heavily glaciated here. Mount Gongga is its highest mountain at 7556 m which makes it the third highest peak outside of the Himalayas or the Karakorum. It is also the easternmost 7000 meters summit on Earth. An interesting question is that why this mountain range has not been popular with mountaineers so far. It is partly because of its location: too far for Westerners and located partly in Myanmar and in the disputed area of Arunachal Pradesh and China. It is also because a number of taller mountain ranges are situated in the nearby. The structure of these mountains is very specific. Its ranges run mostly parallel to each other in a north to south extent. One of them is the Meili Xue Shan with more peaks over 6000 m. A number of them are still unclimbed or summited only a few times. Mountaineering began here in the late 1980's but expeditions to this region are rare. Though, its accessibility is not bad and even trekkers can find reasonable paths around the group of high peaks. Furthermore, the morphology of these mountains is very unique: almost Himalayan landscape is what the adventurer can get there. Steep walls, hanging glaciers and strange rock formations are awaiting the mountaineers. Another sub-range with great potential for climbers is the group of Four Girls. It is also known as Siguniang Mountains. Some very steep mountain faces can be found there which have been becoming increasingly popular with mountaineers over the last few years. They mean a real technical challenge even for the most prepared climber. The highest peak reaches 6000 m here as well.

Crocker Range is a popular destination of mainly those who like to spend some days in the mountains even during a seaside holiday. This breathtaking coastal mountainous area is national park in Malaysia since 1964. Its highest point is at 4095 meters. This is an ideal destination for trekkers and for those travelers who would like to see Borneo from above. Hiking maps have not been made of this area, yet. However, topographic maps of Malaysia cover this area in scale 1:25 000.

Barisan Mountains are a less known volcanic mountain chain stretching along the western coast of the Indonesian island Sumatra. Its length is almost 2000 kilometers. Two volcanoes reach 3000 meters while numerous peaks are between 2000 and 3000 meters. Trekkers are the main target group for this area. Indonesia's national topographic map series cover this area in 1:50 000 scale. However, for some areas sheets of the 1:25 000 map series are also available. Other volcanoes in Indonesia are the Mount Rinjani and Mount Agung. They are located on the island of Lombok. These mountains can be reached without technical difficulties.

4. Data Acquisition and Data Processing for hiking maps

1. General overview

A. What it is all about: the geographical data

Geographical information has a key role in making a map, regardless of what the final product is. It is the most essential unit, the basic element, the core source of data which is captured, stored and then analyzed, managed and maintained with geographic information systems. It is in some ways the same for a GIS like a pixel for a picture. Geographical data gives the location of surface-based objects and features. Some of these are of natural origins while others are human made. Most of the time, these features have concrete locations on the earth's surface. In special cases, these objects can move over time which makes their depiction more difficult. Typically, glaciers belong to this group of objects. Acquiring geographical data serves two purposes: to produce maps and to produce databases aimed at managing and storing the data itself. According to Y. –C. Lee [CHE-01], the role of these databases and analogue maps is almost the same, though databases only store and support the analysis of the data and not displaying it. The term geospatial metadata or simply metadata is also frequently used and refers to the additional information of a digital geospatial data that helps the identification and description of its other features.

Choosing the techniques and methods of capturing these data needed for the target map, is a must before any kind of work. Geospatial data can be collected by digitizing analogue maps, by field surveying or by air- and space-borne remote sensing. Considering the costs helps us select the ideal techniques and methods. This greatly influences the cost of the end product. It is therefore a must to plan the exact workflow and to search for the most cost-efficient ways. In this chapter the focus will be on methods which can be helpful when creating a map. But what steps and processes are needed to create a map? J. D. Bossler [BOS-02] lists three main processes that help to make decisions using geospatial data: acquiring data, analyzing and processing of data and distributing the data.

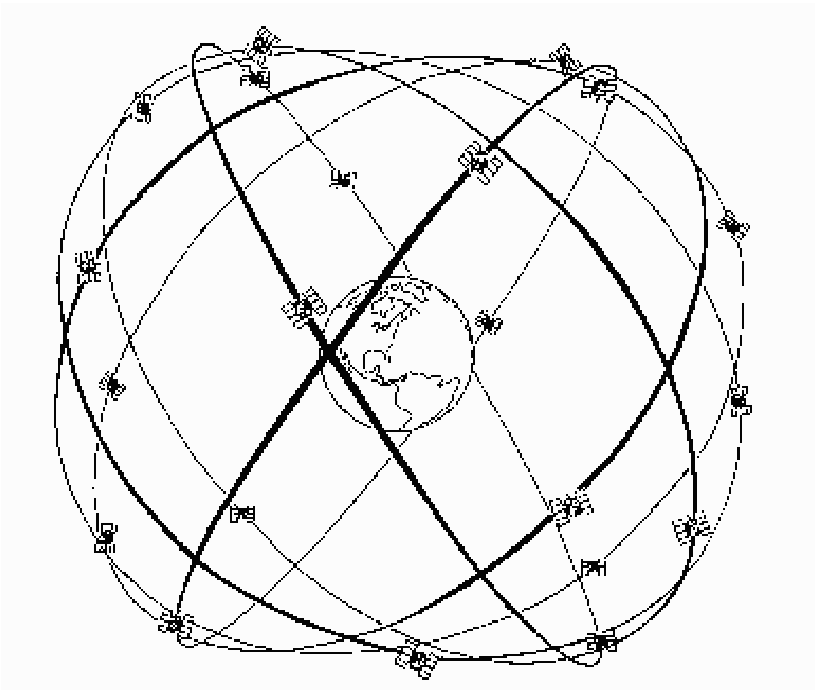
I believe that analogue hiking maps have still a lot to offer to mountaineers. Doing any kind of outdoor activity in remote regions can be highly demanding even for the electronic devices and not just for the tourists. Special conditions only encountered far from the civilization can make our days in the backcountry completely different from everyday life. The simplest reason for using analogue maps is their convenience and reliability. Unlike an electric device, it does not need heavy batteries or electricity from time to time and also extreme weather conditions do not influence its use significantly either. Important for analogue hiking maps is the content and the physical features: using good quality, more or less weatherproof materials are at least as essential as the map information itself. This chapter deals with the latter as acquisition of geographical data means the first step in the map making workflow. During this process, geographical data can be collected from many sources in various ways. I would divide data capturing basically into two groups: capturing and buying of core data that needs further processing and buying fully processed data that is already a product evaluated with GIS. Examples of the former are the buying of core databases of remotely sensed data or making own efforts to collect terrain data. Despite certain preprocessing of certain satellite imageries is needed for their further analysis, it can considered to be first-data even after preprocessing it. Another way of data acquisition is using an analogue map as a data source for further analysis. The other possibility is the acquisition of already processed, analyzed and specially utilized GIS products which can be used as a map since in this case the geographical data had already been analyzed and evaluated with GIS software. Vector maps or processed digital elevation models are such products.

The emphasis is put on the methods of data capturing with short descriptions of them along with answering questions among others like what can they be best used for or how can these data be derived. Of course, understanding technologies is an important task for anybody who wants to use them. The focus is therefore also put on the descriptions of every essential aspect of spatial data and their processing. Regardless of what process of the workflow we are dealing with, having a basic theoretical understanding of the method in question is essential for its proper practical use. It is essential therefore to take a look to the details as well. However, the chapter aims at showing the relations between processes of the map making workflow and to describe what the applied technologies are used for. Furthermore, approximate costs will be taken into account.

Acquiring geographical data can also be done by amateurs. Though mainly experts are dealing with this process, amateurs can also provide data. Especially the last few years were important for this new aspect of cartography, the use and collecting of user-generated spatial data. Nowadays, collaborative mapping is one of the most debated phenomena in cartography. Can it be used when creating a cartographic product? Is the data quality good enough to use them when creating certain layers of the map, is the source reliable at all? All these and further questions are needed to be discussed. Still, I would like to deal with this even popular side of cartography in another chapter as it does not fit into either of the two above mentioned ways of acquiring data, because the use of collaborative mapping alone is not enough for creating any kind of cartographic product. Despite, it can be useful when creating certain map elements. However, data accuracy is one of the problems of this new, free, user-made contribution to cartography. With the help of quality assurance and accuracy assessment processes one can determine the possible errors from remotely sensed data.

B. Positioning systems: a necessary tool for measurements

Accurate positioning is needed for both terrestrial and non-terrestrial data capturing. No matter which method of collecting geographical data we are talking about, the exact position of the measuring instrument and the measured objects has to be known with high accuracy. According to C. Rizos [BOS-02], there are three components of the GPS technology and applications: the space segment, the control segment and the user segment. Satellite segment consists of the satellites and the transmitted signals. Ground control stations necessary for a number of tasks belong to the control segment whilst the user segment means the applications, equipment and the techniques used by users. Navigation devices are the receiver units which can determine their own location in a 3D Cartesian coordinate system either with *x, y, z* values in meter or with the use of geographic coordinates of latitude, longitude and height depending on the user needs, the device specifications and settings. These data is captured directly from the navigational satellites which are moving in an orbit with well-known characteristics. These satellites are circling in different orbits in order to provide complete coverage. The control stations located in different areas on the earth's surface are monitoring them in order to ensure the accuracy of the whole system.



Ill. 20: Orbits of NAVSTAR satellites

To achieve a more or less accurate positioning, the receiver unit has to be in contact with at least 4 satellites. Normally, data from 6-8 satellites can be obtained without difficulties if the receiver is not disturbed. Typically, such effects that can negatively influence measurements are partly caused by the environment where the receiver itself is located. Such phenomenon is the multipath effect during which the incoming signal changes directions from one or many objects before it is processed by the receiver. Tree canopies and other terrain features can cause such effects as well.

Positioning is an important process which aims to determine the exact position of the measuring unit. There is a so called absolute and the relative way to do it. Most importantly, absolute positioning is possible with the global positioning systems and a navigation device. Relative positioning is also possible with the use of GPS information by positioning a receiver relative to a known static receiver. Another case of relative positioning is when studying the spatial behavior of one moving object over the rate of time is desired. In this case we can give its actual position derived from its recorded position at one known point of the past.

Nowadays, various kinds of these systems are available for commercial use. What is common in their system structure is the technology and hierarchy between the satellite, the ground station and the receiver. This original structure was first used by the American Global Positioning System. It is the first space-based satellite navigation system that is freely available for public use. Created by the U.S. Department of Defense in the 1970's, it also serves for military purposes with much higher accuracy. For many years this was the only navigational system which was accessible for the public. Originally, 24 satellites were circling in different orbits in order to provide complete coverage. Currently more than 30 of its satellites are in operation [URL-13].

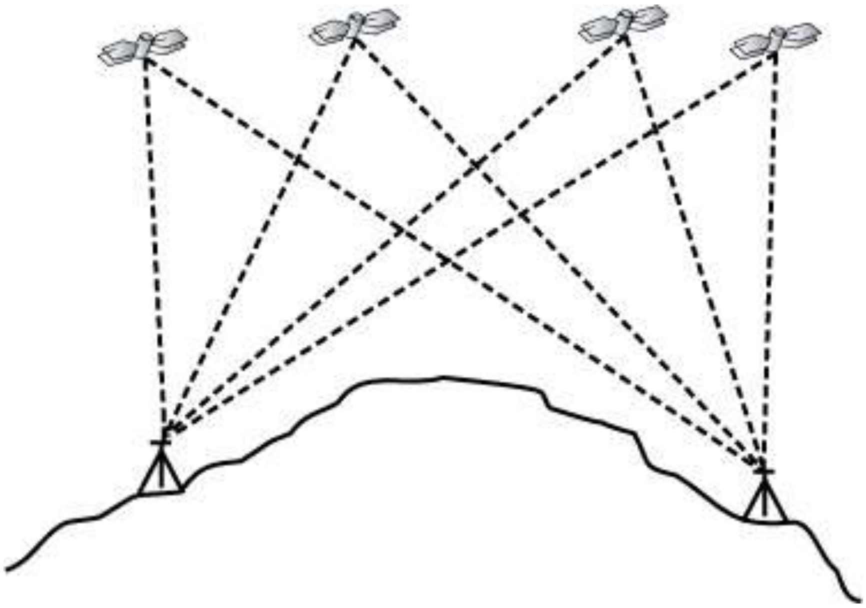
Galileo is Europe's planned satellite navigation system. As of August 2014, it is still in the testing phase. Currently only 4 of its 30 satellites have been launched in order to make system validation. By 2019 however, all of them will be in operation and 3 will be spares. Galileo has been funded partly by the European Union and the Member Countries. Other than that, Israel, the Ukraine, Morocco, Norway and even South Korea have interests in the project. Thanks to the project's goal of open access navigation, the use of the system will be available for the public with about 1 meter of positioning accuracy.

Beidou Navigation Satellite System is China's contribution to the satellite navigation. Although testing began in 2000, it only entered to the market in December 2011, when the operation finally started for the Chinese users. Since 2013, the entire region of Asia-Pacific is served by Beidou. As projected, it will consist of 35 satellites and global coverage will be reached by 2020.

Last but not least, GLONASS is the Russian system developed for military and civilian use. Its global coverage consists of 24 satellites. Interestingly, 18 of them are needed just for covering Russia itself. GLONASS began operation in the 1980's but reconstruction of the whole system had to be carried out since then. Most recently, global players of the commercial sector have begun to use GLONASS system as well.

Accuracy of civil GPS measurements has been influenced by the so called Selective Availability (SA). It aimed to intentionally degrade GPS signals. In 2000 however, the US government discontinued its use. At the same time, unintended errors can obviously not be avoided, but taking them into consideration, measurements can be made with relatively high accuracy. According to Campbell [CAM-02], these errors have several causes: orbital position, clock error, ionospheric and tropospheric effects, noise by the GPS receiver and the multipath error.

Differential GPS (DGPS) is a measuring technique of GPS which allows more accurate, precision positioning for navigational or mapping purposes. Basically, two receivers are enough to make a differential measurement. One reference receiver and a stationary or moving receiver are needed for that. Both of these GPS receivers collect data from at least 4 satellites at the same time. According to E**.** Mok and G. Retscher [CHE-01], data can be evaluated either in real-time or off-line. If it is done during real-time operation then the receivers have to be connected to each other. Using of DGPS technique is usual in field surveying.



Ill. 21: Differential GPS measurements

Another type of positioning systems is the inertial navigation system (INS). It is a self-contained system with several types of measuring instruments like gyroscopes and accelerometers. Most typically, it is used for navigation of spacecrafts, marine and sub-marine vehicles used mainly for military purposes. Terrestrial surveying benefits not too much from this type of systems. Sensors usually work with 8-25 meters of accuracy. Its main advantages over global positioning systems are the independence from other systems, the ability to work in bad weather and in isolated areas like tunnels or in underwater environment. The disadvantages of these systems are the costs, the relative small operational distances and their physical parameters like size and weight.

2. Ways and methods for Data Acquisition

Data can be derived in many ways with the use of remote sensing methods. Depending on the data source, we can make a difference between terrestrial and space- and airborne measurements. In both cases data capturing cannot just be made with instruments which are used only either for terrestrial or for extraterrestrial measurements. In many cases the same technique can be used on satellites or in field surveying as well. It is important however, to make a difference between the two as airborne remote sensing is focusing on the lower scale detection working in the meter to decimeter range while terrestrial measurements can mostly get to the mm range as well. Despite, hiking maps do not need mm accuracy even if a detailed mapping would be desired. Ground based and space- and airborne remote sensing have important roles in surface monitoring and are both important sources of spatial data. Hereby these methods of data capturing are listed in two groups depending on the location of the data collection.

Already existing cartographic products can also be important data sources. Digitizing analogue maps might also be more cost-efficient than buying data which still has to be analyzed before further use. Many questions arise however regarding this way of getting data. All before, the map maker has to be sure that it is allowed to re-use at least certain elements or layers of the particular analogue map. Other than that, data accuracy is also a key question.

Important to mention is that in many cases a basic and primarily data sourcing or evaluation process is usually made right after the core data has been collected. Many commercial Earth observing satellite systems has been constructed to provide its imageries or data with added value and not just to sell and represent the raw image or the array of quantitative values. Depending on the chosen product, it is sometimes essential for the data to be primarily processed as it may not be accessed and used properly at some points of the further evaluations. After all, it is well advised once again to collect information of what is available in the market.

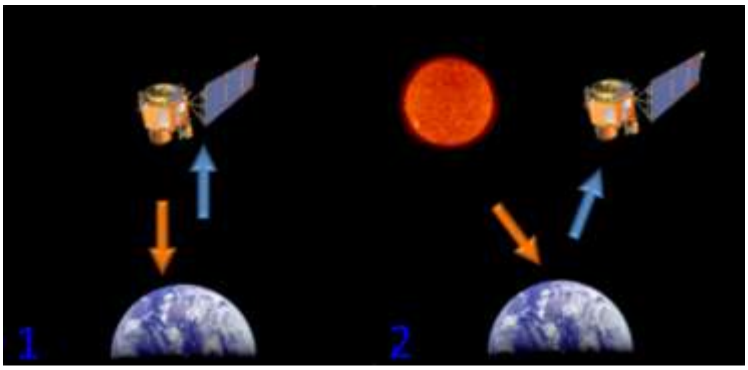
A. Space- and Airborne Remote Sensing

Observing and monitoring the Earth from the orbit has been increasingly popular over the very last decades. Gathering of information at a distance is something very useful for observations of various phenomena on and off the Earth. Various methods enable the user to get a closer look into remote objects, systems and features. Remote sensing is widely used in several fields and for various purposes. Hereby the observation of the earth's land and water surfaces will be described by means of reflected or emitted electromagnetic energy and with use of aerial photos.

Remote sensing of the Earth can be done with two basic types of instruments. One of them displays the information in an image format. These instruments can be used with airborne remote sensing or satellite based remote sensing as well. Others do not take images rather they present values which are evaluated and analyzed. Typically, satellites are those which take imageries. Laser scanning belongs to the other group in which instruments do not portray the results of the measurements in image format. What is also a feature of remote sensing is the use of an overhead perspective during the imaging process.

Passive sensors of satellite remote sensing systems are measuring electromagnetic radiation (EMR) in one or multiple ranges of the electromagnetic spectrum. Based on electromagnetism, it is characterized by the frequency or wavelength of the waves. Measuring the reflected solar radiation is one of the uses of satellite or ex-terrestrial remote sensing. Solar radiation is partly being scattered by the atmosphere. Though, vast part of it reaches the surface and interacts with that. According to the structure and feature of the surface, it is selectively absorbed, transmitted and then reflected. Wavelength influences these progresses, basically. The reflected radiation will again be partially scattered in the atmosphere mostly due to water vapor and aerosols of the troposphere. Satellites detect the waves that were not absorbed, transmitted or scattered completely shortly after they enter the thermosphere zone of the Earth's atmosphere where the loss is almost zero due to the lack of oxygen and aerosols. By analyzing and processing the resulting image, various properties of the landscape can be determined. Radiometers are the sensors integrated into the platform that can measure the intensity of the incoming radiation. Another type of passive remote sensing is when the sensor measures the emitted energy instead of the reflected one. This requires the instrument to detect the waves of the far-infrared spectrum [CAM-02].

A big advantage of space-borne remote sensing over the other methods is the big distance from the particular area that needs to be processed. Carrying out measurements from the space does not need any clearance or permit from a country. It is not the case for airborne or terrestrial measurements. This is one of the reasons that made satellite remote sensing a popular way of collecting data.



Ill. 22: Possible sensor types on Earth Observing Satellites: 1. Active Sensors 2. Passive Sensors

Active sensors are the other type of remote sensing instruments. Unlike passive sensors, active sensors transmit electromagnetic energy towards the objects that partly reflect it back to the measuring unit. Although just a portion of the reflected energy gets back to the satellite due to the above mentioned effects. Such active sensor systems are the active microwave sensors where a transmitter unit transmits the pulses whilst the receiver accepts the reflected signal. The today widely-used LIDAR - Light Detection and Ranging uses laser technology to detect and scan the terrain in high resolution. Just like other active sensors, the use of LIDAR is also based on the own transmitted and reflected electromagnetic energy. This technique also makes possible to measure the vegetation and to define distance to the ground beneath that. SAR – Synthetic Aperture Radar is another remote sensing technique which belongs to this group.

Aerial photography is the oldest method with which air-based images were taken. Taking photos from the air was first done in the 1850's from balloons. The most important period for using this technique was the 20th century without a doubt. During the late 1900's, the first aerial photos were taken from airplanes. After World War I, photogrammetry was first used for aerial photos. It is no coincidence that it became an important way of mapping the remote regions where no other surveying had taken place before. Aerial photography was the only method of airborne remote sensing for decades. With the improvement of the instruments of data interpretation, more appropriate evaluation of the data was possible.

Although it has always been an expensive way of acquiring data, aerial photography is widely used because of the large amount of accurate data which can be relatively quickly collected compared to the long lasting field surveys which were the typical way of data acquisition until the second half of the last century. Generally, stereographic pairs of aerial photographs are used to create topographic maps. Field surveying cannot be dismissed completely as in certain cases aerial photos prove to be useless at some point. A classic example for this is a bridge, under which the terrain cannot be evaluated from aerial photos. Aerial photos have been an important source of topographic paper map interpretations in the past few decades. Usually the national mapping authorities are responsible for managing the aerial photography of any given country. In Austria, the authority responsible for this is BEV – Bundesamt für Eich- und Vermessungswesen. In practice, their task is to maintain and update the national topographic map series of Austria.

A number of innovations have changed several aspects of aerial photography over the last decades. The era of the recently used digital cameras started around the millennium. The commonly used aerial recording devices are able to take panchromatic images even above 250 megapixels, respectively. Thanks to the so called push broom technology, the camera is taking three pictures at the same time of which one is the backward the other is the nadir whilst the third is the forward scene. This simultaneous, multi-angle sensor technology of scanning the surface can be used either for airborne or for space-borne use.

Reducing costs without worsening data quality is equally important for the aerial photography as it is in every segment of cartography. The era of using traditional airplanes with crew for measurements will come to an end soon. Partly because satellite remote sensing have been developing outstandingly over the last decades and also because remotely piloted light aircrafts called unmanned airborne vehicles (UAV) might take the place of the traditional techniques at a lower cost. However, in remote regions flight operations might be limited due to a number of reasons. As these small aircrafts have notably smaller range than the real planes. Moreover, experienced UAV pilots may also be hard to find. Operation of these lightweight aircrafts is also more depending on local weather conditions like high winds, including turbulent air close to the surface where these unmanned aircrafts are intended to fly.

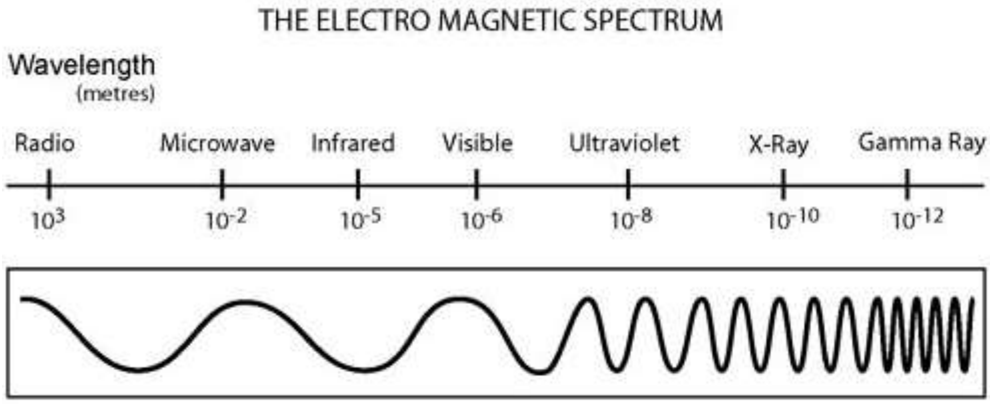
Satellite imagery is also applicable for land use, land cover estimations or for direct sensing of soil properties. For creating a hiking map, information on land cover is the most essential of these ones. Land cover consists of vegetation, which can be man-made or of natural origin. As for its research, land use is abstract while land cover is concrete. However, even natural vegetation cannot be seen as a non-changing cover of a certain surface area. Its type and size also changes over the rate of time. The question is how dramatic these changes are. As mentioned above, some satellites are specifically launched with the aim to monitor these changes of the ecosystem.

Platforms within remote sensing can basically be divided into two groups: the aircraft and satellite platform. According to J. D. Althausen [CHEN-01], advantages of an aircraft platform over a satellite platform is the relative low flying altitude and therefore the high resolution of images. Another positive aspect of aircrafts is the variable flight paths. However, satellite platforms have some advantages as well such as the low geometric distortions or the nadir and off-nadir measuring possibilities.

The orbits of the satellites used for Earth observing and imaging purposes are defined as low Earth orbits as they are always between 160 and 2000 km from Earth. GPS satellites orbit above this range, in the medium Earth orbit between 2000 and 35 786 km: every positioning satellite is located within this range. Interestingly, satellites used in telecommunications use a geostationary orbit at an elevation of 35 786 km [HOF-01].

Most of the Earth observing remote sensing satellites are able to make panchromatic and multispectral imageries. Panchromatic images are black-and-white ones whilst multispectral images are many colored. Multispectral data consist of various channels depending on the particular satellite's instrument, ranging from as few as 3 until more than 200 channels. Interestingly, panchromatic pictures have a higher spatial resolution than comparable multispectral images. That's why is it still used at image interpretational processes. Hyperspectral imageries consist of 200 or even more channels. Spectral resolution can be extremely high. This technique uses stereoscopy to examine images.

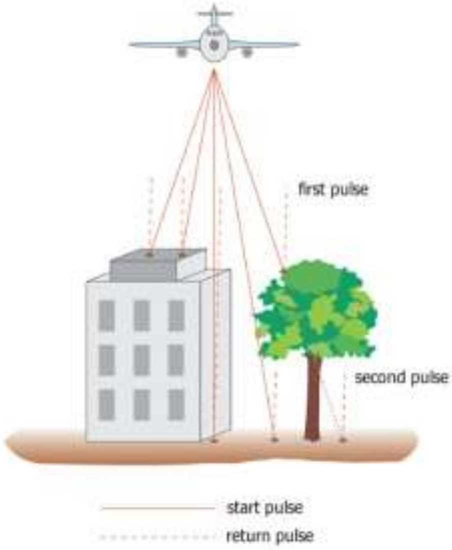
Resolution is a key issue at aerial photos and satellite imageries. James B. Campbell [CAM-02] defines ground resolved distance (GRD) as the dimensions of the smallest objects recorded on an image. In other words the certain value given as the resolution of an image refers to the smallest object which can still be identified. However, these numbers are not always accurate rather just estimated values. Other types are spectral, radiometric and temporal resolutions. Spectral resolution gives the wavelength width of the frequency bands whilst radiometric resolution shows how much radiation intensity the sensor detects. Temporal resolution refers to the frequency rate at which an area is measured again. In other words, it defines the time between two data acquisitions of the same area.



Ill. 23: The electromagnetic spectrum

Satellite remote sensing has been used to collect data of the earth's surface for public and research purposes since the 1990's. During the early 2000's, the first satellite specially designed to observe and monitor the earth's ecosystems was launched. However, the first campaign specially founded for the acquisition of satellite imagery of Earth was Landsat program. It is an important mission of Earth observation satellites. Started in 1972, this is the longest running satellite remote sensing mission for observing the Earth. During more than 40 years, 8 generations of Landsat satellite missions had been launched with a goal to take imageries of the Earth. Landsat 5 had the longest operation so far. It was working from 1984 until 2013, respectively. Recently, Landsat 7 and 8 have been imaging the surface of the Earth [URL-3].

Satellite remote sensing has developed a lot over the last few decades. By the early 21st century, a new type of imagery sensor based on laser technique had been deployed for both airborne and space-borne uses: Light detection and ranging (LIDAR). It is a remote sensing technology which was first used on NASA's GLAS (Geoscience Laser Altimeter System) from 2003 until 2010. It belongs to the active sensor systems as it analyzes the reflected light from the target object only after illuminating that with a laser. In contrast to passive sensor systems, it does not portray the results in an image format. It transmits timed pulses of light and then measures the time delay of the pulse when returning to the instrument. Exact detection of vegetation is possible with the laser technique, as the primary and secondary returns of Lidar can be well separated. Therefore the differential between the shorter and longer Lidar returns give the measures of the vegetation. The Lidar is based on accurate positioning with GPS which helps the documentation of surface monitoring as the constant speed of light is known. According to Gloor [GLO-13], using LIDAR can highly reduce the amount of field works, making this laser-based technique a big potential for making hiking maps of remote regions.



Ill. 24: Laser scanning and the detected returning pulses

Radar Interferometry is another way of deriving very accurate data on surface elevation. Synthetic aperture radars also use this technique based on electromagnetic radiation with microwave frequencies. SAR (Synthetic Aperture Radar) interferometry is very much comparable to stereo photography as radar measurements are made from two different angles in this case as well. This technique can provide very accurate topographic information of a terrain. It is no coincidence that it is an important way for creating digital elevation models. The first satellite that used SAR technique was SEASAT by NASA, launched in 1978. Since then, SAR interferometry had been used for a number of measurements by many satellites. The use of radar needs the following components: transmitter, receiver, antenna and the control unit along with the digital recording system [PEL-10]. As this type of radar is sensible even for some centimeters of movements, glaciers can be studied with the use of radar interferometry. Topographic relief can also be measured with high accuracy if the two imaging radars follow a parallel track to each other. Perhaps the most famous mission using radar interferometry was NASA's Shuttle Radar Topography Mission – SRTM, launched in 2000. Over 80% of the earth's land mass had been covered during its relatively short operation of less than 12 days. Only the Arctic and Antarctic regions and their neighboring areas were not examined during that. Since then, SRTM was used for a number of applications from geology until transportation engineering. It has a 30 m x 30 m spatial sampling for the territory of the USA with less than 16-m absolute vertical accuracy. Data is freely available from U.S. Geological Survey. Most recently, an updated version, the SRTM 3.0 has been released in which all voids have been eliminated with fills from ASTER GDEM2 (Global Digital Elevation Model Version 2), and from USGS GMTED2010, respectively.

Terra is the first satellite which aims to study the Earth and its ecosystems. Launched in 1999, it has been continuously studying the Earth and the atmosphere. For cartographers, the most important remote sensor out of the five it carries is ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer). It has particular importance as it provides high-resolution images of our planet thus helping to create elevation models. Its Global

Digital Elevation Model was released in 2009. Up to that point the SRTM mission had provided the most comprehensive maps. Compared to that, ASTER is able to monitor almost the entire surface of the Earth, including the Arctic and Antarctic areas. Therefore this mission was the first of its kind as it covered more than the 99% of the planet's surface areas. A second and more complete version of it was released in 2011. Another sensor on board of Terra is MODIS (Moderate Resolution Imaging Spectroradiometer). One of its purposed research areas is the observation of land cover and vegetation at a global scale. About 250 meters of resolution can be achieved which is not enough for the detailed, big scale maps.

TerraSAR-X is a recent Earth observation satellite of the German Aerospace Center and *EADS Astrium*. Thanks to the data acquisition from it and its twin satellite TanDEM-X, a DEM covering the whole Earth is commercially available by 2014. It is named for WorldDEM. According to *Astrium*, about 1 meter of imaging resolution is available. Accordingly, radiometric and geometric accuracy is excellent, beating many of its rival satellite systems. As for the access to images, the direct access service has been made which provides a direct connection to the data which ensures a quick way of obtaining radar imagery [URL-7].

Another Earth observation satellite system is the French *SPOT*. Its first satellite was launched in 1986. Since then, a number of missions had been completed. Most recently, SPOT 6 is in the orbit and SPOT 7 was about to be launched 2014. Together they will assure continuity of high-resolution data until the planned end of the mission in 2024. According to the plans, image product resolution could be about 1.5 meters.

Ikonos is the first commercial satellite which provided publicly available high-resolution imagery even at 1 m resolution. Just like *SPOT*, it also features a panchromatic and a multi-spectral detector. Its first mission began in 1999. Since then, *Ikonos* has continuously been providing high-quality imagery for commercial use.

Radarsat is a satellite remote sensing mission financed by Canada. Its first satellite was launched in 1995. Since 2007, Radarsat-2 has been in operation. It has been using the above mentioned SAR technology with great success. Among others it does topographic, land use and geological mappings. Since 2009, a bigger surveillance of the arctic territories of Canada has also being carried out with that [URL-6].

The European Space Agency has also contributed to the range of Earth observing satellites with several missions. *IRS* 1 and 2 and their successor the *Envisat* had been providing imageries for over 20 years. By 2014, it has been replaced by a new satellite called Sentinel 1.

Photoclinometry is a satellite remote sensing method used for depiction of surfaces. It identifies topographic information and features from image brightness. Variations in image brightness at a surface of uniform reflectance contain information on slope aspects and surface morphology. However, this method is usually used for extraterrestrial measurements of other planets' surfaces as the varied surface of the Earth may confuse the topographic interpretation of image brightness and the exact direction of light cannot be estimated precisely. If it can be properly used, generating of accurate topographic maps is possible just like the base for a digital elevation data.

B. Ground-based surveying

Ground-based surveying is obviously the oldest way of observing and surveying the surface of the Earth. Its goal is identical to the space- and airborne remote sending: to give comprehensive and accurate data from the targeted area. The methods and techniques used can be different. The rapid developing of the non-surface-based sensing technologies does not mean that terrestrial remote sensing is not needed anymore. It has developed a lot in the past decades as well. These two types of location based remote sensing methods complement each other well.

Surveying is a key field work that is done right at the target area. Its functions have slowly been changed since remote sensing has been more and more utilized. However, surveying remained a key element of field works which are used for the precision measurements basically needed for cadastre and big scale topographic mapping. Altogether with the other kind of terrestrial activities needed to create a topographic map, the cost of the on-site work can be critical in the mapping process. Results of ground level measurements aimed to support remote sensing are called field data [CAM-02].

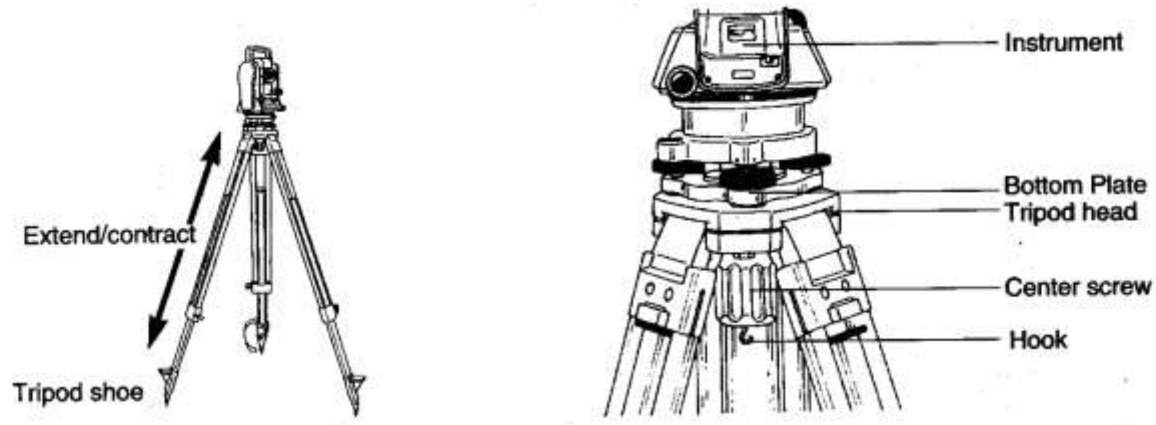
Field surveying have always been a relative slow process. Therefore the aerial photography was a huge step forward in reducing time of data collection. Despite, certain objects and areas still need to be measured on location as well. A good example for that is a bridge. Airborne remote sensing cannot get data from the underlying surface and therefore field surveying is desired. Although, the number of areas need to be measured with ground based surveying is relatively low as airborne and satellite based instruments can simply do the job quicker and still within the required accuracy range needed for a large scale topographic or hiking map.

Not just the cost or the temporal aspect can be decisive for a project. The nature of field surveying is completely different from the satellite remote sensing as the measurements are done within the territory of a certain country. From this point of view, aerial photography, radar measurements or the airborne laser scanning may belong to the group of field surveying, too, as flight operations have to be permitted a foreign country, just like terrestrial field surveying processes. Interestingly, certain flight rules may enable aerial photographic operations anywhere in the world. In aviation, vertical airspace is divided into many categories depending on the elevation and local characteristics. These airspaces are controlled by the national Air Traffic Controls - ATCs. Aircrafts flying into other airspaces must get permit from the local ATC before doing so. However, the typical upper border of these airspaces is at Flight Level 600- FL 600 that means an operating altitude of 60 000 feet. It means that the elevations exceeding that are mostly considered to be a zone of uncontrolled airspace. Despite, operating a civil aircraft above 60 000 feet (about 18.3 km) is rare and almost impossible with most aircrafts.

In certain cases, field surveying might be the better solution over airborne remote sensing. As S. Y. W. Lam and Yong-Qi Chen [CHE-01] point out, measurement of angles and distances is essential to surveying activities. Hatzopoulos [HAT-08] distinguishes topographic instruments according to the purposes they are used for in the following way: instruments for measuring angles, distances, elevations and their differences, angles along with distances and elevations (total stations), horizontal coordinates and last but not least all three coordinates and time (GPS). The exact place and elevation of ground-based objects can be given with that. The well-known instruments of field surveying are the theodolite and the reflector. These are used for measuring angles and most typically to measure distances with the help of an Electronic Distance Meter - EDM. The so called electronic or optical total stations are consisting of an electronic theodolite and an EDM. Recently, robotic total stations are also in use. These unmanned measuring instruments can be operated from the distance as well. Another important tool of field surveying is a level. It can be either auto-optical or digital and helps to measure differences in point elevations.

Not just angles and distances are essential when making a ground-based surveying. Accurate elevation measurement is important, too. A process called leveling serves for estimating height difference between two points. If the distance is relatively big between these two points and therefore point A is not visible from point B, then additional setups are required to build a bridge-like connection between them. This method is called ordinary leveling. With these measurements one can only count the relative height of point A from B or reversed. Relative height depends on the vertical distance of a certain point from the mean sea level. Important to mention is that this vertical datum can be different in many countries depending on the reference sea where the elevation is calculated from. On maps, it is always the absolute elevation which is displayed. Obviously, the final results of height measurements have to be converted from relative or differential heights to absolute elevations. Doing this is only possible if the absolute height of one of these points is known. Trigonometric leveling is a process in which elevation can be calculated after measuring the angle and the distance between two points. At longer distances, one should not forget to calculate the atmospheric refraction and the effects of the Earth’s curvature. The method of GPS leveling is also well-known. It can produce about the same accuracy as the traditional leveling techniques.

Slope meters and measuring tapes are necessary equipments for field surveying. A slope meter is used for counting the percentage slope between two points of the field. It had been a basic tool of surveyors for a long time and it is still very useful. The measuring tape is best used for measuring horizontal and slope distances. For simple and not too large measurements of distances that do not require high precision, however, steps can be used as well if the average length of a step is known.



Ill. 25: A total station

Topographic surveys are usually very time-consuming operations. Decades ago local control points have been created in many countries in order to use them for further measurements. As S. Y. W. Lam and Yong-Qi Chen [CHE-01] write, these points had been measured with traversing, triangulation or trilateration. However, in some areas of the world no such control points have been set. Fortunately, GPS leveling is an accurate way of giving position and also elevations even for big distances. According to M. Stanoikovich and C. Rizos [BOS-02], common problems during a field survey are power loss that causes the determination of a survey, cable problems affecting operations or the uncoordinated data collection. Other typical issues causing problems on- or off-site are loss of data after survey, setup on wrong station or antenna height measurement errors.

LIDAR is one of the newest technologies used in surveying. It enables to do three-dimensional measurements of surfaces. It has been used since the millennium. Nowadays it is one of the leading technologies for creating digital terrain models. In contrast to space- and airborne laser scanning, the instrument is not moving at terrestrial use until the sensing process is not ready. The positioning of the instrument is made with a navigational device. The same process will be repeated from multiple angels in order to get enough data from the object itself. Most recently, the laser scanners used in field surveying are able to contribute a lot to data acquisition for creating 3D models.

Mobile mapping is a new aspect of terrestrial surveying. During this process, geographical data is collected with road vehicles, usually by cars. Typically, measuring instruments are installed on the top of the chassis. A professional GPS receiver records the route of measurements and additionally stores the locations where the measurements were done. Depending on the tasks, mobile mapping may used for imaging, laser or radar detection. Google's global-sized mobile mapping project *GoogleStreetView* is currently the biggest of such ongoing projects. It aims at making every street visually integrated to the company's mapping project, *Google Maps.* This new way of data acquisition might have a bright future, especially because it is a quick response for evaluating near-the-road environments and can help to monitor the possible rapid changes occurring there. However, collecting data for hiking maps using only this technique has its difficulties. One of the problems with it is that remote regions usually lack the well-developed road network essential for these types of measurements. Aerial mobile mapping might help to overcome these difficulties though.

Generally speaking, the use of laser technique opened up brand new directions for terrestrial surveying such as urban modeling with accuracy even at mm range. This can be useful for a number of purposes including visualization of an ancient heritage sites and buildings or to estimate the angle and aspect of rooftops in order to support the decision making process of efficient mounting of solar panel modules.

C. Data acquisition from analogue maps

Analogue maps are in many cases the most important data sources of cartographic information available on high mountain regions of the world. National topographic map series have been created in most of the countries by the end of the 20th century. However, public access to these products is often limited even today, making the monitoring and evaluating of these products difficult. Despite, many countries realized the possible income from selling maps. It is no coincidence that even maps with out-of-date map information are for sale.

As shortly described above, several issues have to be cleared before using an old base map for any further works. As the source product is itself also the result of data acquisition, evaluation and analysis carried out by professionals, the derivative product will basically carry its features. It means that the origin of the derivative map information will be the same as that of the old base map. It not only influences accuracy, it also results in the re-use of the old map content more or less in some way.

Re-use of certain map elements is possible by digitalizing them. Simple examples of this are raster scanning or regular scanning of paper maps. There is a difference between converting an analogue paper map into a vector or into a raster model. Converting a map into a vector model means that its linear information is extracted from the original product. It is a frequently used method to scan the paper map in order to create an editable digital format of it. This is obviously considered to be a raster scanning, though the end product might be a vector model. Vector systems build everything from points. Therefore a single line is also constructed from points. Its advantage is the relatively small space requirement. Nowadays thanks to modern GIS software, both vector and raster contents can be managed with the same software.

A typical instrument used for digitizing was the digitizing table [ZEN-00]. However, use of such tools have been less prevalent lately, because GIS software feature on-screen digitizing making the job easier for the user, creating an editable map in the foreground while showing the original in the background. This eliminates the need to check the device and the computer simultaneously, the GIS software creates a more accurate input environment for digitizing.

Scanning is an important process for digitizing paper maps and in cartography in general as well. It can influence the whole further workflow of map making. As for scanners, there are two aspects of resolution: spatial and spectral [CHE-01]. Spatial resolution defines the smallest details which can still be detected. Spectral resolution determines the smallest value of reflectance that can be stored. Given these data, commercially available scanners can be pretty much different from each other.

Scanners are the perfect tool for digitizing maps. There are specially designed devices which can handle big sized papers as well. Furthermore, the way scanners detect the object also makes them suitable for digitizing maps. Unlike digital cameras, each point of the map is digitized without distortions. One can imagine what happens if the paper map is not copied properly. For example, taking a picture of a map will never have the same result than the scanned one. The reason for that is quite simple. Photos taken with digital cameras can never reproduce the object without any distortions, no matter how good the particular camera is. The problem is that the focal point needs to be exactly above the map points. However, it is impossible as only one particular point can be the source from which the light goes exactly perpendicular to the focal point and straight to the camera. All other sources of light (points) can be detected with slight distortions depending on the distance from the lens. This error influences the further stages of the workflow as this is the image that will later be edited.

D. Acquisition of analyzed data

For many areas of the world, multi-layer vector and raster map files are available for purchase. Their price is relatively high, but they can officially be used as base maps. Other than re-shaping and adding some layers to it, the only work left to do is the cartographic design process. This is the most comfortable but an expensive way of buying data.

East View Geospatial is one of the leading providers of cartographic products and GIS services. They offer a wide range of solutions, among others for data acquisition or data processing. They also sell vector datasets of almost every continent. The national map series can also be found among their products. Moreover, the company has legal access to former military maps of the Soviet Union, NATO and US maps as well.

Google's *Google Maps* and *Google Earth* are web-mapping applications available to view freely for the public. *Google Maps* provide a number of website-integrated services like route planning or marking and rating the interesting sites of users. The map information can be displayed either on satellite images derived from the satellite imageries provided by *DigitalGlobe* or on drawn maps created from the same data source [URL-10]. With the use of *Google Maps API*, these maps can be integrated to any websites, respectively. *Google Maps* also contain a relief layer, which displays the contour lines in the terrain. This function is available for the whole Earth but with various levels of detail. Within remote areas, usually 100 meters is the difference between two contour lines. This is due to the less-accurate imageries and the lack of importance of those territories. On the other hand, Arctic areas and Antarctica cannot be displayed correctly due to the Mercator-type projection which is used for displaying in *Google Maps*. *Google*'s unique service *Google Earth* display these high-latitude areas better, but as getting closer to the poles, data accuracy decreases dramatically.

DigitalGlobe is one of the biggest commercial companies dealing with the selling of space imageries and their processed data along with other types of geospatial contents. It also operates earth observing satellites which provide their imageries continuously. Their most important customers include NASA, *Google Earth* and *Google Maps* along with US state agencies.

Distributed GIS are GI networks in different physical locations as for the system structure. It means that the user interface or for example the database can be found far from each other. This is a special case which is the case at Mobile GIS and Web GIS. Web mapping has been an increasingly popular direction of spatial data services, as a web-based content is easily available for users. On the other hand, it is a comfortable way of selling data for companies to create a web-based service where all of their data is available. The aim and the possible success from the data suppliers point of view is to catch the attention of the user easily and faster and to be able to sell the data comfortably with a chance to integrating it to the on-going services. GIS connected web-mapping is also a dominant direction in cartography according to Z. R. Peng and M. H. Tsou [PEN-03]: "Underlying reason for the adoption of Internet-based GIServices is the need for communication in the GIS community".

It is not a coincidence that several GIS producers also created web-based solutions for their users. A further improvement in this progress is the so called cloud computing. In GIS it is a relatively new and easy way of data distribution or from the user point of view a data acquisition method. It means that the data is stored on servers connected to the internet and they are therefore easily available as a service. In other words, these services called Software as a Service (SaaS). Just like in information technology in general, it seems to be used as a way of sharing data and as an additional service of GIS.

Most recently, *Astrium* delivered its new global elevation dataset *WorldDEM* in 2014. It is stated to feature relative vertical accuracy of 2 m. This would be the first DEM available for the entire surface of the Earth that has a relative high resolution and accuracy. According to *Astrium*, data used for creating the DEM is not more than 2.5 years old. Especially for remote mountainous regions this new product can be extremely useful as it is a lot more accurate than ASTER GDEM2 or SRTM data which currently provide the most accurate elevation information of many high mountains.

3. Orthoimages and Preprocessing

A. Making Orthoimages from Aerial photos

Orthoimages are the result of orthorectification of aerial photos which can be used for further evaluation in the map-making workflow. Georeferencing an aerial image refers to the creation of an orthophoto. However, the process needed is not a georeferencing in the classical sense as 3D coordinates have to be used in order to consider the elevation as well. Zhilin Li [CHE-01] lists three requirements which have to be fulfilled in order to create orthoimages: image points have to be registered in a geo-referencing system; every point of the resultant image should have the same scale or otherwise the scale variation has to follow a map projection; the relative relationship between features should also be retained.

When creating an orthophoto, the first step is the making of geometric transformations. With transforming image points into image coordinate systems, so called Easting (E) and Northing (N) values refer to the location of each point of the original image. These values can identify the position of any objects within the image in a geo-referencing system. Ground control points are important aids in this progress.

Depending on the needs, orthoimages can be derived either from single or stereo (overlapping) images. A major difference between single and stereo images is that height information can only be derived from image pairs. Estimating the elevation during creating orthophotos from one single aerial photo is impossible if the Z value is unknown. Nevertheless, elevation data can be derived in many other ways such as using Digital Terrain Models and interpolation.

Radiometric transformation is the next step of creating orthophotos from aerial images. This process aims at giving grey color values to each pixel originated from the aerial photo. The color value provides essential information on ground cover and vegetation in the analysis of remotely sensed images, as each kind of natural objects has their own specific color range given with the grey-values. According to Zhilin Li [CHE-01], approximate mathematical models are used for the geometric transformation, while in radiometric transformation the model's nearest neighbor and bilinear interpolations are widely used.

In practice, aerial photography produces images of one area that are most of the time generated from two different positions in order to provide multi-angle imageries called stereo photos. To be more efficient, the digital instruments take continuously pictures of the target area when flying right above them. Most typically, the aircraft flies along previously defined strips above the target area with using navigation systems that completely meet the requirements of civil aviation standards. With the help of on-board aid systems, effects disturbing the cameras during operation can be completely recorded and calculated.

Using stereo images ensure the accurate estimating of terrain elevation. The method for this is quite simple. In order to get elevation data from an image pair, the exact location and angle of the camera has to be known from where the photos had been taken. Furthermore, the two photos have to cover the same area. If the photo pairs are given, the next step in the workflow is the further analysis. Special methods and tools are needed to define the accurate elevation from the images. Such a method is to view the stereo pairs in so called stereo models: if one eye watches only the one, the other only the other image then a 3D model of the two photos can be seen. A stereoscope is one of the tools that help to generate stereo models as the view of angle can be precisely set along with the overlapping of both images. Important to mention is that this way of deriving elevation data is nowadays less used but the stereoscope had been an important instrument before the era of digital photogrammetry.

Radial triangulation of stereo pairs is a further stage in the evaluation process. It differs from the method of stereo models as the goal of it is to create vertical images from the stereo pairs. Its basic principle is to estimate angles and distances in the overlapping areas of the image pairs. Radial triangulation is in close relation to an advanced process, the aerotriangulation which is based on the joining of these above mentioned strips. It is a widely used way of imaging from aircrafts. The use of these strips also reduces the number of control points needed for the accurate measurements. The less number of these points do not influence positioning negatively.

Over the past few years, digital stereo photogrammetry work stations were developed in order to carry out all of the processes regarding to evaluation of aerial photos with only one instrument. Certainly, these work stations has been increasingly used in photogrammetry. King [CHE-01] describes one important advantage of digital processing is the image matching which helps automatically create orthoimages from stereo image pairs. It is usually based on examining and matching the level of grey values of the two photos. Moreover, these applications can derive the accurate elevation data from the stereo images as well.

Recently, cheaper yet precise software solutions are also available that can derive data even from photos created with hobby digital cameras. Although some of them are not specially designed to create orthophotos from aerial images, functions like smart image matching make this software useful for cartographers, too. Others are specially designed to support the evaluation of remote sensing imageries.

B. Preprocessing of remotely sensed data

Preprocessing is a preliminary step to the main data analysis. Preprocessing deals with special processes needed for eliminating certain effects from the measurements that should not be a part of the final dataset to be analyzed with GIS software. This is a complex process which has quite individual steps and tasks depending on the type of data and the user requirements. Basically, preprocessing aims at improving data and image quality [CAM-02].

Feature or information extraction is one type of these processes during which unneeded channels of multispectral images can be eliminated in order to make the further analysis more accurate. Selecting relevant areas, subsets of images also belong to preprocessing. During this only the relevant areas will remain for the analysis and processing. Another goal of preprocessing is the image restoration [CAM-02]. Such a method is radiometric preprocessing. It can modify the brightness values of the image whilst image matching aims at putting a map to its right position. Resampling is a type of geometric correction processes.

It aims at manipulating the image values which can then be added to the other type of geometry. The process of finding control points for image registration can also be defined as part of preprocessing

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4. Data representation: making map from the data

A. Coordinate systems, Datum and Projections

Making maps of objects without knowing their position and spatial extent is impossible. Each object intended to be shown on a map has to be placed in a coordinate system in which each point is described with at least two specific values. These values show the exact position of the certain point within that system. These values are coordinates that give the position of an object either in meters or in grades. Coordinate systems are two and three dimensional. An object in a two dimensional system is given with only two values whilst three dimensional coordinate systems use a third value as well.

The Cartesian coordinate system is frequently used for giving geographical locations. Unlike in mathematics, the axis X and axis Y are replaced in surveying. The reason for that is in practice the North direction has to be at first and not the East. Following this logic, the X axis will then be the axis that points North and the Y axis the one which points East. So (X, Y) or (N, E) are the horizontal coordinates whilst the height in 3D systems is defined by Z, respectively. Such 3D Cartesian coordinate system is to be imagined as its origin is the centre of the sphere and the axis are pointing North and East in the previously discussed way. However, this is not the best way of using coordinates as the range where the vast part of objects would be measured is obviously not under the surface, in other words not in the sphere rather outside of it. Therefore it is essential to define a Z value from which the absolute elevations can be measured. This reference zero elevation is calculated from average sea level of either the Baltic or the Adriatic Sea. Doing that means that this reference surface is the so called vertical datum, from which elevations are measured.

As the Earth is not a sphere, special conditions apply when its surface is modeled as a map. Scale influences the base on which the representation of the reality, the map is modeled. Depicting the reality of a small area on very big scale can be displayed without dealing with the Earth’s shape. However, a usual hiking map in scales 1:50 000 have to be represented on a physical, non-existing mathematical earth body called horizontal datum which is defined with many parameters in order to create the best model of Earth for more accurate positioning. Horizontal coordinates are again referenced in a Cartesian coordinate system but this time the axles are parallel to the horizontal datum.

Ellipsoid is used for better approximation of the Earth’s shape. Unlike the irregular geoid, ellipsoids can be exactly defined with mathematical formulas. This makes ellipsoid the best reference body to the Earth. E. Mok and J.Chao [CHE-01] point out, that local-fit ellipsoids are needed for minimizing the separation between a geoid and the ellipsoid surface as the two are obviously different. Geodetic or Ellipsoidal coordinates can be defined in form of latitude, longitude and height – geographical coordinates, or again as Cartesian coordinates. Conversion of these coordinates is also important, which can be carried out using GIS software making manual calculations unnecessary.

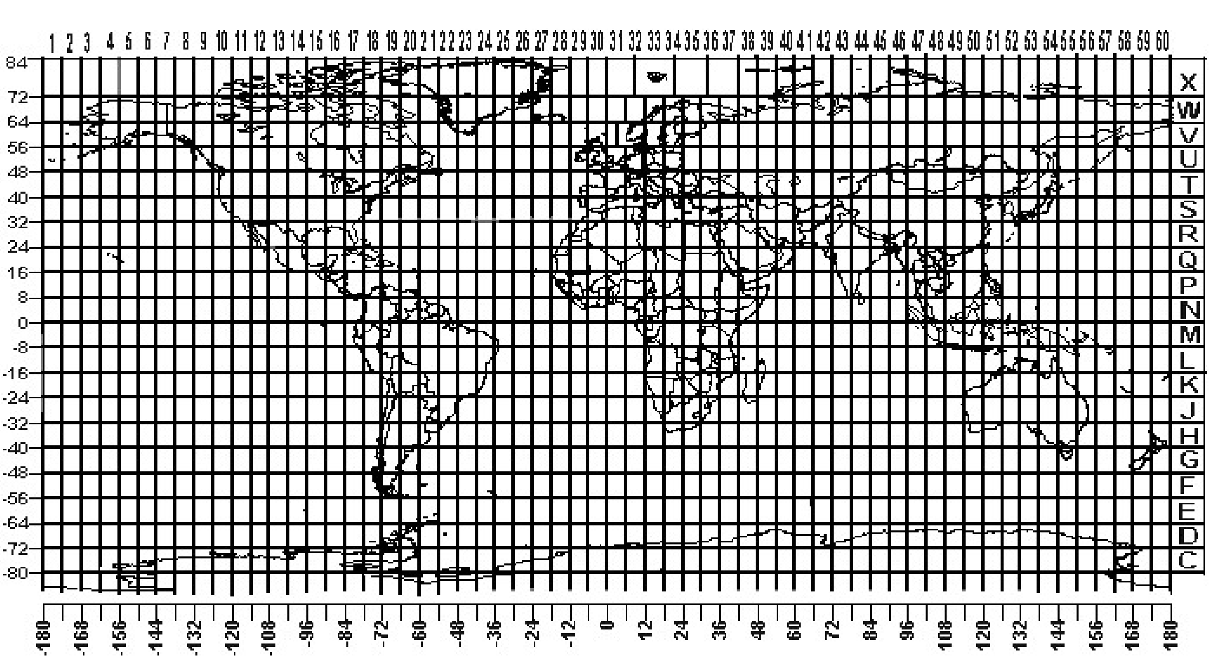
Map projections always aim to produce the most accurate maps possible. However, each of the projections is just approximately accurate. Over the last decades, several projections had been created and used for a variety of maps. Depending on the map scale and the modeled area, several types of projections can be used. Y. –C. Lee [CHE-01] defines map projection as the following:

"A map projection is therefore a conversion, or a *mathematical transformation*, between two coordinate systems: the geographic system in latitude and longitude () and a system based on the plane surface. There are two popular choices in the latter case: one is the *Cartesian system*, and the other is the *polar system*. The Cartesian system yields to (X, Y) coordinates, whereas the polar system yields (Range, Angle). "

Map projections can be described with equations, which place a point to a certain position defined by its latitude and longitude and can convert it to planar coordinates. As mentioned earlier, no projection is 100% accurate. There are always distortions that can be categorized as: length, area and shape distortions. Each map projections have special characteristics of such distortions depending on its type.

Some projections are best usable for modeling high-latitude regions whilst others are created to fit for the northern- and southernmost areas of the Earth. Therefore it is essential to select the best projection for our map that is accurate enough for that particular latitude. It depends greatly from the position of the so called projection centre which is actually the centre of our map. Typically, problematic areas are those located at higher altitudes, especially if a mid- or small scale map is to be created of such a larger area. Therefore choosing the right map projection is not easy. A. Habib [BOS-02] lists five characteristics that influence projections: area, shape, scale, direction and special characteristics.

One of the most-used projections for topographic maps is Universal Transverse Mercator, shortly UTM. Originally, NATO decided to choose and use a common projection in order to make the frequent need for coordinate conversions easier as many countries used to have their own map projections. Additionally, a new grid system was established for the common use. Currently, its reference ellipsoid or datum is the WGS84, a standard spheroidal reference surface. Naturally, its meridian at the zero longitude crosses the Greenwich Royal Observatory. UTM is the best-known and a widely used projection in the world even for civilian use. It is a type of Mercator projections which means that it belongs to the cylindrical map projections. As major distortions would occur when using this type of projection for modeling polar areas of the Earth, UTM only applied for areas extending from 84°N to 80°S. There is a special system designed for modeling areas of the highest latitudes called Universal Polar Stereographic Projection or shortly UPS.



Ill. 26: UTM System

Interpretation of analogue maps are often aided by certain number values that are actually coordinates helping the navigation. Typically, they can be either values of a national system or most importantly UTM coordinates. Letters are used for UTM zone designators vertically and numbers are used horizontally. Zones of the system cover 6° of longitude. Interestingly, the used letters exclude I and O are not zone markers in order to avoid false identification and misuse of I, 1 and O with zero. Each of such letters marks one of the 8° belts of latitude. Another strange feature of it is that the scale of letters starts from the south. Polar areas are marked by A, B and Y, Z.

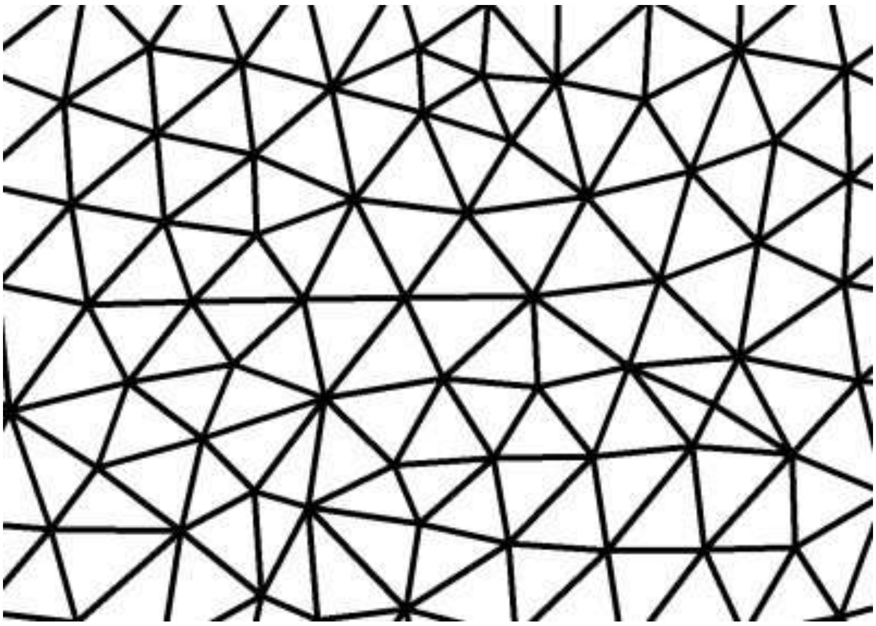
UTM Grid is a rectangular system specifically designed for identifying locations of objects. It is a Cartesian coordinate system but in a horizontal position. It means that position of points can be identified without knowing their elevation. The reason for creating the UTM Grid was to provide uniform grid systems in each zone. Furthermore, this system of zones also aims at reducing possible user-made mistakes when identifying positions. It is important to mention that X and Y are given with meter values and not with degrees: they mark the Northing and the Easting of the certain point within the particular zone. When identifying a point in the world-wide coordinate system, the proper Northing and Easting has to be given just like the exact location within an above mentioned zone and belt. If a map covers an area located in two zones, measuring the exact position can be problematic. In this case, either of the grid systems can be extended 40 km to one side [CHE-01].

B. Representation of images and surfaces

Based on spatial data models, there are raster and vector type methods for field representation. Vector data usually used for the representation of directed line segments like rivers or roads. A basic raster or grid data is a curve, as its shape can be irregular and therefore it does not belong to vector type data. Imageries also consist of grid data. Images like aerial photographs or satellite images are always raster data.

One of the key elements of surface modeling is the representation of the elevations of an area. Digital Elevation Models (DEM) that are 2.5-3D representations of the surface can be created from the terrain elevation data provided by remote sensing methods. DEMs are important sources and representations of elevation data for topographic maps. Many GIS programs can derive contour lines from them which making these models quite valuable. The resolution of the DEMs is very important as the accuracy of the elevations in the map is depending on that.

Triangulated Irregular Network (TIN) models are frequently used in GIS for surface representation. With the use of the method Delaunay triangulation, triangles from the elevation points of the area are formed, visualizing the surface characteristic of the area. These are vector based applications of DEMs which has some advantages over raster systems. As for data storage, vector data models generally need less space. On the other hand, its graphics is not comparable to a raster dataset. Generating TIN from DEM or DEM from TIN is possible with geographical information systems.



Ill. 27: Triangular irregular network – TIN

C. Geographical Information Systems (GIS)

Making a map not just mean the displaying of spatial data, it is much more than that. As D. J. Peuquet [PEU-02] points it out: "The power uniquely inherent in the map lies in its ability to provide a portrayal within a spatial context that goes beyond the data and individual elements". Perhaps the most important applications that help the cartographer during the map making are GIS software. These spatial information systems have a very compact task: data handling, data processing, analysis, data structuring and its representation. These GIS software packages are suitable for processing and analyzing the spatial data that is derived either with field surveying, remote sensing or digitizing analogue products. James B. Campbell [CAM-02] described relationships between remotely sensed data GIS software as follows: (1) Manual interpretations of aerial images or satellite images then on-screen digitizing or (2) the data are analyzed using automated methods either to produce conventional maps and images or (3) to be retained in digital format for entry into the GIS using the needed corrections or (4) data is entered directly in their raw form as data for the GIS.

Naturally, GIS software can not generate geographical data. It needs to be connected to a data source in order to be an effective tool of map making. Although, *ArcGIS Server* aims at providing data needed for maps. However, this initial is not suitable for accurate data acquisition of remote regions. It is more like a cloud computing environment designed for deriving thematic information for maps. GIS are highly dependent on spatial data itself. GIS software packages have been an important tool in cartography since the last decades of the 20's century. However, it was not until the very end of the last century that increasing need for these new applications made them a dominant tool of digital map making.

The wide use of these software packages has been used extensively even shortly after the millennium. According to R. B. McMaster and W. J. Craig [BOS-02], it is used for mapping of land use and transportation or utilities infrastructure and in a variety of further applications like natural resource assessment or geodemographic analysis.

During the workflow of making a map, working with GIS software are ready to deal with a number of work stages: the data processing, its visualization, adding the map information, doing the essential graphics and making the final layout of the map. Therefore buying the right software is a key for being successful. Nowadays, most of the latest available GIS software can unify the above mentioned stages of the workflow with comprehensive functions from data analyze until map layout. There is an increasing number of GIS software represented on the market today. Still, these products are not reasonably priced due to the relative narrow customer basis. There are also free to use GIS software packages which usually integrate less functions and tools. In some cases, they are trial versions for limited use. Some of the well-known or more or less dominant GIS software as well as those useful for making hiking maps are discussed below.

Perhaps the most popular GIS software on the market is *Esri*'s *ArcGIS*. *Esri* (Environmental Systems Research Institute) is a private company based in US state California. Its products have dominated the market of GIS software over the past several years. Their continuously updated and reedited product, *ArcGIS* is a well-known solution for analyzing and managing geospatial data and to create maps and other cartographic contents and helps to provide and share the products with the end users. *ArcMap* is the main part of the *ArcGIS* suite, it is their well-known application for processing geospatial data [URL-12].

AutoCAD Map 3D is the current mapping software of the well-known computer-aided design (CAD) software maker *Autodesk*. It operates with CAD and GIS data. *Autodesk* has been successfully creating CAD software for various uses. At the beginning of the 1980's, their first software revolutionized the market of technical drawings and graphic designing within engineering. *AutoCAD Map 3D* was specially designed for GIS use and able to evaluate, analyze spatial data and also helps in accessing it. Data management, data conversion and advanced survey functionality are also featured in the new version.

MapInfo Professional is desktop GIS software of *Mapinfo* used for a number of purposes but mainly for making geospatial analysis and thematic maps. It has integrated web-based applications as well. Interestingly, this was the first desktop GIS produced already during the late 1980's. One of the early goals of the company *Mapinfo* was to create a low-cost yet precise desktop mapping application.

GeoMedia is a product of *Intergraph Corporation*, a US software development company. It offers a GIS package specially designed for doing spatial data analysis, making digital elevation models and generating contour lines. It is also good at managing geospatial databases and publishing geospatial information. This GIS is not just available for desktops; smart phone and tablet compatible versions are also available.

GRASS GIS is a free, open source system available for *Linux*, *Microsoft Windows* or *Mac OS X*. The software uses a graphical user interface and can handle vector, raster and graphic data. Originally, *GRASS* was designed for *Linux* operation systems but it is now available for other systems as well.

D. Remote sensing applications

Using only GIS software is not always sufficient, especially if image interpretation is needed. For such purposes, special remote sensing applications have been designed which can prepare the data for further processing with GIS software or with other graphic software. These applications can evaluate satellite imagery and are able to create orthophotos from aerial photos. Evaluating radar data is also possible with some of them. Some of the most used software solutions are listed below.

Satellite imageries are usually available in Tagged Image File Format, or shortly just TIFF. Currently it is maintained by *Adobe Systems*. It is one of the most popular file formats for images and graphic contents. Another wide spread file format is the GeoTIFF. Images in this format are usually georeferenced, meaning that the image displaying a certain area of the Earth's surface contains geolocation information.

ERDAS IMAGINE is a remote sensing application for interpretation of imageries and for satellite image analysis. Its functions like mosaicking help to make orthophotos from aerial images. Although it is considered to be raster graphics software, it is a bit more than that thanks to these enhanced functions that aims at helping the evaluation of remote sensing data.

RemoteView is another remote sensing application created by *Overwatch Systems*. *RemoteView* software was specially designed for space- or airborne image processing. The two currently available variants called Desktop and Pro. Among others, US Government is one of the long-time users of this software package.

Exelis Visual Information Solutions (Exelis VIS), better known for GIS as *ENVI*, is an image interpreting software created by *ITT Exelis*. *Exelis VIS* is used in for a number of purposes and not just in remote sensing. *ENVI* provides geospatial solutions and integrate with *ArcGIS* of *Esri*. According to the website of the software, using *ENVI* is possible for amateurs for doing image analysis as well due to the integrated on-hand solutions that help image interpreting.

E. Vector and Raster graphics editors

The use of graphic software in the workflow of making maps is still popular. However, many GIS software are suitable for enhanced graphic works. Graphic software packages should not be missing from map publishers' offices. Besides input of linear map information or styling most of them also provide image analysis and editing tools. The wide range of graphics editors has a much bigger market than the GIS. A huge number of them have been released over the past decades.

There are applications which are dealing only with vector based graphics while others are made only for raster contents. The best of these software packages allow the user to work with vector and also with raster data. Nowadays, several well-known graphics suites can handle both types of data and even enhanced data conversion is not a problem for them. There are also freeware graphics editors which are free to use, though typically less tools are integrated to them. Commercial graphics editor packages are capable of carrying out a wide range of graphical operations.

Adobe created one of the most professional graphic suites currently available on the market. *Adobe Illustrator* is a vector graphics editor offering several tools and graphic solutions contributing a lot also to the map making procedure. The software is able to handle lots of image data types and data conversion is also not a problem for it. Another similar product of *Adobe* is *Adobe Photoshop.* Although this is graphics editing software as well, it is designed for image editing and graphic design. The software is available in two editions, of which the user can choose which product can best support the work to be done. The software is currently available for *Microsoft Windows*, *Android* and *iOS* operating systems. Basically, *Adobe Photoshop* is a raster graphics editor, thus editing of vector graphics is also possible with that.

CorelDraw is a vector graphics editor produced in many versions since 1987 by the Canadian *Corel Corporation*. The software is a big rival of *Adobe Illustrator.* As a whole, *CorelDraw Graphic Suit* offers many valuable applications including *Corel Photo-Paint*, a raster graphics editor that can be best used for image editing and for basic graphic designs. According to their website, *CorelDraw Graphic Suit* offers superior vector illustration and page layout and versatile drawing and tracing tools which help to design websites, too.

IrfanView is popular freeware among raster graphics editors. It can be used for viewing, converting, resizing images and can also be used for basic processing. First created 1996 in Vienna, this software is one of the most popular freeware image editors.

5. Collaborative Mapping and Hiking Maps

1. Neogeography and Collaborative mapping: a new mapping method

A. Neogeography and Collaborative mapping in General

Neogeography is a new-wave interpretation of cartography and geography. It refers to the activities of non-expert individuals who document, share and process their field activities for further use. Neogeography has seen a rise up over the past few years thanks to the wide range of publicly available GPS receivers and the Web 2.0 which made user collaboration and data visualization easier. Neogeography is all about sharing of geodata with each other [TUR-06].

The reason why people want to experience more and try new activities is coded in us. Humans have always been trying to use and implement new techniques in the everyday life. Nowadays, the slight decrease of working hours and therefore the growth of free time have changed the free time activities over the last decades. For instance, people travel a lot more and it is possible to get to remote areas of the world as it is easier than ever. On the other hand, there is a growing need for creating maps and route descriptions for these new tourist destinations. Neogeography and collaborative mapping can also aid this progress.

Collaborative mapping is a relatively new direction of cartography. It is part of the Neogeography, a term which is mostly used during the past few years. According to Turner [TUR-06], "Neogeography provides non-experts with easy-to-use, collaborative mapping tools". This major rise lasts since the revolution of Web 2.0. The essence of this new method is the user-generated content. The available new technologies, the human effort and activity make it possible to generate maps from the data which has been collected by the hobby-users. Thanks to the World Wide Web, publishing data is easier than ever. Furthermore, many websites are specially designed for processing and visualizing user-collected geographic data. It is clearly visible, that a worldwide reachable network, the internet is the main medium for the gathering society of hobby-map makers.

The reason for the rush development of collaborative mapping can be explained partly with the human nature and on the other hand with the publicly available tools, programs and applications which are user friendly. Collaborative mapping can be characterized as a web-based phenomena as the primarily cohesion force behind it is the network. Nevertheless, storing maps is also important just like sharing it. Each person who is actively taking part in that is a small element of this network which means the non-spatial connection among them.

Ill. 28: Web. 2.0

Collaborative mapping can be divided into many groups depending on the type of activity which is contributed by the user. It can be as simple as taking a picture with a digital camera which is equipped with a GPS receiver and then sharing it on a website which supports photo sharing. Then the photo is geotagged. It means that the location of that particular picture is recorded and can be given in coordinates. In other cases, the user can edit some layers on a map of a certain area like a cartographer. Collaborative mapping can be used for many purposes. Although this method has existed for several years, the real effect of that for the cartography can only be estimated since the force behind it is the bunch of amateur users who are keen on using the newest technologies and like to share their free time achievements.

What is really useful for the public in this new trail-blazing direction in cartography is the user-to-user mechanism which creates a circular data flow among the users. In a typical case it means that user A can share spatial information recorded with a GPS receiver with the others and B might provide another part of the same route and then both will be available on a particular website which aims to collect these collaborative map edits. Just to continue this example, user C might share the tracklog for this whole route again which would mean another data source for the same route. Every of these re-edits can increase data accuracy. However, one cannot forget how sensible this system is: most of the time the user is amateur, the GPS receiver is not accurate enough and the visualization is poor. Therefore very accurate data cannot be provided.

The role of the enthusiasts in cartography is perhaps underestimated. It is not a question that user collaboration can be advantageous in many aspects. It is necessary however to monitor and correct the leaks. It is like the real life when certain authorities can judge decisions in a democracy. The role of GIS professionals will not be unneeded just because user generated data appeared. Perhaps, this is a fear and a blocking effect for many experienced cartographers and obviously therefore the debate on the role of these user contributions do not ease the situation.

Of course, even these editable maps have not been created only out of user-generated data. Depending on the type, they have base maps which were usually provided freely for the project by different authorities. Commonly these maps consist of the basic road and rail network, the water surfaces and the boundaries of populated areas. This digital map can be either a satellite image or a drawn map.

B. When it all started

Collaborative mapping is one of the newest aspects of digital cartography. Basically, the user contribution consists of the data deriving and its sharing or visualization. A GPS receiver is usually a basic instrument of the workflow. No matter what the end product would be, the navigational receiver units are publicly available since the 1990's and for today, they can even be built into watches, digital cameras or smart phones.

As this contribution is usually made as a free time activity for lots of users, the spatio-temporal circumstances are relevant. Therefore it is a high time for that in Web 2.0 as the visualization of the data is easier than ever. There are plenty of programs and applications which can make a visual representation of our recorded spatial data.

Over the past few years, this public mapping method has been increasingly popular. Since many websites support it with strong visualization background and data storing, user-generated data can be shared and accessed easier than before. This is one of the big improvements of Web 2.0 which originally aimed to support user interaction and collaboration. Although at first this term was used in the late 1990's, the real Web 2.0 era lasts since the mid 2000's, respectively. It was the time when the first well-known collaborative geographic information system *OpenStreetMap (OSM)* was founded.

Recently, there are a growing number of websites which aim to create maps from user-generated data. As many smart phone applications have been made over the past few years supporting this new direction, data deriving became much easier as some users would not buy a handheld GPS just a smart phone in which a GPS receiver may be integrated. This also helped a lot for the improvements of these communities. Other than that, several other contributions were also needed. Some of these are the capability of online storage of big data or the fast file sharing.

C. Purposes of collaborative mapping

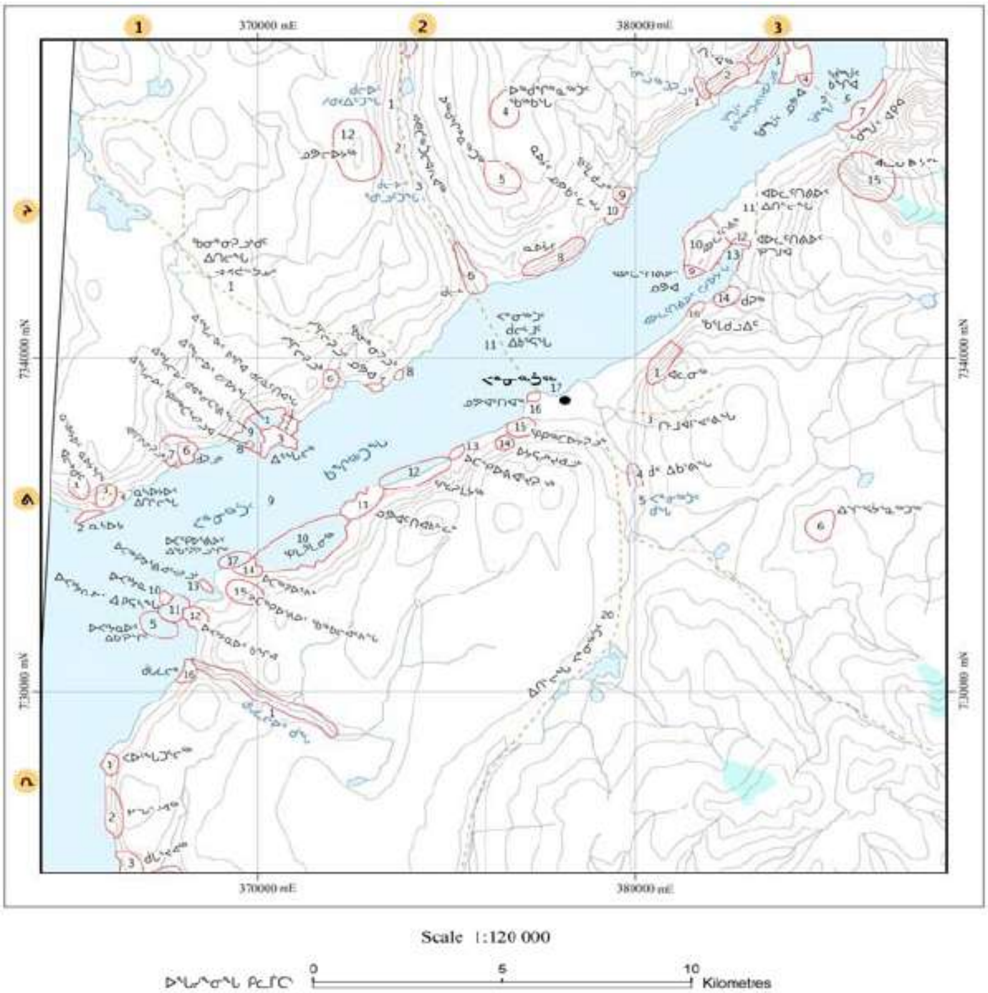
The common idea of a collaborative GIS is to reach as many users as possible and to give them inspiration for deriving data at least on a local level which can then be shared for these projects. In this system every user can access these data. This is a non-commercial way of data deriving, sharing. The further use is depending on the project for what the data has been shared. However, data is usually not used for products that intended to be sold in the markets.

New type social media, social networking and easy file sharing in the internet opened up a new chapter even in geography and cartography with the above mentioned neogeography or new geography. Collaborative mapping is a part of that but it can not only work in the typical way of user-surveying and data sharing. Thanks to the user activity and interaction in the well-known websites of social media like Twitter, a map of the most recently used terms and topics can be displayed in moments. These web maps are based on the spatial information which is provided sometimes even behind the back of the user as the location of the device with the internet access can be identified. This is a kind of mind mapping of the users which can be very useful for further investigations regarding the opinion of the public. In other ways geotagging or adding geolocation to a photo also provide spatial information which can easily be evaluated.

The advantages of a collaborative GIS are quite obvious. Given the many users who are willing to provide their GPS tracks of various locations, a comprehensive dataset of these data can be established. This type of user contribution makes data accessing easier. On the other hand, these friendly GIS solutions mean a quick and cheap alternative for data deriving for free-time uses. Other than that, the relative easy handling makes their use even on smart phones comfortable.

For cartographers and especially for the topic of the thesis is the classic-style handheld GPS-generated spatial data can be more important. This is a direct way for the average user to make a contribution to an online map. It has many ways depending on the application. In most cases, user-generated data is evaluated before putting it to the product. Therefore GIS professionals or pro enthusiasts are needed to make this final contribution with the data.

Although collaborative mapping aims at creating a user-generated and freely available system of spatial data, in some cases the end user of these public map edits try to use the data for commercial purposes. A good example of it is *Google*, that runs its *Map Maker* service in order to provide and update map information for *Google Maps*, which is one of the most notable and well-known commercial mapping projects.



Ill. 29: Map sheet of the Topographic Prototype Maps of the Canadian Arctic using VGI

2. Collaborative Geographic Information Systems and other user-generated spatial contents

A. Collaborating Mapping projects

Many GIS based on user-generated data have been created over the last years. Several of these projects have been achieved ten thousands of active users who are mainly amateur enthusiasts that like to contribute and share their spatial data which is either collected during one of the popular outdoor activities or created specifically for collaborative mapping projects. It is also enabled for the user to edit map contents and not just to add the data. Therefore this new trend in cartography is just similar to a bit older web-mapping projects which originally aimed at online-publishing the results of one's desktop mapping contributions created with GIS packages. The users of these new projects usually don't have professional desktop mapping software at home, rather then they use the integrated editing and visualizing solutions featured in these collaborative GIS.

One of the most importants is *OpenStreetMap (OSM)*. It is a private British project carried out since 2004. Originally, its basic goal was to create a digital, freely available web-based map of Great Britain. Thanks to the success of that, it has spread worldwide by now. It uses VGI - Volunteered Geographic Information along with government and commercial data. It is one of the biggest collaborative mapping projects now. Its maps are usually redistributed for further use even for big companies. According to official sources, there are more than 1 000 000 users of *OSM* of which the most are amateur enthusiasts whilst others are GIS professionals. As for its data format, *OSM* uses topological data structure.

The project *WikiMapia* has been started in 2006. According to their website, it aims at "marking all geographical objects in the world and providing a useful description of them". It is stated that the user number of *WikiMapia* is somewhere around 2 million, respectively. *WikiMapia* is also the name of the owner commercial company, which is of Russian origin and is not a brand of *Wikipedia*. It uses the maps of *Google Maps* as base maps. It is a bit different from *Open Street Map* as a description of map features is a characteristic of this project.

Google Map Maker is another collaborative mapping project. Being the service of *Google Maps*, it also uses maps of *Google* in certain territories. Founded in 2008, *Google Map Maker* aims to provide additional user-generated map data to *Google*'s well-known *Google Maps* application. Although it is not so popular like *OSM*, the basic data source of this project is the enthusiast user once again, who likes to share spatial information. Maps created with that are provided to *Google Maps* for further use. It is the only well-known collaborative mapping project which does not offer licenses for accessing its data. It means that every user-generated spatial data ever integrated to *Google Map Maker* is the data of *Google* who not just runs but owns it as well. Most recently, *Google* made its *Street View* service also editable for users who from now can upload and connect their own photo spheres. They will then be available for *Google Maps* and *Google Street View* users.

HERE Map Creator is a project started by Nokia in 2012. The basic idea of that is to allow users to contribute to a free map with mapping their own residential area. It is still a service not well-known. According to its website, users can add new roads, new places and trails to the map and they are also able to edit them. This project is only available for some countries, yet.

Wikiloc is a track-sharing website available for users who would like to document and share their activities with others. It supports several kinds of activities. The aim of it is to discover and share the best outdoor trails for a lot kind of activities, according to its website. Users can freely upload tracks and they are also able to see trails uploaded by others. *Wikiloc* is featured in *Google's Google Earth* as well.

Endomondo is a sports tracker, with a bit less geo-content. Users can add the tracks of several kinds of sporting activities. They can also get access to other routes as well. Every of them are uploaded by the users, creating an online community of active people. Everybody benefits from this kind of file-sharing because possible new tracks are exactly documented and times also have to be recorded. Using such applications doesn't even require a GPS: if the track is exactly known and can be drawn on a map then only a clock is needed to measure the time. In this case, our route can be added afterwards as these applications feature online maps – usually base maps of collaborative mapping projects.

An interesting website, *Every Trail* aims at sharing the uploaded contents of users in connection with travelling. Sharing trips with the aid of geospatial data or just descriptions is one of its tasks. Other than that, community building of the users is also important, according to the website. *Every Trail* is also featured in *Google's Google Earth* which actually gave a bigger fame to this project.

Generally, most of the collaborative GIS of today put the emphasis on visualization. Not like a mostly by professionals used desktop mapping software, these web-mapping applications cannot provide detailed data processing and data analysis functions. There are pre-defined tasks of the users which these easy-to-use programs best serve for. However, serious contributions are necessary of an IT crew background of each such project to build the system architecture and to maintain the operation.

B. Image sharing with spatial information

As described above, user-generated content that contains spatial information are shared not just in collaborative mapping projects. Images can also provide important information for navigation if the exact location where the picture was taken is known. Most typically, the use of a GPS receiver can solve this problem. Nowadays, digital cameras with built-in GPS receivers are available which can make positioning easier. When using a smart phone, geotagging is also possible with the help of its camera and the GPS receiver.

The most geotagged photos can be found on *Flickr* and *Panoramio* which are well-known image and video hosting and sharing websites. *Flickr* is the brand of *Yahoo*, while the owner of *Panoramio* is *Google*. These two sites are based on user-generated content and therefore their mechanism and goal is similar to the collaborative mapping services. Nevertheless, many images appearing on *Panoramio* can be found in *Google Earth* as well. The geotagged images are placed according to their coordinates in the digital world map which allows the easy viewing and handling of them.

C. User-made aerial photography

User-generated aerial photography is another new type of user contribution to the mapping processes. Vehicles used for transporting the cameras are a bit different from the usual ones. Typically, kites and balloons serve for the transporters of the imaging instruments. Depending on the camera specifications and its height above the ground, the characteristics of these amateur photos are different.

Taking aerial images of the Earth's surface does not automatically mean that they are considered to be orthophotos. Just like photos taken by the specially built manned aircrafts, these ones have to be processed and mosaicked as well. This is a more complicated and more expensive activity for the users. Not just the costs of the airborne carrier is what is added to the expenses but a sophisticated software is also needed that can handle the aerial data and generate orthophotos from them. However, the new and the increasingly available solutions have been helping the growing number of enthusiasts over the past few years. Cameras used by enthusiasts are able to take pictures with a pixel resolution of 1-10 cm depending on the usual working range of 20-150 meters above the ground [URL-14].

Kites are always operated by a person who is located below that on the ground which makes their use efficient only for small and well-accessible areas. Usually, maximal operating distance from the ground is varying between 10 and 150 meters from the ground, depending on the size of the kite and the wind speed which has to be between 10-50 km/h.

Balloons can get higher, but the problem with it is the same since the size of covered area is limited. However, with enough patience on well-accessible locations, perfect images can be taken. Not like kites, balloons can be lifted in windless conditions. Imaging in windy weather is mostly done with kites.

Most recently, small remote controlled helicopters are available in the markets in the double-digit euro range. They may carry small cams which can take proper photos. The altitude range where these small machines can be operated is some 10 meters from the remote control unit. It means that the same height can be achieved with that like with a smaller kite. Furthermore, it can also be placed precisely where we want it to fly within the given range. However, operating them above a certain altitude is not possible due to the thin air. It makes their use impossible in high mountains. Therefore a very detailed mapping is possible but the covered area is limited.

Grassroots Mapping is a mapping community started by some activists in 2010. It deals with user-made aerial imagery. It is a starting point for those enthusiasts who would like to take part in the interesting activity of aerial photography. Every step of the workflow is described in details just like the tools which are needed for the measurements. Other than that, processing of the aerial photos is also described. The user can make orthophotos from the own images, which can then be uploaded and shared so that other users can access them freely as well.

3. User-generated content at a glance

A. Accuracy of collaborative map edits

Data accuracy is always an important topic in cartography and GIS. The source of the data, the acquisition methods are influencing the further workflow and the quality of the end product. User generated data and VGI – volunteered geographic information appeared as new data providers for cartography. Even some decades ago, spatial data had been derived only by professionals and therefore the data quality was guaranteed. These new data sources have still not found their place within cartography. The basic reason for that is the data itself: how accurate is the data of an enthusiast and what methods are on hand in order to filter them?

For hiking maps, the user contribution is usually the recording of the route with the use of a handheld GPS receiver. After that the data can be evaluated and added to the map as desired. Usually these publicly used receivers can make positioning only with a few meters accuracy. Therefore already at the moment of data capturing come uncertainty of data accuracy occurs. Depending on the scale of the end product, these small variations may not be crucial when displaying the routes. Usually at scales bigger than 1:10 000, it is important to make more accurate measurements. On the other hand, hiking maps of remote regions are usually not so detailed due to the vast territories which they have to cover.

What is also important is the documentation of points of interests along the route in order to have fix points with coordinates. Marking known or easy-to-find objects is also useful in order to identify and eliminate unneeded sections of the recorded route which have been recorded as part of the track but which are not parts of the desired path.

At the process of the data, another problem that can influence the data management is the variation in coordinate systems. The user has to make sure that the reference coordinate system is one and the same like the one in which the data would be inserted.

B. Licensing and re-use of user-generated data integrated to a GIS

User-generated data is the essential data source for a collaborative GIS. However, as it is integrated to a certain collaborative map, licensing will be provided to it depending on the project and the service to what it had been integrated. Licensing clearly defines the further use of a product. It allows certain purposes what it can be used for and also regulates how it shall be done. Licenses are important permissions which can be issued by authorities. Typically the owner of a product can grant a license to the licensee who can use that particular product according to the restrictions of the license. So the licensor can give special rights for further use of the product which is a basic point of licensing.

Many collaborative GIS projects use the *Creative Commons* license. It means that such a product can legally be shared, distributed and built upon by others. As it has many types, the allowed level of further use is defined depending on the used CC – Creative Commons license. The above mentioned *OpenStreetMap* also uses this type of licensing from the category Attribution Share Alike (CC BY-SA) [URL-9]. It is the second level of these licenses which mean that copying and redistributing of the material is allowed just like the remix, transform and build upon. Data can be used even for commercial use. There are 4 other levels which have more restrictions on the use of the products. Level four of the *Creative Commons* licenses is currently used by *WikiMapia*. his is the slightest non-commercial (CC BY-NC) type license which does not support the commercial use.

What is important to mention is that using *Creative Commons* licenses for commercial use – for example the level 2 used by *OpenStreetMap* as well – can only be done at some of its licenses. Furthermore, even the licenses which allow the commercial use may limit the further use of the product or certain parts of it. For example the *Creative Commons 2.0* license allows the commercial distribution of the product if the end product will have the same or similar license as the original one. Therefore using this type of licensed data for hiking maps is not the best choice as the end product – the analogue or digital map – will once again use the creative commons license.

Deriving data from *Google Earth* is not allowed for free just like accessing data of *Google Map Maker*. Although, valuable user-contribution have been uploaded to both applications. Since no-look regulations have not been made by any companies, one can get good ideas freely from anywhere.

C. Availability of user-generated mountain tracks for remote regions

When making a new hiking map either a digital or an analogue one, the searching for other similar products is a usual practice of map makers. It is always useful to check the related cartographic products especially because of the map content. Since user activity has grown in GIS, checking the online available data sources is also possible. One can get information not just on the possible routes or points of interests of that certain area but it provides a first impression on how popular that particular area is for tourists. The first impressions regarding popularity can already be taken after a brief look at the number of available data sources of the area. For example, one can instantly see how much user-generated content have been added to a particular area. A good example for that is *Google Earth* where after selecting the desired area one can see the density of the user-added map content like photos and tracks.

A tracklog is the collection of points containing spatial information which are automatically stored when a GPS receiver is moving. Each track recorded with a GPS receiver consists of points of equal temporal distance. This period between two points can be defined as the speed of moving. Obviously the measurement is more accurate if this period is small like 1-3 seconds. Tracklogs can be analyzed with several freely available programs. Then they can be uploaded to a number of websites. Some of these pages list only the available tracks while others also place them onto a base map. Some pages offer free data to download and others sell them. Tracklogs can not only be created by hobby users but the number of the user-generated and shared routes has been increasing over the last years.

As for the target areas of this thesis, the number of these shared GPS routes is variable. Not surprisingly, Europe has the most tracks which are available online. Even the area of the Dinaric Mountains is more or less documented by trekkers and mountain climbers, not to mention the Alps or the Pyrenees.

North America is another paradise considering the user made contributions with a GPS receiver. Despite, the Arctic territories are almost untouched by tourists and therefore the available sources for any track information are limited. Some expeditions were organized to get to these remote areas over the past few years but generally only some bits and pieces like geotagged images and coordinates of camps or important waypoints can be found.

South America and the Andes is a beloved destination of trekkers. The user contribution has been increasingly dominant. This is one of the most relevant area for high mountain collaborative mapping. The reason for that on one hand is the growing number of these active tourists visiting the Andes, on the other hand the huge number of unmarked trails which are important mountain paths. Thanks to the detailed topographic maps, these trails could be easily added to these maps, not to mention the potential of imageries.

Compared to the mountaineering potential of Asia, the user contribution in spatial data is very slight there in the mountainous areas. Even the worldwide frequently available geotagged photos are missing completely in some mountainous areas of Central Asia. The reason for that is definitely the lack of visitors and the local conditions which may cause a limited use of instruments like a GPS receiver. For the mountains Caucasus, Karakorum and the Himalayas, there are comparably more GPS tracks available.

Africa is again various in terms of high mountainous user generated spatial data. Some of the well-known areas like Mount Kilimanjaro or Mount Kenya are well documented while data from other areas is almost not available at all. This is the case for Ethiopia and for the Saharan mountains as well with the slight difference that even geolocated images are hard to find. Collaborative mapping from locals not exist at all due to the lack of infrastructure and poverty.

GPS tracks and geotagged photos of mountains in Australia are easy to find. This is not the case for the whole continent. The island of New Guinea is still an untouched natural beauty with a slightly growing tourism focusing mainly on its coastal areas. Nevertheless, the highest peak of Oceania, the lowest but technically most difficult peak of the Seven Summits is located on the island. Even today, not many trekkers could reach the higher mountains which are located above the lush tropical forests. This is one of the reasons why there is a lack of user-contribution from the area. The other reason is the big areas of uninhabited areas and the locals’ poor life conditions.

The remotest continent, Antarctica is once again a different case. As mountaineering is limited in its whole area, not much relevant information is available from the highlands. This is not the case at the coastal areas where tourists can officially get to onboard of ships. Especially geolocated photos provide information on the southernmost continent. Other than that, research bases are mostly situated on coastal locations.

6. From Planning until Selling: Processes before and at the end of a mapping project

1. Editorial works and Production of hiking maps

In this chapter I would like to sum up those processes which are essential when creating hiking maps yet are not considered to be first-hand cartographic processes. Basic planning and scheduling of the whole map making is before all others. The process of map authoring is in close connection with it, thus it aims at describing and answering several questions concerning a mapping project. Last but not least, map production is the final part in the physical workflow of map making. This chapter focuses on map production of analogue paper maps. The process of production or reproduction consists of several steps including the choosing of the right paper for the map or the selection of the printing method. It is a unique part of the workflow which focuses on the physical properties of the product. It aims at choosing and defining those elements which are influencing the physical and visual properties of the end product: the paper map.

Physical properties of a paper map include color, size, paper quality, weight and its eventual folding as well. Size is influenced by several things like map scale, area of modeled surface. When creating the map layout, the map maker has to keep in mind the next step of the workflow which is actually the printing. The paper map is born during printing according to the settings used in the software and the capability of the printer. Using the right color management and a good paper along with the correct map dimensions are keys at this final stage of map making.

Despite, map production not only consists of the physical production of the units. It is a lot more than that. Focus has to be put on the map authoring and map conception as well. Map conception has to be made first in advance right in the planning process of the map. Product marketing is important in map making as well. Without potential market, the product cannot be sold. Identifying the customers is also essential, both for map conception and making possible commercial promotions and adverts.

A. Color Management of hiking maps

Color management is an essential part of making a map. A basic problem is that the same color can vary significantly in digital form and on the paper – after printing. Basically, the on-screen color is always the original one and its printed version is always different from the digital one. However, this difference can be reduced significantly.

Color models have an important role when creating a map. Red Green Blue (RGB) model is an additive color model. Colors can be made from the mix of the three colors, red, green and blue. Usually, RGB is used by output devices like TVs and video cameras. Computer screens use this model as well. Interestingly, color printers are not using this color model. This is the main reason why there is difference between the on-screen and printed colors. Obviously, there is a need to create the same color which is selected during the map making. Therefore so called spot colors are used. These are colors generated by an ink in offset printing whereas four colors are used for printing: Cyan, Magenta, Yellow and blacK (CMYK). Spot colors serve for identifying a certain color which can then be easily produced with graphics editors or GIS software if they are compatible with the desired spot color classification. It makes the precise selection of colors possible without big surprises in terms of color variations after printing. Despite, paper quality and the ink are two further factors which still influence the result of printing.

Selecting colors for an analogue hiking map is to be done during the working with GIS and graphics editor software. It is important to think of the printing beforehand in order not to get surprised by the result. Identifying the used colors (using spot colors) already at the map editing or digitizing processes makes our work easier. Obviously, using RGB color model is the better choice if the map is made as a base map for navigational devices as both the GIS software and the GPS uses the additive color model for displaying colors.

Spot colors can be classified into many systems of which are each more or less industry standards. The American *Pantone* is one of the better known color matching systems. It is used by a number of printers. *HKS* is another wide-used color matching system of German origin offering about 120 spot colors and more than 3500 tones.

B. Map Size and Printing

Choosing the proper map size influences a number of things. When creating a map, the size of target area and the desired map scale can already provide the approximate height and width needed for the representation on the paper. Planning the real map dimensions is possible with the use of either a GIS or professional graphic designer software. Size considerations are important due to the printing and the usability of the map.

Printers are usually set to dimensions used by the International standards (ISO). These dimensions are used for paper sizes: a well known A4 paper has a size of approximately 210mm x 297mm. Paper width and height increases with the decreasing numbers of this code: A0 measures of standard paper sizes are 841mm x 1189mm (1 square meter). Usually the A-series of ISO is used. It is officially used almost in every country except of the United States and Canada.

Quality of printing also depends on the software settings and the printer. Just like digital image quality, the maximum resolution of a printer is also given in dots per inch (dpi). This value measures the maximum number of dots which a printer can place to the x and y directions. It can easily be the case that resolution settings are set to such a high value that the particular printer technically cannot create it.

Special printers are used to produce maps. The reason for that are the big paper dimensions which would be too vast for regular printers and that the efficient way of printing aims at cost minimizing yet creating high quality products. It means that the average unit cost of one map should be relatively low in order to reduce printing costs. Depending on the number of products, the printing technique is also a subject of choice.

Originally, dot matrix printing was widely used for creating analogue cartographic products as well. These printers could not make high resolution images as their dpi resolution was too low. The other problem with them was the limited number of character sets that they could print. Nowadays, the use of this printing technique is out of date. Instead, two other types of printers are used and sold for commercial use. Both ink and laser printers are able to make high quality images. For high resolution images, inkjet technology seems to be the better choice. Although, some laser printers can also guarantee an image quality of even more than 1000 dpi which is more than enough for a topographic map. Typically, unit costs are basically the same for inkjet and laser printers though for lasers it is slightly lower and they are usually faster. Another technology used for printing is the Light Emitting Diode (LED). These printers are very similar to laser printers. A maximum resolution of 1000-1200 dpi can be achieved with this technology.

Frequently used printing technique is offset printing. It is based on in-based technology and used for printing industrial quantities of books, papers, magazines. Although, it is one of the most important printing technologies for maps as well. When making commercial quantities of maps, offset printing is definitely the cheapest method. The computer to plate technology ensures high quality prints.

Before printing the product, the map has to be completely ready for printing. This means that the map information, the graphic design and even the layout of the map has to be complete. There are usually mistakes or small elements need to be changed or removed, which are only visible after printing, when the map maker first holds it in the hands. Therefore test-printings are always needed. By the time of printing, the exact number of units has to be defined, not to mention the paper needed for the printing. What is also useful to know, is that some paper types cannot be used for certain printing methods. It is important to discuss the details with the chosen printing office.

C. Paper Quality and Folding

Selecting the right paper for outdoor use is essential for hiking maps, as the possible severe weather can easily make a paper map useless. Unfortunately, my personal experiences in the field of paper quality are quite bad. Usually, the material of today's hiking maps make only the long-term indoor use possible. Especially for hiking maps of remote regions, very good materials should be used which can last long even after severe outdoor use. In today's world, trends are changing in many ways, even in production. As maps can already be found in digital form as well, map makers do not make serious efforts to create high quality paper maps. On the other hand, maps are updated relatively often, depending on the map maker. So there is another reason not to make long-living analogue products. However, I think that hiking maps of remote regions should not belong to this category of mountain maps. The mountain ranges which are targeted by such maps are not located in densely populated areas or in well-maintained environment where circumstances change rapidly. These maps do not need to have updates in every third or fourth year. On the other hand, these products have to be robust in order to cope with the severe weather. Therefore high quality materials have to be provided which makes the unit price higher. Despite, it is essential to use the best materials.

Materials used for analogue paper maps are of a lot of kinds. John N. Hatzopoulos [HAT-08] writes that the use of transparent papers, tracing paper and even Xerox paper is proper for most of the applications. Probably, plastic based paper made of polyester can be the best choice for these hiking maps if we consider the possible negative effects to the paper as a result of outdoor use. What is also really important is to select material which does not suffer permanent deformities due to heat or other possible effects. Polyester papers mean a good solution against humid air or occasional smaller water impacts. Coated paper is also preferable as it slightly water resistant, too.

A special property of papers is their weight given with grams per square meter (g/m^2). A usual A4 size paper weighs about 80 g/m^2. It makes this paper one of the simplest solutions for map making as it is relatively cheap, though its structure is also not too strong. The more weight a paper has, the longer it will last. This is a basic truth at paper quality. As I mentioned before, it is not just the weight that matters. The material is also important. Each type of materials measure differently therefore the 80 g/m^2 Xerox paper cannot be compared to a polyester paper with the same weight.

Weight is an important issue for expeditions but even for a multi-day mountaineering. Limiting weight of the equipment is therefore essential. Paper maps mean a good choice therefore as well. Despite, using GPS cannot be replaced fully with using paper maps: in bad visibility (dense fog or darkness) positioning can be limited so that paper maps alone are not enough to do it. In that case, knowing the altitude is already a big help. Combining it with the advantages of a GPS is even more useful. Nowadays, watches can contain GPS receivers which can be a solution instead taking a heavy handheld receiver, presuming that the paper map cannot be fully replaced by a GPS.

Folding the map correctly is not simple; it is always made in a systematic order. When designing the folding, it is important to mind several things. For example, the distances between two creases in both width and length are equal to the minimal map size. It is important to be relatively small in order the map not to be blown away in high winds. On the other hand, making too many creases makes map reading and navigation more difficult. Interestingly, map folding is a problem in combinatorial mathematics. It deals with finding every way of folding a map with rectangular shape. Given the results depending on the size, it can be decided which way seems to be the best solution. Choosing the proper material is important because of the folding, too, as big maps have to be folded many times and a simple 80 g/m² paper may not be a good choice that time.

Not just folding is a way for reducing the product size. Wire binding is another technique used for maps. However, it is rarely used for hiking maps as it can make route planning difficult after one page has obviously limited area. This technique is more frequently used for road atlases where folded maps can be more problematic to use because of the limited space in a car. Although, folded maps have similar disadvantages as for using them in the mountains where the high winds can make their use sometimes extremely difficult.

Editorial Planning	Title of map, aim
	Source Material
	Format (type area, feather edge, max. print format)
	Scale (LOD, graphical density, degree of generalization of source data, map test/sketch necessary?)
	Map projection
	Frame map, cropped map?
	Choice of design elements (weighting/balancing of components, legend, dimensioning)
	Place names
	Margin elements, back, cover
	Choice of printing technology

Tab. 2: Editorial planning (Hurni – 2011)

2. Map Authoring and Marketing

A. Map Authoring

Making a map conception is a necessary task of map authoring. Listing the necessary steps of the workflow and making a plan for the map making process is something inevitable. According to Hurni [HUR-11], the map authoring process consists of several steps such as the search of appropriate data, the consideration of quality aspects, the search for editorial resources, the setting up of an editorial plan and finally the possible drawing and setting up of working instructions.

Pre-calculations are also essentially needed. The definition of the exact budget has to be made with big efforts, considering every single step in each stage of the whole workflow. According to Hurni [HUR-11], a map authoring process requires about 50% of the resources of the map making workflow, respectively. It is well-advised to plan costs and time-management beforehand for every of the three phases of map conception, planning and map production.

Reasons for map project	Demand by market
	Legal order
	Complementary visualization of special findings of investigation
	Special order
Involved experts	Client
	Data provider
	Map author
	Map editor
	Cartographer
	Distributor
	Map user
Analysis of map topic	Aim of the map
	Data properties (qualitative, ordinal, quantitative)
	Interpretation and classification
	Choice of data scales (discrete, staged, metric)
Graphic design of map elements with graphical variation	Area
	Line
	Point

	Text
	Diagram
Choice of design principles in Thematic Cartography	Generalization (Selection, Simplification, Aggregation, Accentuation, Omission)
	Choice of colors (bright, pastel colors for areas, the smaller the darker, dark tints for point and line elements)
	Number of grades of class data: 5–7 steps. More important data = more shiny
	Clear contrast between background elements (lighter, pastel) and foreground elements (darker colors, stronger contours)
	Superpositions: Areas with textures, Text masking or other color, Color definition according to standard scales or associative
	Text placement if possible in empty areas or masking when similar colors

Tab. 3: Map conception (Hurni - 2011)

B. Marketing

Marketing is a key process with the goal to promote the value of the product for the customers. In capitalism, products are made in order to fulfill the needs of users or in other words to meet the market needs. Making a product without monitoring the user needs is a non sense. Finding and identifying the possible costumers is also important, yet very difficult. Personal experiences and facts can in many cases be extremely helpful to start a mapping project. After it turned out that the particular project is worth it and it might be needed for a particular market segment, the project can be undertaken. Although, the complete planning stages as described above has to be carried out.

Good marketing strategies serve for reaching the costumers with higher efficiency. Finding and communicating the value of our product is essential. Especially the small private companies have to be able to stay in the race in which big companies get most of the attention. From a cartographer's point of view, map makers have to prove that they are able to create great valued product that is truly competitive in the market. Creating a hiking map series of remote high mountains may seem to be a risky project for many map makers. However, I am pretty sure that filling the void in terms of creating the first hiking maps of certain areas might bring success for the brave entrepreneur.

Finding the right channel where the map is best promotable is very important. Finding the targeted customers and to promote the map for them might cost too much. It is therefore good to search for cost-efficient strategies in promotions as well. Web 2.0 can therefore be very attractive, too. The new social media opened up new possibilities for small companies as well. If it is carried out properly, web-based social media can also be a useful way of promotions. The well-known social site *Facebook* also supports low-cost possibilities for small businesses with advertisements reaching many users depending on the previously set filters of the target users and of course, the money what we would like to spend for the adverts.

7. Costs and conditions in each segment

Generally, planning the costs and time scheduling are essential part of a mapping project. Without accurate cost estimations, mappings cannot be made. Therefore, some basic issues regarding the project have to be determined.

Staff assignment	Division of work
	Definition of competences
	Sub-contracting
Equipment	Hardware
	Software
	Consumables
Costs	Pre-calculation
	Tender
	Controlling
	Final accounting

Tab. 4: Panning staff, equipment and costs in a mapping project (Hurni – 2011)

Even previous planning of different costs will not mean a 100% sure budget but it can certainly lead to an approximately successful pre-calculation that is close to the real costs. Pre-calculations however, are just estimations and not exact values. It is therefore needed to be able to have additional capital for the possible extra expenses. What is also a good way of doing the pre-calculations is to add slightly higher costs to every step. There is no rule for that but planning about 20% more for the costs in the pre-calculation is advised. That time, if our estimations are correct, the chance for a big negative surprise at the end of the project will be lower.

A. Satellite data and imageries

Obviously, every content and map element cannot be made without accurate data which is for commercial uses almost never free. Landsat images, SRTM and ASTER GDEM are though accurate free data sources for map scales around 1:100 000, respectively. Costs of data acquisition influence highly the cost of the end product. Therefore the selection of data sources is essential in advance. Consideration of what it would take for the further data processing and analyzing is also important. For example, buying aerial photos without being able to process them has no sense at all thus it may deliver the information needed for our product. Before beginning the project, one have to be sure of either getting the right type of data that can be evaluated with the given software environment or we may opt to buy data which we can process the use of new technique. Hereby the biggest providers of imageries are listed. Among them are some private and non-private projects and companies [URL-11].

Buying data from Earth observing satellites is possible, yet in many cases pricy. Over the last few years, the market of publicly available data has grown significantly. Like in other fields, a contest has been evolving among the rival data provider missions which are obviously good for the users interested in the end product as the quality just gets better, while the prices of the imageries or numeric data will probably follow the distinct tendency of falling product prices due to the increasing number of data providers.

Imageries of the American Landsat missions are available for free from NASA. Yet, these images for big scale mapping purposes are not detailed enough as the spatial resolution varies between 15 and 60 meters. Recently Landsat 7 and 8 missions are going on but thanks to the archives, millions of images are available from the past. These images are free for further evaluation and even available for commercial use [URL-3].

The Geoscience Laser Altimeter System (GLAS) contributed a lot also to surface elevation modeling with obtaining backscatter profiles. Its captured data is available for public use. According to official sources, data quality was good or excellent only during the early observation period of 2003 and 2004. Despite, its operation ended only as late as 2010 when the last laser failed to work. Even during the best period, the vertical and horizontal resolution did not exceed 76 and 175 meters which is not enough for accurate mapping purposes.

Like in case of Landsat, data from NASA's Shuttle Radar Topography Mission (SRTM) is available for free. However, this is also a data which due to its resolution not proper for map making as the elevations are given for points located 30 meters from each other horizontally. For non-US areas, a resolution of only 90 meters is available. Its 3.0 version with the same resolution and eliminated voids is available since November 2013 with the same conditions like before.

Since 2011, the updated second version of ASTER sensor's data is available for commercial use. ASTER is a Japanese sensor on board of NASA's Terra satellite. Unlike SRTM, Its Global Digital Elevation Model covers the whole Earth at 30 meter resolution. It is also freely available for download from NASA. If data is used for representational or publishing purposes, then it is required to include the following citation stating: "ASTER GDEM is a product of METI and NASA.".

Ikonos, as the first commercial observing satellite, offers a wide range of products of its panchromatic and multispectral imageries. Depending on the needs, prices are varying between $ 10 and $ 45 per sq. km. Use and resell of the original images or parts is prohibited but certain distributions of them are partly allowed after obtaining a special license from *GeoEye* which can almost double these costs. However, vector extractions are allowed also for distribution at no extra cost needed for a license as stated in the IKONOS product guide: "Other Derived Works (vector extraction, classification, etc.) have no restrictions on use and distribution."

The French *SPOT* provides data at lower prices which are given only for scenes which are representing an area of 60 km x 60 km. Although, buying just image parts is also possible; the minimum area is 20 km x 20 km which can be obtained. A full scene of 20-m color and 10-m B&W costs € 1 900. Images with 2.5-m resolution cost more than € 8 000. Additional products of *SPOT* like *SPOTMaps* would be also useful for further mapping purposes. These are seamless, uniform, orthorectified, territorial coverage with up to 2.5-m spatial resolution. Considering its price at € 2 / sq. km, this solution for further evaluation seems to be quite cost-efficient. Good to know, that these maps cover only certain parts of the Earth. As for the license agreement of both products it is stated that: "any Digital Elevation Model or Digital Terrain Model (in any form whatsoever, i.e. database for instance) derived from a PRODUCT shall never be considered as DERIVATIVE WORKS". Along with other conditions of the agreement, it means that the user can freely distribute data which is not representing the original raster product. Vector models are also not prohibited.

Thanks to *TerraSAR-X* radar Earth observation satellite, the most accurate Digital Elevation Model covering the whole Earth has been available since 2014. Its resolution is 12x12 meters with relative vertical accuracy of 2m and absolute of 10 m, respectively. There are a number of products offered by TerraSAR-X services. The price of basic archived image products is ranging between about €1000 and €3000. The dataset used for the project *WorldDEM* will be consistent as it is less than 2.5 years of age. One other advantage of it is the radar technology. It can operate independent of cloud coverage and lighting conditions.

Radarsat imageries are available for entire Canada. Images are available from $ 3 600. *Radarsat* provides spot images and SAR data as well. Its big advantage is that the Canadian Arctic is well-represented.

B. Field Surveying and Track making

Field surveying has always been an expensive process. Partly because of the man power and logistics needed for that and also because of its relative slow speed compared to space- and airborne remote sensing. Last but not least, the equipment needed for the measurements are also cost intensive.

There are a number of problems concerning field surveying. As previously described, making any kind of field works is simply impossible in a number of countries. In many cases the problem is not the money rather the politics. Although many times the two cannot be separated from each other, selling hiking maps would probably not cover financially these spending. Doing field works legally is also a sensible issue for foreigners in many countries. The logistics of surveying is also something not to be underestimated. It includes a long process from the previous preparations and project planning until the getting of permits and ensuring the on-site accommodation and food distribution for the surveyors. Therefore it is rare that a private company makes such detailed terrestrial mapping in a remote area. Usually, countries make their own surveys which might then be sold for commercial use, too.

Handheld GPS receivers are useful tools best suitable for recording tracks and marking special features of the terrain which then can be evaluated and represented on the map. For today, it became an essential tool for mountaineers as well. It is the most used instrument of amateur users who contribute their data to websites where spatial data is represented in some way. Handheld GPS receivers are available for even less money as the time goes on. Actually, their new prices are mostly somewhere in the € 50-500 range, respectively. Although, there are different types of them made for different purposes like driving, sailing, flying or mountaineering. Typically, in the lower end one can find basic navigation systems specially designed for driving. A number of details make them useless for mountaineering including the battery and the big screen that uses too much energy. Another problem is the constant road searching which can sometimes make positioning impossible. Therefore, the low cost navigation systems are not suitable for mountaineering. A real handheld GPS specially designed for multi-day tours is relatively light yet robust, has a small (touch) screen, easy to handle and quite small. Preferably it uses batteries instead of rechargeable lithium-ion battery in order that it could be used in the backcountry for a number of days. What is also important is to have enough space for the data. Some new GPS are waterproof which is also useful. Such handheld instruments cost about € 200 and up, which is still a great value for money if we consider the fact that in many situations in the middle of nowhere, it can save our life.

C. Software Costs

For processing the image and vector data, special software solutions are needed. As mentioned above, several companies have contributed to the market of the GIS software. The comprehensive solutions, which these GIS software can offer, make them inevitable parts in the workflow of a mapping project. And of course, GIS software is mostly just one essential tool of making maps. The other is the graphics editors or the related remote sensing applications which are suitable for satellite image interpretation or capable for editing aerial images.

Mostly the particular software needed for the map making is available in many editions. As new functions and applications are added to them, new versions are available on the market. Even within one version, there are usually many licensing levels available. Depending on the need of the user, software packages are provided with various services and applications. Not just these services, but the prices of these packages show a variance.

As I mentioned earlier, *Esri's ArcGIS* is a famed and one of the most comprehensive GIS software available. Currently, several versions of *ArcGIS* can be purchased depending on the user needs. *ArcGIS Desktop* is specially created for desktop use. It is available in three license levels: Basic, Standard and Advanced, each one offering different functionality for various users. Depending on the user, pricing of *ArcGIS* is highly variable. If educational use cannot be proven, the use of the software package on a single computer can cost relatively a lot, ranging from about € 10.000.

AutoCAD Map 3D is another well known software package offering GIS solutions. According to the website of the software maker *Autodesk*, the software can be downloaded directly from the website not just for US users. Excluding VAT, a new stand-alone license costs € 5.500. Additional subscription on a yearly basis to it costs about € 950 which includes upgrades for latest software editions, the possible use of the software in multiple locations and the technical support. *Autodesk*'s graphics editor solution, *AutoCAD Design Suite Standard 2014* is available for € 5.400. Nevertheless, it is also available under rental licensing ranging from one month until one year and more. Monthly license is available from € 385 whilst the rental license for one year is available for € 3.075 plus the not mandatory advanced support per annum for € 275.

The company *Mapinfo* created its GIS software during the late 1980's. This was the first of such Geospatial Information Systems. *MapInfo Professional* proved its competitiveness in the market and is still a dominant player there. According to *Pitney Bowes*, the desktop version is available for about € 2.500 with the first year mandatory maintenance. For making hiking maps preferable *Vertical Mapper* extension costs an additional € 1.500. *Mapinfo* is also proud to have their own GIS server which is a good solution for many enterprise related solutions. The company also sells reference maps from all over the world.

GeoMedia of *Intergraph* is a GIS mainly used by users overseas. It offers special extension for a wide range of uses including transportation analysis and management, parcel manager or applications for terrain management. Exact pricing is unknown, however, basic using costs for one user are considered to be somewhere a bit under €10.000, respectively.

ERDAS IMAGINE is perhaps the most used remote sensing application in the world. Just like GIS software, this image interpreting application also has more versions depending on the user needs. Its use is based on licensing as well. Prices for the single use are relatively low, ranging around a few hundred Euros per annum.

RemoteView, created by *Overwatch Systems* is another sensing application used by US authorities as well. For international users, several products are provided in the field of imagery interpretation and geospatial analysis. Applications like *Feature Analyst, Global ImageViewer, LIDAR Analyst* and *RemoteView* are solutions specifically designed for international users.

Exelis Visual Information Solutions (Exelis VIS) or *ENVI*, is also a digital image interpreting- and analyzing software used for military and defense purposes as well. These products are priced in the four-digit Euro range but pricing and licensing conditions vary and prices are depending from the user, once again. *ENVI* is capable of processing panchromatic, LIDAR and SAR data, multispectral and hyperspectral images as well.

As for pricing of graphic editors, the same strategy is being used as for the above described GIS software packages. Licensing for certain periods is the only way to get for example the latest version of *Adobe's* popular graphics editors, *Adobe Photoshop CC.* Fees for using it are depending on the user type and the desired duration of the access. Hereby *CC* means the Creative Cloud technology, the previously described cloud-based infrastructure which is so popular today. According to estimations, this new version might be affordable for more users as the calculated costs for a four year long use seems to be significantly lower as it was by the previous version. The costs for such period would be about 500-1500 Euros depending on the exact specifications. Obviously, the monthly sums would be higher if a shorter period is chosen, as *Adobe* also tries not just to get rather to keep the customers for a longer time. The other graphics editor of *Adobe*, the *Adobe Illustrator* also came up with its new, cloud-based version. *Adobe* has once again come up with new features and tools for the new versions. The three dimensional working environment is one of these newly added features. Annual fee for the business license of *Adobe Illustrator CC* is available for about € 500. Considering the applications and tools of this software, this price cannot be considered as too high, though it may be beaten.

Corel's *CorelDRAW Graphics Suite X6* is another popular graphic designer software package. For the European Market, the price of this graphics editor is about € 630, including VAT. This is the price of the downloadable version. Unlike *Adobe*, *Corel* still do not use that type of licensing and so this price is valid for unlimited use and not for unlimited use within a given period. Given that this package contains a photo editor and a graphic designer application as well, this price can truly be considered as a bargain and as a whole it is a good value for the money. Furthermore, it also includes a website creator and a useful bitmap-to-vector tracing tool. This software package is also ready to work properly with other files generated by even the latest versions of *Adobe*'s products. Other useful tool, the color management engine helps to overcome the color differences between the on-screen and the printed colors with using amongst the *PANTONE* system. The software also supports more than 100 file formats including AI, PSD, PDF, JPG, PNG, EPS, TIFF and DOCX, respectively.

D. Platform demands

An important aspect of making maps is the platform, where the needed programs can run without any difficulties. In other words, it is obviously not enough to have just the software, it is equally important to have the hardware environment needed to be able to use the software. However, it is also relevant to have an operating system (OS) which manages the hardware system. Especially some decades ago, having the proper platform was a difficult case. Nowadays, buying a platform that has sufficient performance is a lot easier task as high performance personal computers are available for much better prices like decades ago.

Platform needs are depending on the software. Many of the new versions of the packages listed above, have been designed to meet the requirements of the currently available operating systems sold on the market. In most cases, some previous operating systems are also compatible with them. As for the processors, it is usually a basic requirement to have an *Intel Pentium 4* or another such type that belongs to the similar category.

Storage capacity is an important aspect as well. This has been a problematic issue earlier, too. At the beginning of the digital cartography and GIS utilization, there was a higher need for storage capacity. That time, it was more difficult to get the needed storage space. Nowadays, one can find external hard disks with storing capacity of 1 TB for less than € 100, respectively. This is value for the money, especially if we consider that this space is enough for more series of satellite imageries as well.

Platforms that meet the listed minimum requirements can be bought for less than € 500. Despite, it is well advised to buy a modern and high performance computer which will probably suitable for later software versions, as well. These computers are available for a bit more but are still within the triple digit Euro range.

E. Printing- and material costs

Unlike digital maps, paper maps have to be printed as well. Afterwards, either folding or wire binding is used for reducing the size of the product. For wire bindings, smaller sized printers can be used, too. Despite, this binding technique is rarely used for hiking maps. The reason for that is the small area which is covered in one page. It makes route planning more difficult, especially if the map scale is big.

As described earlier, printing can be done with various technologies, depending greatly on the required quantity and the product material. It is a general rule, that prices of the single printed unit is highly depending on the number of units, in other words, the number of maps that need to be produced. Unit printing costs can generally be lower with the increase of produced units. Let's take just one piece of paper that should be color printed. Its price is in this case relatively high but at a map series where 500 maps are produced, the unit costs can be reduced to even the half of the original price. For 1000 units, it is about the 45% of the original unit price. This price reduction for digital press printers usually lasts until 10 000-50 000 copies where the unit cost can be as low as the 25-30% of the original single unit price. These numbers also show how much the price decrease in unit cost is if the production is increasing.

Material of the map is one of the smallest items to be purchased at a mapping project. Yet, if the pricing of the product is to be relative low, cuts are needed at every segment of the workflow including the used materials as well. Therefore polyester is sometimes considered to be luxury for maps, in many cases transparent or Xerox papers are used instead. The good quality material however is essential especially for a hiking map. The price difference between the materials used for one single map is considerably low, but for a whole map series it can be reasonable. That's why several map makers do not take the risk of spending more for the map material. Instead, they use a bad quality material and save the money for other work segments. Needless to say, that many of them plan the products only for some years until the new map edition is created. Despite, a storm can reduce the lifetime of a map with low quality paper dramatically, to even one single tour. It is therefore better to use the slightly higher priced polyester material that obviously also cannot be used for a lifetime but will certainly last for years. Other than this, the quantity of the needed material will influence the unit cost greatly but perhaps not so dramatically like it is at printing.

Comparing the two types of bindings in price aspects to each other, no significant differences can be taken. It is true, that the wire binding needs a special technology to be used, but map folding and the big sized printing also requires special efforts. What is a plus for the wire bindings is that the material used for the back and the cover is different from the content pages. It should be consisting of a stiffer material.

F. Operating costs

Obviously, several aspects of costs exist. One should not forget to consider the running costs as well. In other words, running costs are operating costs that cover a wide range of expenses needed for the everyday life of the company, including rental costs, salaries, advertizing, maintenance costs, insurance and so on. However, operating costs do not cover the capital costs that include the work tools and instruments.

Operating costs partly aim at covering the running costs of the capital costs. In this chapter, the emphasis was put on the sharing of only some features of capital costs without taking a glance at the running costs as it would go too far from the original topic. It is important to mention, however, that both types of costs are equally important. There is no map production if the operating costs were underestimated because then the operation of the instruments cannot be guaranteed.

Of course, the ratio of capital costs and operating costs of the total costs can be various in many cases. For example, a big company can have their own office and instruments, a smaller may meanwhile not afford this. Having an own property or working infrastructure means lot higher capital cost. If an own office is not given then the rental costs will increase the operating costs.

8. Making a low-cost touristic map of a remote high mountain range in the practice: Mount Cameroon

1. Choosing the area

When choosing an area from the list of the target areas to be mapped, the focus was put on those mountains which are relatively well-approachable and can be covered with one touristic map sheet without difficulties. Considering the existing user contribution for the area was also decisive. Mount Cameroon seemed to be perfectly eligible for these criteria, especially after having seen that large scale topographic maps are existent for the area.

Mount Cameroon is one of the last hidden natural treasures of the high mountainous regions of Africa. Its location however is not so remote like some of the famous ranges such as the Rwenzori or the Ethiopian Highlands. Located close to the Equator, the climate of the area is extremely hot and wet during the whole year. The mountain and the surrounding area is part of the Mount Cameroon National Park. The starting point for the tourists who want to climb the mountain is definitely the town of Buea located at the southeastern side of the mountain range. It can be easily approached from many airports of Cameroon along the country's road network. The volcano reaches 4000 meters in altitude and is a perfect destination for trekkers and adventurers. There is even a well maintained path leading up to the top from Buea. There is an option to hire guides for the trip.

Mount Cameroon is an active volcano which is affecting the nature and the life in the few villages located on its slopes. The last major eruptions happened in 1999. The new lava fields are well visible in the Landsat images as well, which proved to be particularly helpful when identifying the vegetation. One of the lava flows of these most recent eruptions reached the coast, stopping just about some dozens of meters from the sea and reaching the coastal road as well.

2. Data Sources and the Software Environment

A. Data and Data Accuracy

As I described earlier, one goal of the thesis is to find cost-efficient ways of making maps of remote high mountain areas. Low cost mapping has therefore importance during the making of the Mount Cameroon touristic map, too. After choosing the area, the search for the data began. Most importantly, the vegetation and the elevation are the two key elements for the map. Finding low cost and good quality data was the next step. When planning the map one important step was to find a proper scale best fitting the map. As for the morphology of the mountain, rock formations are not dominant at all therefore a detailed depiction of the mountain faces can be made smoothly even in scales around 1:100 000. However, I did want to make a bit more detailed map as it is obviously more useful when navigating in the terrain. On the other hand, I had to take into account what the low cost or eventually the free methods make possible in terms of data accuracy.

For modeling the vegetation, Landsat imageries seemed to be the best choice. Since they are available free of charge, it was obvious to choose this image source. It is however important to check the data accuracy. The newest satellite of the Landsat, the Landsat 8 was launched in 2013 and is able to provide multispectral imageries with a global resolution of 30 meters. The accuracy of its panchromatic images is even better, around 15 meters. Making true color pictures however can be made from multispectral images. According to the general rule in cartography, the location of objects on the map must be given with an accuracy of maximum 0.4 mm when viewing it in the original scale. It means that the maximal 30 meters derivation of these Landsat images must not exceed this 0.4 mm on the map. Therefore the map scale has to be not bigger than 1:75 000.

Choosing the cost efficient or free data source for the elevation was another key task for this mapping project. Since more SAR-based elevation database is available freely, I took account of their accuracy for a possible large scale topographic map. As mentioned earlier, SRTM and ASTER GDEM2 are the two nearly global scale projects from which data is accessible for free. SRTM is less accurate in areas outside of the USA: the estimated resolution is about 90 meters globally with a vertical error of less than 16 meters. The other project, the Aster's Global Digital Elevation Map has a resolution of 30 meters and not just for the territory of the USA like SRTM.

I wanted to check if Aster's elevation model works really better in mountainous environments. According to the study of M. Rexer and C. Hirt [URL-2], the newest version, the ASTER GDEM2 is more accurate than any other free high resolution digital elevation data sets. Another study carried out by G. Timár and D. Karátson [KAR-05] shows that even the use of SRTM model guarantees relatively good terrain depiction of high mountainous landscapes at scales around 1:100 000.

Taking the above written facts into consideration, it was obvious that Landsat imagery and Aster's Global Digital Elevation Map was to be used to create the Mount Cameroon hiking map.

B. The Software

Choosing the right software is at least as important as to choose the right data sources. It is also essential to make a plan of what we really need from the software side. As the vegetation is to be identified from satellite images, graphic software is needed that can handle multispectral images and evaluate and edit them. Since free graphic software cannot be used for complex image interpretations, purchasing one is a legal way to go ahead. Selecting an older version of such software can greatly reduce the costs. *Adobe's Photoshop* is a good choice for such operations. Currently older versions like the *CS3* or the *CS4* are available even for 5-10% of the original price in the double digit Euro range. Test or trial versions can be downloaded even at no cost. The other way to do it is to join the newest edition, the *Photoshop CC* with a month license for even less. The drawback of that however is the limited period for using the "rented" software.

Graphic software is needed for the map drawing and making the layout. Buying it the same way is cost-efficient as the same conditions apply here than for the image interpreting software. An older version knows basically everything needed for a cartographer. Classic software for these purposes is *Adobe Illustrator* and the *Corel Draw.* Just like *Photoshop*, old versions are available for € 50-100, respectively.

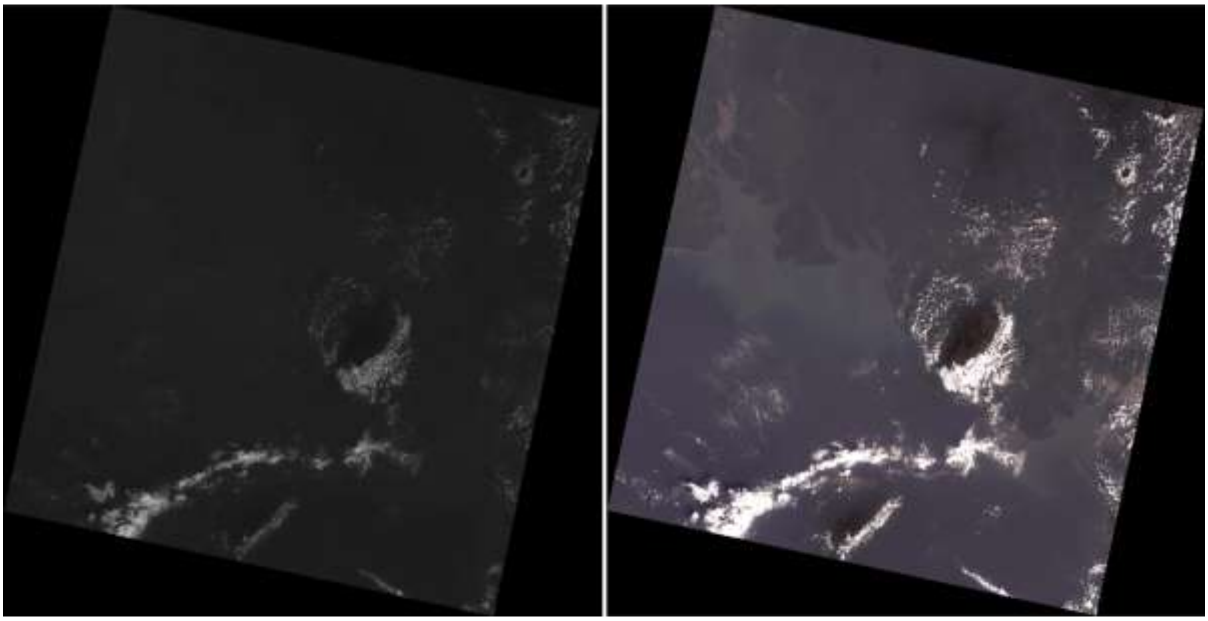
For generating contour lines from the ASTER GDEM2 images, GIS software is needed as well. As no complicated operations will be needed, basic, free GIS software should be good choice, too. QGIS is freely available and can cope with such exercises. Georeferencing causes no problems for it at all. Moreover, it can be used for more complex works as well like making terrain analysis.

3. Making the map from the data

A. The Basics

After planning the workflow and getting the needed software environment, the data collection begins. Landsat data products held in the USGS archive are downloadable at no cost from GloVis (http://glovis.usgs.gov) or EarthExplorer (http://earthexplorer.usgs.gov) after registration. The LandsatLook Viewer (http://landsatlook.usgs.gov) also displays Landsat scenes. The first step after selecting the desired area is to search for relatively cloud-free images where the vegetation, settlements and other objects are visible. Because of the effects of the tropic climate, these features at Mount Cameroon are typically hard to observe as between 1000 and 2000 meters of altitude the constant cloud cover disturbs the flawless imaging. This is especially disturbing at the southeastern side of the mountain. It is not a coincidence as annual rainfall over 10 000 mm is possible at some lower parts of the National Park.

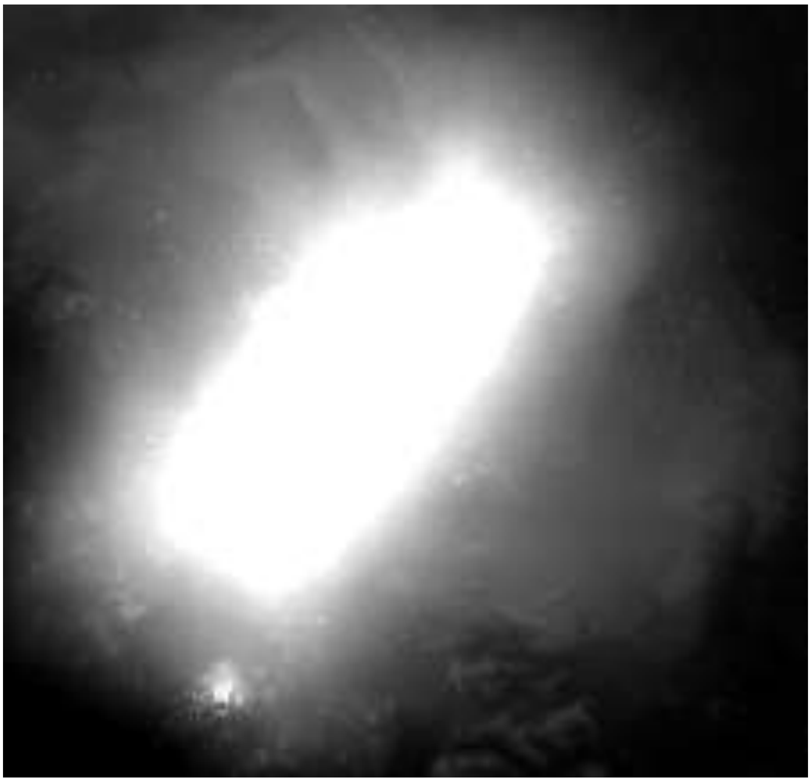
When selecting the images, it is even better if they are relative young. It means that the up to date situation is represented with them. Therefore it is worth selecting from the Landsat 8 images which have been collected since 2013. For comparison or further processes every of the Landsat images are available, dating back until 1972 when the first Earth observing satellite of this series was launched. As for the resolution of the images, significant differences can be experienced: Landsat 1 took images with 80 meters resolution, while the latest satellite of the project, Landsat 8 is able to achieve 15 meters of resolution for the panchromatic and 30 meters for the multispectral images [URL-3].



Ill. 30: Landsat 8 greyscale image covering the Mount Cameroon (on the left-hand side) and its surroundings compared with a processed RGB image

After selecting and downloading the Landsat images, the elevation data is what comes next. ASTER GDEM2, the newest version of the *Aster's* digital elevation models can be downloaded from the following page: http://gdem.ersdac.jspacesystems.or.jp/ right after registration. Selecting the data is quite easy. The result is a Tiff file which can be opened with any GIS software for further processing. In some cases it is possible that one tile does not contain the whole territory that is needed. In that case every of the needed tiles is to be downloaded and imported to the GIS software.

It is also well-advised to take a look at the user contributions that can greatly affect our work especially in regions like this, where every kind of information about the mountain paths or mountain huts is worth a lot. *Google Earth* is a good place to start the search for the user generated data. By the way, *Google* uses the images of Landsat for visualizing the area of the Mount Cameroon. Other web sites that are worth a checking are the previously mentioned *Wiki Loc* or *Every Trail*. Other than these global scaled GIS communities it is sure that other local web pages, travel forums and further interesting mediums are also dealing with useful information, tracklogs and points of interests. Geotagged photos are the other main source for useful spatial information, supported by *Flickr* or *Panoramio* just to mention some global scaled pages.



Ill. 31: Mount Cameroon and its surroundings as seen on an ASTER GDEM2 image.

B. Data Processing

After downloading the data and ensuring the right software (and hardware) environment, the map making begins. Individual processing of the multispectral Landsat images makes sure that colors, lighting and other characteristics can be set right that way as we want to see them. The basic image interpretation needed for making a true color satellite image can be more or less easily done with the help of some tutorials. However, making a true color image of an area where disturbing atmospheric effects are present is not easy. The worst are clouds and haze which can greatly influence the result of such an image interpretation. The target area is also heavily affected by these phenomena. Especially at altitudes lower than 2000 meters is the high humidity, the cloud cover and haze disturbing. Eliminating them or at least reducing their extent is possible, except of the massive cloud cover. Unfortunately, making clouds completely invisible is not possible. Therefore is it essential to choose as cloud-free as possible images. Fortunately, USGS's application (http://landsatlook.usgs.gov/)

makes it possible to search for images with low cloud cover percentage. This is the way how to find relatively cloud-free images, too. It is however impossible to find images with less than 15% of cloud cover for the area of Mount Cameroon. It may be possible that some areas are not cloud free. The solution for that is the using a mosaic of more images which help to eliminate the areas with cloud cover. Illustration 32 also shows the disturbing effects of the clouds and haze [URL-1].

As a first step, the originally multispectral Landsat 8 images are converted to one single true color image as this will serve as the basic image for the vectorization in the graphics editor. After downloading the Landsat 8 images for the area, all we need to use are the B2, B3 and B4 color bands, each stored in a single Tiff image. For Landsat 8, B2 is the red; B3 is green while B2 is the blue band. It is important to mention that this color-band identification is not valid for other satellite images of previous Landsat satellites or any other satellite images.

After loading the three images to the software used for image interpretation, the next step is to merge the channels to get one image out of the three. It is necessary to set the above mentioned band codes as the given colors. This is followed by special image adjustments such as image brightening with methods like white point correction. Further color adjustments of each three colors red, green, and blue also help with making the colors brighter and the surface to have lively, natural impression for the viewer. As mentioned before, haze and clouds are disturbing effects which cannot be erased completely. The goal however is not to make beautiful true color satellite images, instead just to create a good base layer that can ensure the accurate vectorization of the objects that are grouped to layers and sub layers according to their spatial extents are identity types.

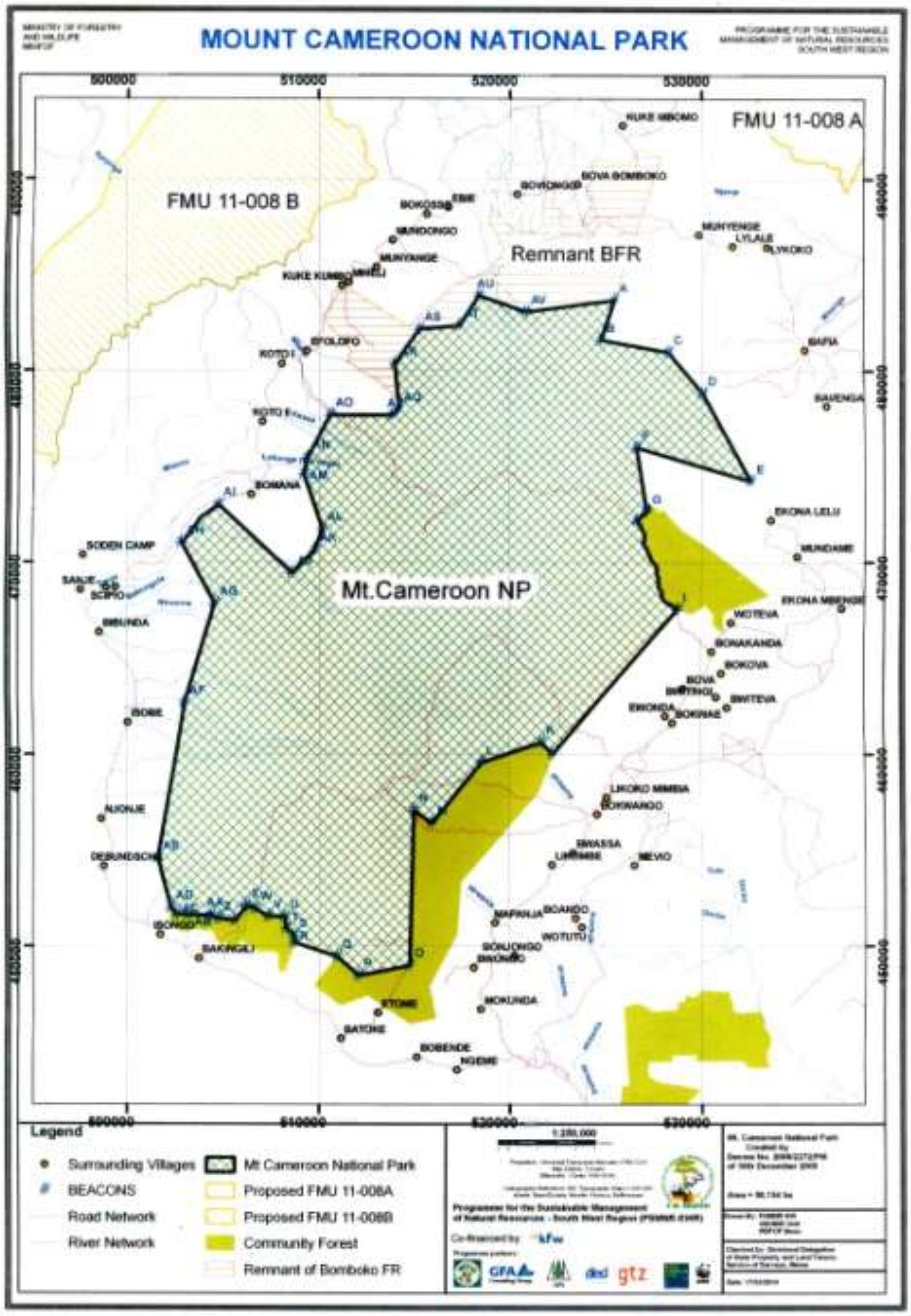
Even if the possible efforts had been made to reduce the area covered with cloud cover and haze, there is a probability that some parts of the ground cover would not be visible. Making mosaics from more images is a useful method for reducing the undesired effects of the atmosphere. Nevertheless, it means the use of more images made in different time which may result other colors for the vegetation or even objects that are not visible in the other image. It is therefore well advised to choose images with relatively equal temporal distributions.

Not only multispectral images are important for the further processing. The panchromatic images of the Landsat 8 satellite mission have much better resolution, about 15 meters. It means that the extraction of linear features such as road network can be done more accurately than the extractions of those map information that can only be derived from true color images like vegetation. Not just the paths or roads but the inhabited areas and other facilities can be extracted from the grayscale images. A method called panchromatic sharpening helps to increase the resolution of the original true color image [URL-15]. Firstly, the grayscale image is adjusted to be lighter and more contrasting. Then we add the Band 8 image as a new layer on top of the natural color image. Further sharpening helps to make the image even more detailed.

One other important question is how to collect the village and camp names and locations. The Mount Cameroon National Park created a sketch map depicting specifically the borders and the villages around the mountain range. The aim of the map was also to show some information for the forestry like location of community forests and nature reserves. It is however cannot serve as a hiking map as no information of elevation is given at all. It makes possible the identification of the inhabited areas. For doing that, this sketch of the national park has to be georeferenced to identify the coordinates of the objects.

Ill. 32: Mount Cameroon on a true color Landsat 8 image

Another problem is how to identify the altitude of special objects on the map. For example, the 3 huts that are located next to the normal route of the mountain, have to be measured exactly. Not to mention other natural terrain elements like mountain peaks and other relevant terrain features. Relief depiction can be made accurately enough with the downloaded elevation data but this 1 arc second resolution is not proper for the estimation of elevation of single objects like houses or mountain peaks. User generated data can be extremely useful in such cases, but the possible elevation data retrieved from a track log is also far from the accurate height values. Yet, it can give a valuable help for the users.



Ill. 33: A sketch map depicting Mount Cameroon National Park and the surrounding areas

As for the elevation data, only one of the two files we will need which is usually downloaded for one tile. The one containing “dem” is what we should use. With QGIS the Tiff image can easily be converted to contour lines with a generated shape file. The distance of the contour lines is one pretty important feature of the map that is obviously determined right before creating the contour lines. In this case, I decided to generate them after every 100 meters of height difference. The reason for that is the scale and the relatively big altitude changes within a small area. In this case it is the best choice towards good usability. After generating the lines, we would like to use them in the graphic software. In order the contour lines to be used in a graphics editor, converting the shape file to “dxf” file is necessary as shape files are unknown for most non-GIS software. This makes possible the contour lines to be opened as a new layer in the graphics editor for further processing.

It is however important to mention that georeferencing is necessary for laying the shape file of the contour lines on to the Landsat image. Both have to have the same projection in order the contour lines would be spatially well located. This process can also be done with the QGIS or with most other freely available GIS software. Georeferencing the panchromatic or the sharpened image is also needed.

Ill. 34: Contour lines of Mount Cameroon generated with QGIS from ASTER GDEM2

C. Creating the map

The vectorization of the needed information from the satellite image is the base for creating the Mount Cameroon hiking map. The result of the image interpretation, the true color image is now ready for this process. This image is the main source for many layers of the map, including vegetation, surface characteristics and water surfaces. The panchromatic image and the panchromatic sharpened RGB image can both serve for identification of the road network and populated areas.

Map layers are established in the graphics editor before the drawing begins. As this is a hiking map, accurate information on the vegetation types is essential. Therefore the layer vegetation contains many sub layers which contain the different categories of ground cover in the lower and in the alpine and volcanic zones. This aims at providing useful information for the user in terms of moving in the terrain. For example, the zone of savannah or the lava field with vegetation refers to those areas where the ascent is possible, yet possibly difficult. The more preferable surface type for trespassing is depicted with the lava field without vegetation, which symbolizes those areas where the surface builds up from volcanic rocks without any or with limited vegetation. These two zones cover entirely the areas over the forests, from about 2000 meters upwards. Savannah-like vegetation can be found in the upper region of the forest range and at the lower parts of the lava fields with vegetation sub layers. The tree-free zone is located just above 3000 meters. Here the mountain and sub-alpine grasslands can be found. Thanks to the volcanic effects, however, the exact vertical boundaries of the vegetation zones cannot be identified as usually. In some cases, the traces of lava flows make vegetation impossible even in areas close to the sea level. The latest eruption of Mount Cameroon in 1999 influenced the vegetation heavily with numerous lava flows, from which one almost reached the Atlantic Ocean as well. These relatively new ash and lava fields are visible in the satellite images, too. This is also one of the reasons why the use of recent images is necessary. The belt of the dense forests is located between the sea level and about 2000 meters of altitude. In the upper parts of this belt, vegetation changes to sub-mountain and mountain forests. Evergreen lowland forests are located around 1500 meters while mangrove forests and freshwater swamps feature forests at lower elevations.

As usually, the contour lines generated from the ASTER GDEM2 were not proper for instant use as a map layer. Therefore every single contour line had been vectorized according to the contour lines created with the QGIS, respectively. Moreover, the small points and other disturbing lines had been removed as well. This process was the generalization of the contour lines that was needed due to setting the scale to 1:150 000 which does not enable some special details. Each of the hundred meters elevations are marked with contour lines. In some relatively flat areas, dashed lines mark the fifties among the hundred meters as well. The main contour lines are those with an elevation of 500, 1000, 1500, 2000, 2500, 3000, 3500 or 4000 meters of altitude.

The road network is quite simple in the area of this hiking map. Basically, four types of road categories exist there. Most importantly, mountain paths can be found at some parts of the national park, but vast areas are lack of any kind of paths. The reason for that is the altitude of villages: settlements hardly reach an altitude higher than 1000 meters and all of them are located below 1500 meters. Above that, the forests are the part of the national park where forestry is limited. The other road class, the dirt road is connecting some of the villages. Their exact quality is unknown as the frequent rain showers can destroy them at times. The paved roads can be divided to first and second order roads. Mountain villages and towns can be approached through these mostly one lane carriageways.

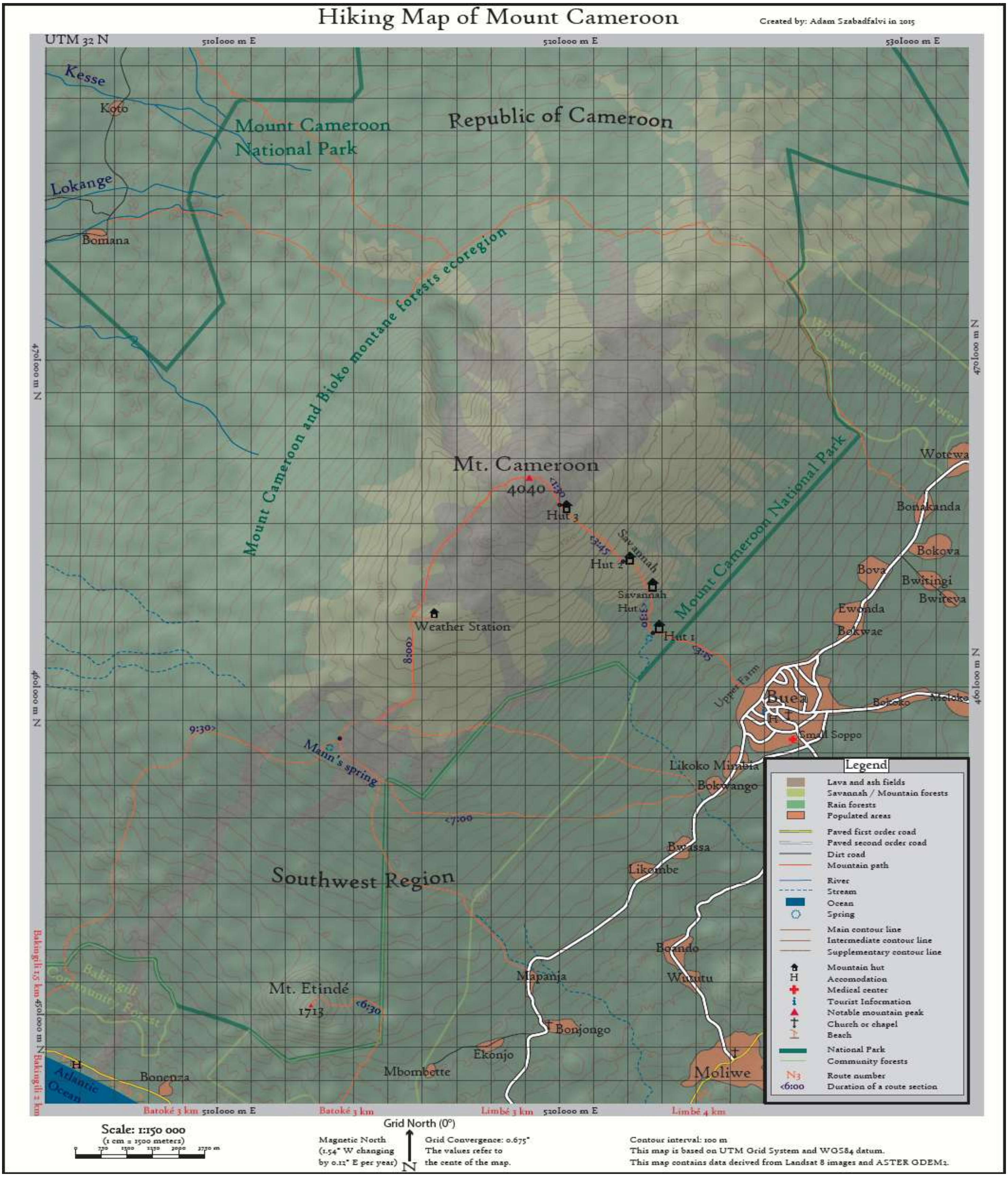
Symbols, another category of the map layers cover several types of features. One main unit of the symbols is the huts. Even in the Mount Cameroon National Park there are mountain huts. All three of them were built along the main path leading to the highest point of the mountain from Buea. Unfortunately, exact elevation of these buildings is unknown, at least within some meters accuracy. Route descriptions made by users give the elevation of these huts relatively well, just like geotagged photos. Some relevant points of interest like medical centers, hotels or beaches were also displayed on the map. Red triangles were used for marking the only two peaks with known elevations, Mount Cameroon and Mount Etindé. These symbols belong to this layer as well.

The sketch map mentioned earlier in this chapter was pretty useful for this hiking map. Especially the exact boundary of the national park could be depicted. Other than that, some villages and additional mountain paths were successfully placed as their locations are shown on this forestry map. It was not until this stage that the depiction of even small populated areas was possible. This sketch map combined with the data gained from descriptions, tracklogs and geotagged photos made possible the depiction of many map features accurately. What also helped my work a lot with tracks and data is the running race organized each year from Buea to the peak of Mount Cameroon. During this race, hundreds of athletes try to be the fastest in reaching the top of Mount Cameroon.

A further layer contains the surface water. Streams, rivers and the ocean are the three sub-layers in that. Interestingly, there are no lakes within the territory of the map at all. The difference in the depiction of streams and rivers is visible: unlike rivers, streams are displayed with dashed line. Water names, just like every other name belong to the layer names. Other than this, the name of towns, villages and special areas and mountain peaks are the part of this layer as well.

Like on most maps, populated areas are important to be depicted on this hiking map, too. A comfortable and the most often used way for approaching the national park is the path starting from Buea, the biggest town on the map which could be called as the entrance to Mt. Cameroon. Its population is estimated at 100 000. It is also one of the oldest towns in the area that once also served as the capital of German Cameroon. It is no coincidence that even colonial buildings can be found there. Buea has everything what is needed for a successful trip to the mountain: accommodation, food store, the office of the national park, guide agencies for hiking tours. It has a medical center too if the trip to the mountain was not that successful. Moliwe is another town located between Buea and Limbe. Other than these towns, there are a number of villages especially along the southeastern side of the mountain. The depiction of the inhabited areas is very basic: only the major streets and the basic facilities are shown.

Cartographic visualization of the terrain is a challenging task of the map maker. If it is done in an adequate way, the map reader may be impressed by the relief characteristics of the depicted area. Relief shading is an important feature of the Mount Cameroon hiking map. It is however not easy to identify the exact slope and aspect in some parts. The volcano does



Ill. 35: The hiking map of Mount Cameroon

not have very steep or overhanging mountain faces that would dominate the overall terrain. Therefore creating an exact rendering in the map scale 1:150 000 cannot be achieved easily. Relief shading can be created with a GIS using the original satellite images. Further image interpretation can be evaluated with graphic software that makes it possible adding on the other map layers.

The legend of the map is placed to the lower right-hand side as there are less interesting objects. It contains obviously all the symbols and the color- and graphic styles that were used for each of the above mentioned layers. Scale, scale bar and north arrow are also featured in the legend. A short statement of the data sources are also provided there.

Last but not least, this hiking map can also be conveniently used with a GPS. Therefore coordinate frame and kilometer grid had been put on it in order to enhance positioning and navigation. The used colors for the map were selected from the Pantone + CMYK coated color set.

4. The End-Product

A. Résumé of this mapping project

The hiking map of the Mount Cameroon is a large scale map made from freely available data. Every data used for creating the map was legally used and added to the map layers. The basic goal with this project was the demonstration of what can legally be done with a small budget when it comes to making of hiking maps of remote areas.

During creating the map, most of all I was focusing on the free data sources. Obviously, cutting costs on the software side was the other key goal to be realized. All in all it was demonstrated that a basic hiking map can be created in a cost-efficient way. As some processes like satellite image interpretation require high-end tasks from graphics and image editors, I chose rather not free but older and cheaper versions of well-known software packages for making the map. However, using only free software solutions might be possible as well.

This mapping project certainly featured many positive but also some negative experiences. For instance, selecting and downloading the Landsat images was relatively easy. On the other hand, trying to eliminate the cloud cover for the better visibility was a more difficult task. I also experienced difficulties when trying to vectorize the populated areas. Even the 15 meters resolution of the panchromatic Landsat images seemed to be low for real accurate interpretations of populated areas. It is obvious that a hiking map should not be used in the town rather in the terrain, but a bit better accuracy would be useful. Nevertheless I have to mention the cloud cover and haze again which affected the populated areas the most. The other issue is the lack of points and objects with accurately known elevations. On the other hand, realizing small terrain features like volcanic craters is also impossible when using only the free ASTER GDEM2 data. It is a perfect database for creating contour lines in the 1:50 000-1:100 000 scale range, but it cannot be used for getting accurate height information of known map points. In areas like this remote, the only possible way for getting elevation data is either to buy or to get the data with local field works. Nevertheless, such processes are simply impossible for a low budget project like this.

B. Possible low-cost mappings with the same methods in other areas

The target areas of this thesis are of several kinds. Some of those mountain ranges are located in the tropic while others lie within the Arctic Circle. Even in extent they are different, not to mention their accessibility. Some of these mountain ranges can be depicted in a single map sheet while others are a good base for a whole map series. One thing is sure: hiking maps with larger scales than this 1:75 000 map cannot be made from these data sources. It is however obvious, that vast mountain ranges don't require better accuracy than this. Even the ASTER GDEM2 data should be basically enough for the terrain depiction for most remote mountain ranges.

Landsat images are freely available for the Earth's whole landmass but the two freely available elevation datasets cover only certain territories of the Earth. Data of SRTM is only available for areas from 56° S to 60° N. The other free elevation source, ASTER GDEM2 is available beyond these areas as well, covering the landmass of the planet from 83 degrees north to 83 degrees south, respectively. It means that 1 arc second accurate elevation data can be obtained for each of the target areas, making it available for each of the target areas listed in this work. Unlike SRTM, the data accuracy of ASTER GDEM2 is not getting worse in elevations over 7000 meters, either.

9. Synopsis

1. General goals of the thesis

This thesis deals with a very interesting aspect of cartography, the making of hiking maps and doing that on remote high mountainous areas which represent probably the last hidden natural treasures on the Earth's continental surface. The emphasis was partly put on the following problem: some of the high mountains have not been mapped in big scales at all and therefore no available hiking maps have been made so far. I was also dealing with those high mountains of which big scale maps were created but which are not hiking maps. I summarized these potential areas which are considered to fit into these categories. The reason for that is quite simple: global tourism grows by 3-4% annually and that even more travelers and mountaineers get to remote areas that were forbidden to go to or simply inaccessible before. This was one of the research areas of the thesis.

Another interesting aspect of this work is the technical background of such kind of mapping projects. Comparing the available technologies to each other may help in decision makings. Selecting a certain data acquisition method will strongly influence the costs of a project, not to mention the further requirements needed for that in the data evaluation and data analysis. It is therefore important to consider the technologies that may help to get data in a cost-efficient way. Listing data acquisition methods also require the short description of the theoretical background of the techniques. This thesis is focusing on the cost aspects of a hiking map project of remote areas as they are unique as for data acquisition as well. Taking the cost issue into account is needed to the practical side of the thesis. Despite, no definite suggestions can be found in the work. I think that promoting a certain product or software package would be far from either a correct evaluation or a scientific work.

Certain new aspects of today's cartography might be useful for a new hiking map project. Collaborative mapping is such a new and interesting phenomenon especially for hiking maps. The basic element of the collaborative mapping is the user-generated data which is also important for hiking maps depicting a remote high mountain range, as big number of tracks are uploaded to various websites with geospatial contents. It is no coincidence that one of my research fields is collaborative mapping and its possible contribution to such a project. User-generated data is important from many aspects. Not just the data itself but the location where it was recorded provides also interesting information. The distribution of these uploaded tracks shows how popular certain routes or mountains are.

2. Research areas and research questions

A. Listing the target areas

The target areas, so those mountains that are important for the topic of this thesis have been listed in a whole single chapter. Mountain ranges are grouped by continents. There is a short description containing the mapping situation of each of the mentioned areas. Mapping situation cannot be accurately examined and discussed. From the user point of view, several maps are not available for commercial use. Most typically, national topographic and military maps belong to this category. There is a chapter where the high mountains and the high mountain cartography are discussed with the same manner as the target areas.

Continents	**Mountain Range**	**Country**
Africa	Bale Mountains	Ethiopia
	Hoggar Mountains	Algeria
	Mt Cameroon	Cameroon
	Rwenzori Mountains	Congo, Uganda
	Simien Mountains	Ethiopia
	Tibesti Mountains	Chad, Lybia
Asia	Barisan Mountains	Indonesia
	Crocker Range	Malaysia
	Hengduan Shan	China, Myanmar
	Hindu Kush	Afghanistan, Pakistan
	Kunlun Shan	China
	Meili Xue Shan	China
	Pamir Mountains	Afghanistan, Kyrgyzstan, Tajikistan
	Siguniang Mountains	China

	Tien Shan	China, Kazakhstan, Kyrgyzstan
Europe	Dinaric Alps	Albania, Bosnia and Herzegovina, Croatia, Kosovo, Macedonia, Montenegro, Slovenia
North America	Arctic Cordillera	Canada
	Watkins Range	Greenland
South America	Andes	Argentina, Bolivia, Chile, Ecuador, Peru, Venezuela
	Cerro de la Neblina	Brazil, Venezuela

Tab. 5: The main mountain ranges that are considered in this thesis as 'target areas'. Only the main mountain ranges are listed without further information on sub-ranges

The list of the target areas however is quite various. Some of the listed mountain ranges only have an area that can be depicted on one map while others are a lot bigger. An entire map series would be needed to cover for example the whole territory of the Tien Shan or the Kunlun Mountains, two of the longest mountains in Asia. Even the scale of a hiking map used there should be smaller from the one depicting for example a certain sub-range of the Dinaric Mountains. Yet, it is possible to produce detailed and big scaled hiking maps of each mountains, just the right area should be selected. In most cases, it means the highest or most popular peaks and their neighboring areas. The strangest of this all is that Asia or the Andes is full of these dominant sub-ranges.

The mountains listed as target areas are various as for the activities that can be done there. There are mountain ranges like the Arctic Cordillera which would obviously not become the paradise of trekkers but it might be a popular destination for extreme mountaineers due to the great mixed (rock and ice) climbing routes leading on steep mountain faces. On the other hand, the Crocker Range in Malaysia can even be a destination for those who travel to Malaysia just for spending some days of the holiday there.

B. Data Acquisition and Data Analysis

The other research field was the search for data acquisition methods for the map making, focusing on valuable solutions for both deriving and processing data. Collecting data from remote areas is not comparable to a data acquisition for a hiking map depicting certain areas of the Alps. In many cases, data is not easy to find as there are less number of data sources and sometimes the data is inaccessible. It is therefore important to find a good data source of remotely sensed data available for the target area. Satellite remote sensing might serve with data for the entire surface of the Earth. It was therefore important to list the most important projects of satellite remote sensing and also to describe shortly what can certain active or passive remote sensing technologies offer or what these projects can provide for the user. Airborne remote sensing can be an important source of data just like space-born measurements. In some regions however it is very difficult or impossible to find commercially available aerial photos. It is however obvious that for real low coast mapping projects purchasing any kind of data means a significant expenditure from the budget. Therefore optimizing the workflow for freely available Landsat images and either Aster or SRTM elevation data is more or less desired. For instance, creating the Mount Cameroon hiking map in larger scale then 1:150 000 could have resulted in the use of expensive data, as these free data are not accurate enough for using them in scales much larger than this.

This work also showed that terrestrial remote sensing is not the best way of collecting data for such a hiking map project. Field surveying is an extremely cost-intensive and slow process compared to non-terrestrial remote sensing. Its other drawback is the logistics that is needed to provide the essential equipment needed for the measurements. In some areas it is almost impossible because of the lack of roads or airports. On the other hand, making measurements in foreign countries, especially in disputed areas or conflict zones would make the whole surveying extremely difficult to be carried out.

Another way of collecting data is the data acquisition from analogue maps. Digitizing and re-use of a map as a whole or just some of the map information cannot be done legally in many cases. On the other hand, old analogue maps are sometimes hard to find as public access is limited to some of them still today in some countries. Despite, some of these old map series like military maps of the Soviet Union or Yugoslavia are accessible for the public.

There is also a possibility to buy already analyzed data if proper products are available for the target area. Certain restrictions may apply here, too, depending greatly on the product type what we have chosen. After paying the relatively expensive price for them, analyzed satellite data and imageries can be legally used to create derivative products. The other way to do things is to completely simplify data acquisition with buying the vector map of the target area. Nowadays, several companies are dealing with digitizing analogue products legally. During this process, the paper map is digitized and layers are integrated to which the map information is added. In most cases, one map sheet of these vector maps cost triple or four-digit Euros.

Analyzing the data is done by GIS, regardless of what the data source is. I listed the most important and well known ones. Not just GIS are important tools for making maps. Graphics editors are equally important because of the graphic planning and design. Finding the best value for price is important at both types of software.

C. Collaborative mapping and user-generated data and hiking maps

Collaborative mapping and user-generated data as a possible aid for making new hiking maps was the third research field of this work. The technical revolution of the last few years provided both the growing number of GPS receivers used by the public and the fast improvement in file sharing and the new direction of the web 2.0, respectively. This also meant the beginning of the user collaboration in cartography. Several websites are currently based on file sharing, many of them with the goal to share user-generated spatial data. In most cases, tracks and waypoints are submitted to these web communities. Some companies created their own manner for user contribution to map making. Usually, a group of analysts monitor these efforts and manage the whole process.

User-made aerial photography is another aspect of collaborative mapping. Taking aerial images is possible in a number of cost-efficient ways. Only a digital camera and a transporting vehicle are needed to it. Typically, kites or balloons are used for transporting the camera but small remote controlled helicopters are available as well. Moreover, converting aerial photos to orthophotos is also possible with special applications. The big disadvantage of this way of data acquisition is that only small areas can be processed precisely. Just like field surveying, the user-generated aerial photos have the similar drawbacks: they can be made even for smaller areas and doing measurements in foreign lands may be restricted.

Using user-generated data for further maps may be limited. Licensing as described in the chapter *Collaborative Mapping*, is a very well organized regulation used for a number of fields also in GIS. It clearly defines the further use of a product, allowing certain acts and re-use of the data depending on the exact type of the license. User-generated data however is important for new hiking map projects, because uploaded tracks can serve as a necessary aid for finding new tracks. Not the data itself, but the approximate location of the track can help a lot for example in path identifications in unknown areas where no marked trails can be found. It is important to mention that user contribution is not as frequent in remote mountain ranges as it is in popular hiking areas. The content of spatial data sharing web sites also verifies it as there is comparably less number of such mountain tracks available from remote regions.

3. The Mount Cameroon project: Realizing a hiking map according to the described methods

Chapter 9 aimed to deal with the practical approach in terms of how low cost mapping of a remote area is possible. The Hiking Map of Mount Cameroon is to be found in the appendix to this work. As shown on the map, the original scale is 1:150 000.

All in all, this project showed that a basic touristic map can be created from freely available data even for remote areas. Obviously, the variety of the map information cannot be compared to hiking maps of the Alps, yet this map is ideal for hiking tours on the mountain. Yet, elevations are almost completely missing from this map. The lack of known elevation points in deed makes the map not completely eligible for strict cartographic rules.

My personal opinion on such projects is that it would be desirable to visit the area which is depicted on the hiking map. Track recording, finding and collecting points of interests can be maintained this way well. It is however obvious that this kind of field work for big territories takes several days. This is especially the case if the covered area is even larger or if the path and road network is poor. Therefore this is another aspect why collaborative mapping and user-generated data can be very useful. Other than these, the lack of points with known altitudes is a serious problem in many remote areas. For measuring accurate elevations, the simplest handheld GPS receivers are not proper. For nearly free, real low-cost mappings such expensive field works are not realizable.

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*"Further websites" contain web pages that helped generally a lot during the preparation of one or more chapters and information stated in this work.

List of Illustrations

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Abstract

This master thesis focuses on those relevant high mountain ranges, which haven't been mapped for touristic purposes, yet. There are several regions on the Earth, which are still remote and not captured by mass tourism. Some of these mountainous territories are new even for cartography. The thesis would like to show methods how new cartographic products can be created of mainly remote, yet even more popular high mountain ranges. I would like to put the emphasis on cost-efficiency in every segment of the workflow when creating a new product. Researches and trends proof that enhanced geographic mobility along with discovering far-away places are important features of today's tourism. Non mass-touristic destinations and mountainous regions are even more popular with eco-tourists, mountaineers and adventurers.

Kurzfassung

Die vorliegende Masterarbeit beschäftigt sich mit Hochgebirgsregionen, über die trotz ihrer touristisch relevanten Eigenschaften bislang keine Wander- oder Freizeitkarte gemacht wurde. Es gibt viele Regionen der Welt, womit die Kartographie sozusagen noch wirklich viel zu tun hat. In dieser Masterarbeit beschäftige ich mich grundsätzlich mit diesen Hochgebirgsregionen. Diese Arbeit handelt von praktischen Ansätze und Lösungsvarianten des gesamten Workflow. Natürlicherweise werden die Kosten jeweiliger Methoden auch berücksichtigt. Forschungen und Nachweise machen uns eindeutig, wie die Freizeitmobilität und gleichzeitig die Popularität der Nicht-Massentouristische Destinationen steigt. Die Bergen, die für immer mehr Leute attraktiv scheinen: Naturfreunde, Bergsteiger, Abenteurer.

Declaration

Hiermit versichere ich, dass ich die Masterarbeit selbstständig geschrieben habe. Bei der Erstellung dieser Masterarbeit habe ich die angegebenen Hilfsmittel benutzt. Diese Arbeit wurde weder im In- noch im Ausland (einer Beurteilerin/ einem Beurteiler zur Begutachtung) in irgendeiner Form als Prüfungsarbeit vorgelegt.

Wien, 09.06.2015

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