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Mt. Aconcagua - Multisensoral Remote Sensing Data for Mapping Purposes

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Abstract

The investigation area is located in the Aconcagua Provincial Park (Argentina). Mt. (Cerro) Aconcagua (6962 m) is the tallest mountain in South America and is located in the midst of the Central Andes in Argentina, one range east of the ridgeline that defines the border with Chile.

This paper discusses the integration of various remote sensing based data (SRTM, LANDSAT Stereo, and ASTER) for generating a topographic map (contour lines) of Mt. Aconcagua (Argentina). Due to the lack of appropriate official topographic maps (1:50.000) Remote Sensing data are the only source to provide adequate topographic information. The available SRTM DEM shows well documented limits due to „zero-information "regions within high mountain relief. Therefore, an integrated approach of height analyses with stereoscopic LANDSAT-TM imageries, ASTER data, aerial photographs and conventional topographic maps provides a contour line map of Mt. Aconcagua. This contour line map represents a preliminary product for a tourist map in the scale of 1:100.000 and perspective views.

KEYWORDS: High Mountain Cartography, DEM, Multisensoral, Aconcagua, Satellite Image Map

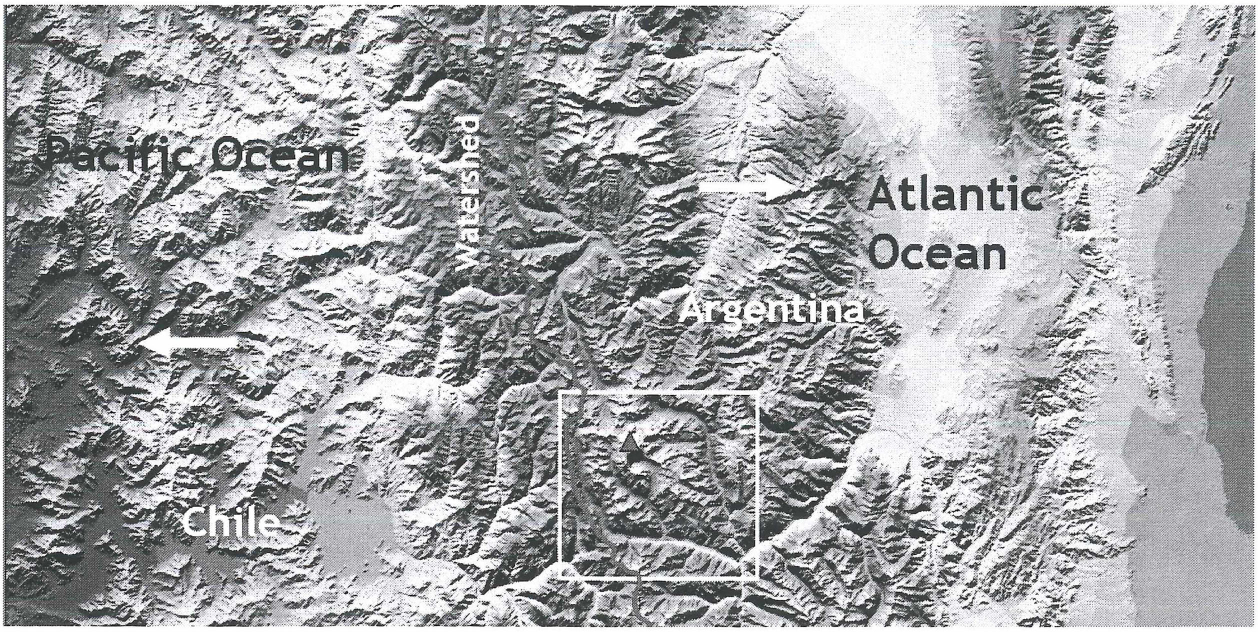


Figure 1: Location of Mt. Aconcagua and extent of the map.

1. Investigation Area

The Mt. Aconcagua (6963 m) is the highest mountain of America, the highest mountain of the southern hemisphere, the highest mountain of the western hemisphere and the highest mountain outside of Asia. These attributes make the region very attractive for tourists and researchers.

The Aconcagua Massif is located in the transaction zone between the Southern and Central Andes and belongs to the Argentinean provinces of Mendoza in the South and San Juan in the North. The Aconcagua is part of the High Cordilleras (Cordillera Principal), which are mainly formed by volcanic activity, though the mountain itself belongs to a zone (28°-33°S) with no active (Cenocoic) volcano like many of other northern and southern mountains of the Andes (Tupungato, Maipo, Ojos, ...). A mighty, tertiary complex of Hornblende-Andesit (Aconcagua complex) was shifted above a Mesozoic (mostly marine) basement. The Aconcagua is not located along the main ridges of the High Cordillera, which forms the watershed and political border between Argentina and Chile. The highest peak of America lies about 10km east of the main crest.

2. Satellite image map of Aconcagua at scale 1:100.000

2.1. Available Geodata

The selection of used geodata is based on their easy availability, low or no costs and their common applicability for typical high mountain research tasks:

Topographic maps	DEM	Remote Sensing Data
Chile (50K, 100K)	ASTER	Aerial Photographs
Argentina (50K, 100K)	SRTM	LANDSAT
Private Cartography	LANDSAT	ASTER

Topographic maps are available with scale: 1:500 000, 1:250 000, 1:100 000 and 1:50 000 in Chile and at scale 1:50.000 and 1:100.000 for Argentina. During the process of scanning, geocoding and mosaicing the severe problem was to unify the different geodetic systems of the two countries (see Figure 2).

Due to the limits of GIS suitable parameters and due to the low quality of the maps there was no possibility for further contour line digitizing for generating a DEM of the investigation area (see Figure 3).

Additional information about infrastructure (traffic network, tourist infrastructure, names, etc.) cannot be provided from the maps in Argentina due to the fact that the maps have been published in the Fifties of the last century. The location of streets, settlements has changed, modern tourist infrastructure is missing.

The only solution getting appropriate information for the map was to use pure satellite image data. This can be achieved only by a multi-temporal and multi-sensoral approach. Different image data will provide different kind of map information:

Feature	Source
Image information	• ASTER/LANDSAT
Contour lines	• DEM: ASTER/SRTM/LANDSAT
Vegetation cover	• LANDSAT/ASTER
Glacier/Lakes	• LANDSAT/ASTER
Traffic network	• GPS/LANDSAT/ASTER
Perspective views	• DEM/LANDSAT/ASTER
Name	• MAPS, FIELD WORK

The geometric basic for the map sheet is a georectified LANDSAT TM image of 1999. The rectification quality (RMS Error) meets the requirements of a map with scale of 1:100.000. The determining factor for using this satellite scene is the high radiometric quality and low snow cover. Additional LANDSAT TM and ETM+ scenes (1975, 1986, 1987, 1989, 1999 and 2000) and ASTER images (2002 and 2004) are used to provide actual and detailed information about glacier/snow and vegetation distribution. ASTER data, especially, are very suitable for morphological and situation details, due to their higher spatial resolution.

2.2. DEM generation

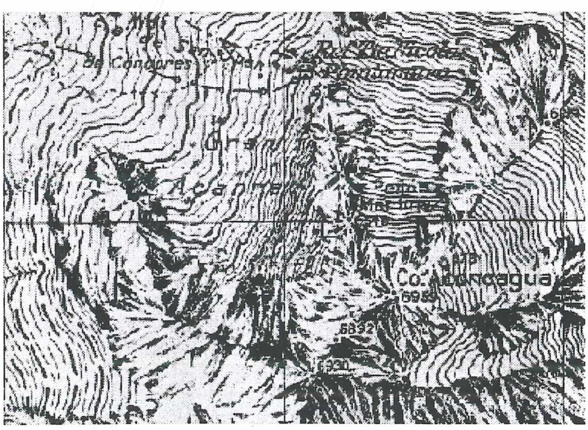
For a DEM generation a combined analysis of multitemporal and multisensoral DEM`s was used. M. Gamache (n.y.) discusses the application of many of the common sources for free GIS data, including ASTER, SRTM, and LANDSAT. In this case study different ASTER DEM´s (to fill up and reduce the aerial extent of "zero-data-values"), a digital elevation model from stereoscopic LANDSAT ETM+ data (Wurm, 2004) and the available SRTM elevation model with a resolution of 100m were generated. A raster to vector and contour line conversion provides a contour line map with an equidistance of 50 m. The accuracy of the contour lines is within the limits of a map at scale 1:100.000.

SRTM:

The objective of the Shuttle Radar Topography Mission (SRTM) is to produce digital topographic data for 80 % of the Earth's land surface (all land areas between 60° north and 56° south latitude), with data points located every 1-arc-second (approximately 30 meters) on a latitude/longitude grid. The absolute vertical accuracy of the elevation data will be 16 meters (at 90 % confidence) (http://srtm.usgs.gov, 2006). Figure 4 documents the zero data values, which occur in high mountain environment. Small "holes" can be interpolated, whereas in large areas (see south face of Aconcagua) data errors will be kept.

ARGENTINA: 1:50K	CERRO ACONCAGUA	CERRO AMEG-HINO	LAS CUEVAS	PUENTE DEL INCA	PUNTA DE VACAS
Geodetic System	No information	No information	No information	No information	No information
Terr.Photogrammetry	1924,1929, 1945	1929, 1945	1924, 1945	1924-29/44/45	1929/43/44/45/48/49
Edition	1950	1951	1951	1951	1952
Representation	Legend, colour edition, Equidistance: 25m, 100m; rock representation				
CHILE: 1:50K	**RIO DE LOS LEONES**			**PORTILLO**	
Geodetic System	Int. Ell. 1924, UTM, Mer. 69°W, Lat.:10 000 km S of Equator, height: Nivel Medio del Mar				
Aerial Photograph:	1955				
Fieldwork	1964				
Revision	1977			1981	
Edition	w1985			1994	
Representation	Legend, colour edition, Equidistance : 50 m, 250 m; rock representation				

Figure 2: Available Maps of Mt. Aconcagua Region.



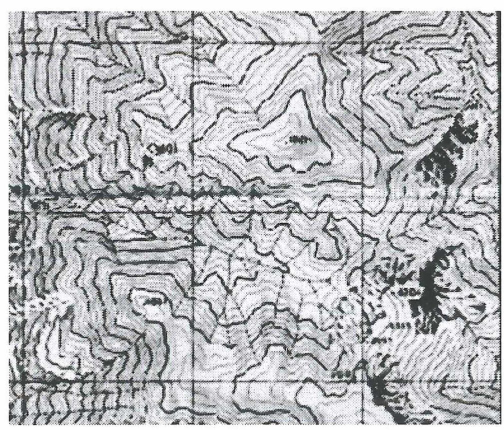


Figure 3: Topographic maps of the investigation area.

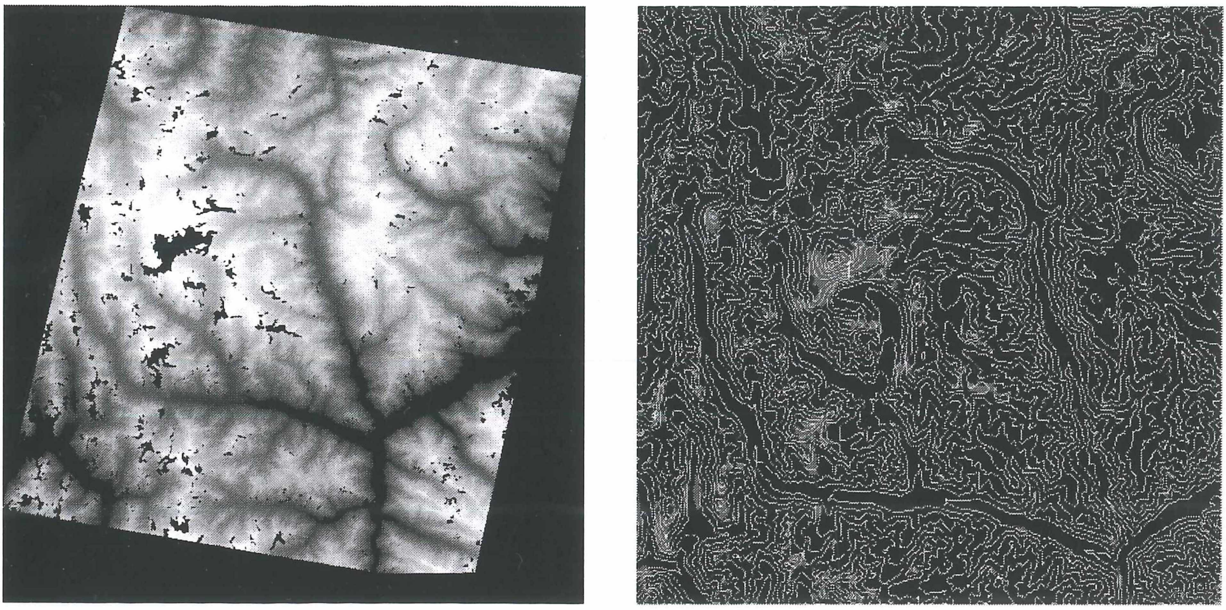


Figure 4: SRTM Elevation model and derived contour lines.

ASTER:

Due to the system configuration of ASTER 2 different types of DEM´s can be ordered: Absolute DEM's use external GCP´s (provided by the Customer) and Relative DEM's without external references (GCP´s). This means, that the horizontal and vertical accuracy will extent from 7 to 10 m. This accuracy lies within the tolerances of e.g. US cartography products with scale 1:250.000 to 1:50.000 (ERSDAC 1999, ERSDAC 2001, USGS 2003). Besides of zero data values the ASTER Data are showing typical striping structures, which can be reduced by filtering operations. Figure 5 shows the effects of the striping in derived contour lines.

LANDSAT:

Generally seen, LANDSAT satellites are not very suitable for stereo mapping due to its rather small overlap between the scenes and the acute angle. For some special cases though, it is possible to generate a stereoscopic model of the investigation area, but this is quite limited in its geographic extension. The overlap between two LANDSAT scenes depends on the circle of latitude (see Figure 6).

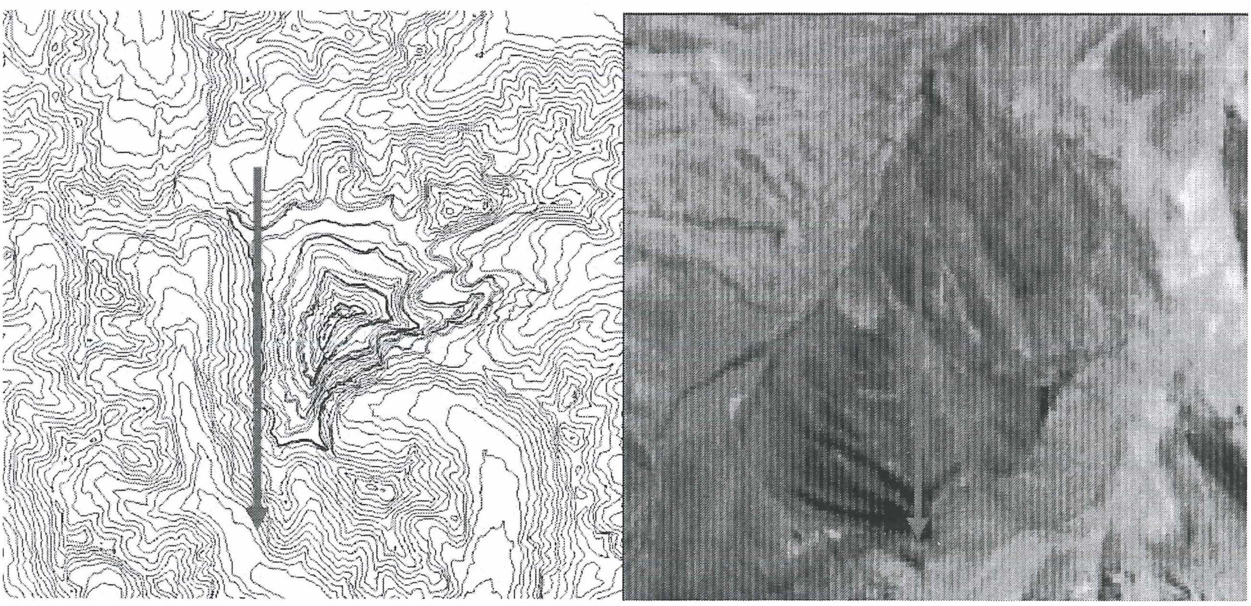


Figure 5: ASTER N/S Striping.

Circle of latitude (Degrees)	0	10	20	30	40	50	60	70	80
Overlap (%)	7.3	8.7	12.9	19.7	29.0	40.4	53.6	68.3	83.9

Figure 6: Dependence of overlap on the latitude.

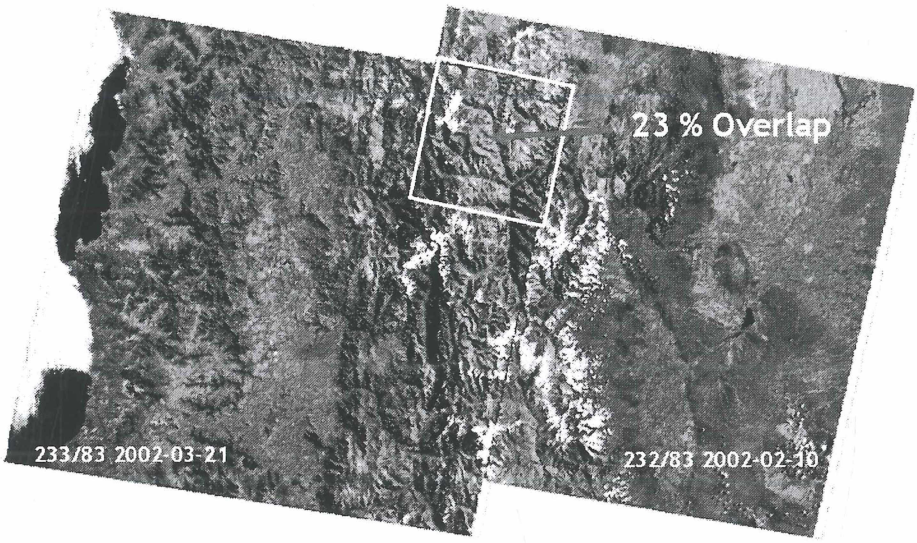


Figure 7: Two Landsat-7 scenes and their overlap (rectangle).

In this special case of the Aconcagua, the requirements for stereo mappings are fulfilled. The scenes show an average overlap of 23 % and a time-lag of 39 days. The investigation area is mostly covered by both scenes and they show hardly any cloud coverage. The difference in snow coverage though is problematic for the automatic matching process.

The stereo mapping for this purpose was done with RSG (Remote Sensing Software Package Graz), developed by JOANNEUM Research. The workflow can be described in three steps:

1: Geometric modelling: Derivation of a parametric mapping model.

2: Automated image correlation for detection of homologous points.

3: DEM-generation.

The external GCP were measured in the topographic map Portillo, which only covers the very lower western part of the investigated area. The reason for this was the lack of knowledge about the Argentine geodetic model used for the topographic map.

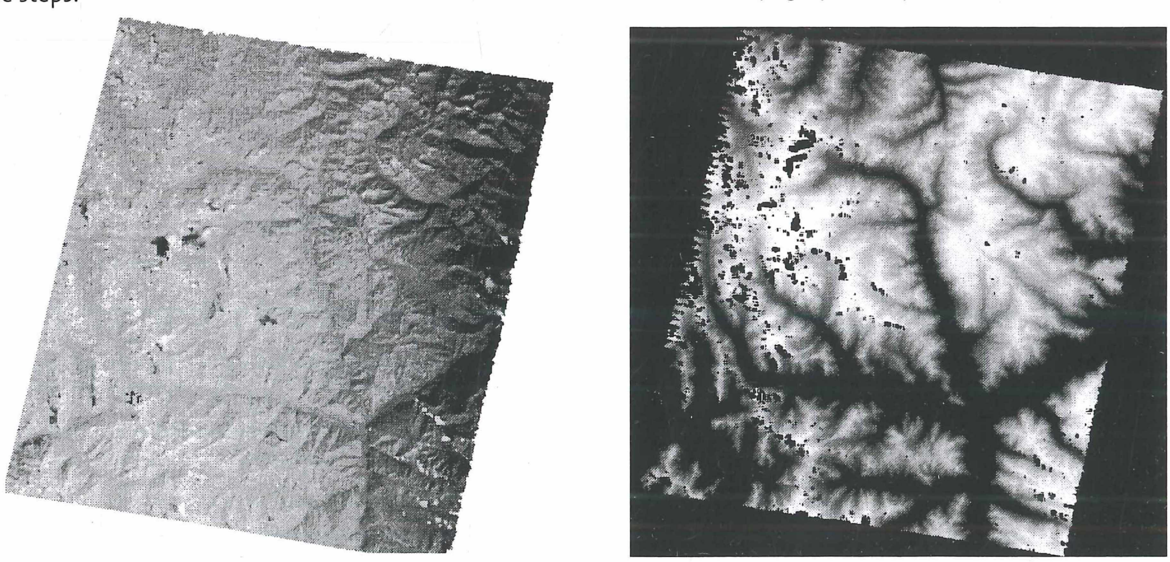


Figure 8: Difference image between SRTM – ETM+ (left); Result of the stereo mapping process (right; Wurm 2004).

Residual Statistics Image:1 Units of residuals: PIXEL			
Control points: 34	Res-X	Res-Y	Res-XY
RMS	1.51	1.40	2.06
MEAN	0.00	0.00	1.96
STD	1.51	1.40	0.64
MIN	-2.75	-2.43	0.22
MAX	2.44	2.50	3.67

Residual Statistics Image:2 Units of residuals: PIXEL			
Control points: 34	Res-X	Res-Y	Res-XY
RMS	1.52	1.40	2.06
MEAN	0.00	0.00	1.92
STD	1.52	1.40	0.77
MIN	-2.53	-2.83	0.44
MAX	3.24	2.83	3.44

Residual Statistics Units of residuals: METERS			
Control points: 34	East	North	Height
RMS	19.4	21.8	59.2
MEAN	0.0	0.0	0.1
STD	19.4	21.8	59.2
MIN	-28.9	-39.8	-118.0
MAX	28.9	38.3	110.5

Figure 9: Root mean square errors in the stereo mapping.

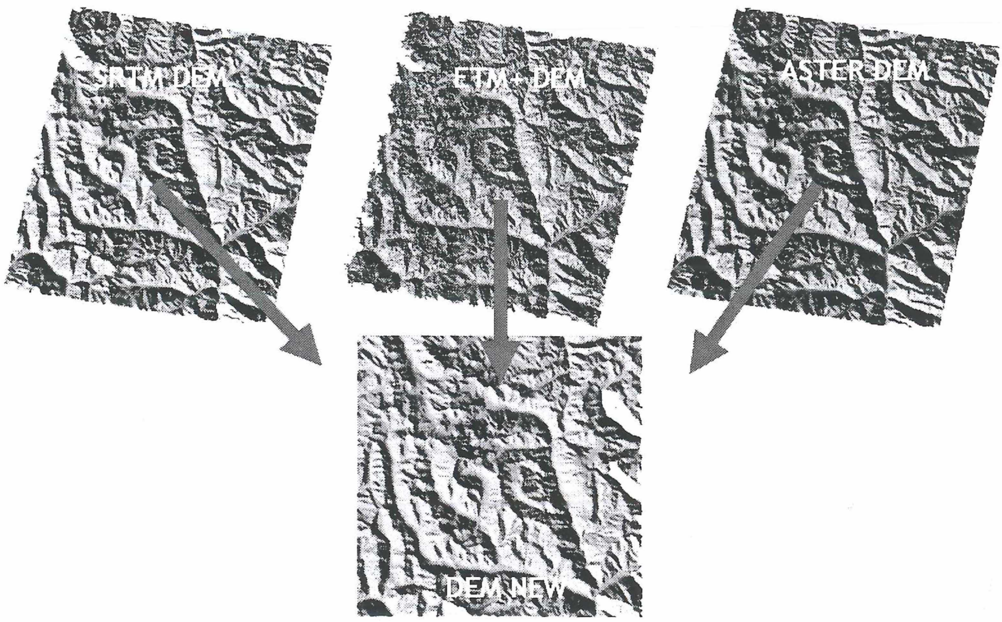


Figure 10: Multitemporal and multisensoral DEM generation.

This resulted in a stable model in the south-western part and a higher deviance in the north-eastern part due to the lack of GCP. This can be seen in Figure 8 below.

Difficulties were also experienced in the snow-covered part of the images, where the automated matching process could not detect homologous points. For these areas there are not given any elevation values in the DEM-generation process. Regarding the quantitative quality of the resulting DEM, it can be said, that the images show a rmse of about 29 m in xy-direction and 59.2 m in z.

Especially in high mountain regions Remote Sensing techniques provide useful information about the environment. Remote sensing images from space - in this case - can be very useful for high mountain research. So ASTER and LANDSAT ETM+ data can be used to obtain information about glacier and snow distribution (with a multi seasonal approach) and by means of a digital landuse classification a vegetation layer can be generated. The Aconcagua region is dominated by an alpine vegetation environment, where grassland can be found only in lower parts.

The importance of topical information about changing high mountain environment can be exemplified through the Horcones Inferior glacier (Figure 12). The left photograph shows a photograph taken by an airplane from January 2006. The Horcones Inferior glacier indicates debris covered - thinned out - glacier tongue, with a length of about 11km. The glacier is reaching the end of the valley, near Confluencia at a height of about 3400 m. The right figure shows a perspective view of the same area with ASTER data from January 2004. At this time the glacier has no clear indicates for a glacier surge, his tongue ends 2,5 km above the valley conjunction. A similar behaviour of the glacier could be observed during 1984 – 1986 (Bottero et al., 2000).

The traffic network (roads and railway) was recorded by GPS measurements during the field work, although these elements are well recognizable in the ASTER and LANDSAT data. The main drainage system has been digitized visually in the ASTER images. The information about the name of peaks, rivers, settlement and tourist infrastructure could be obtained by other maps and field work.

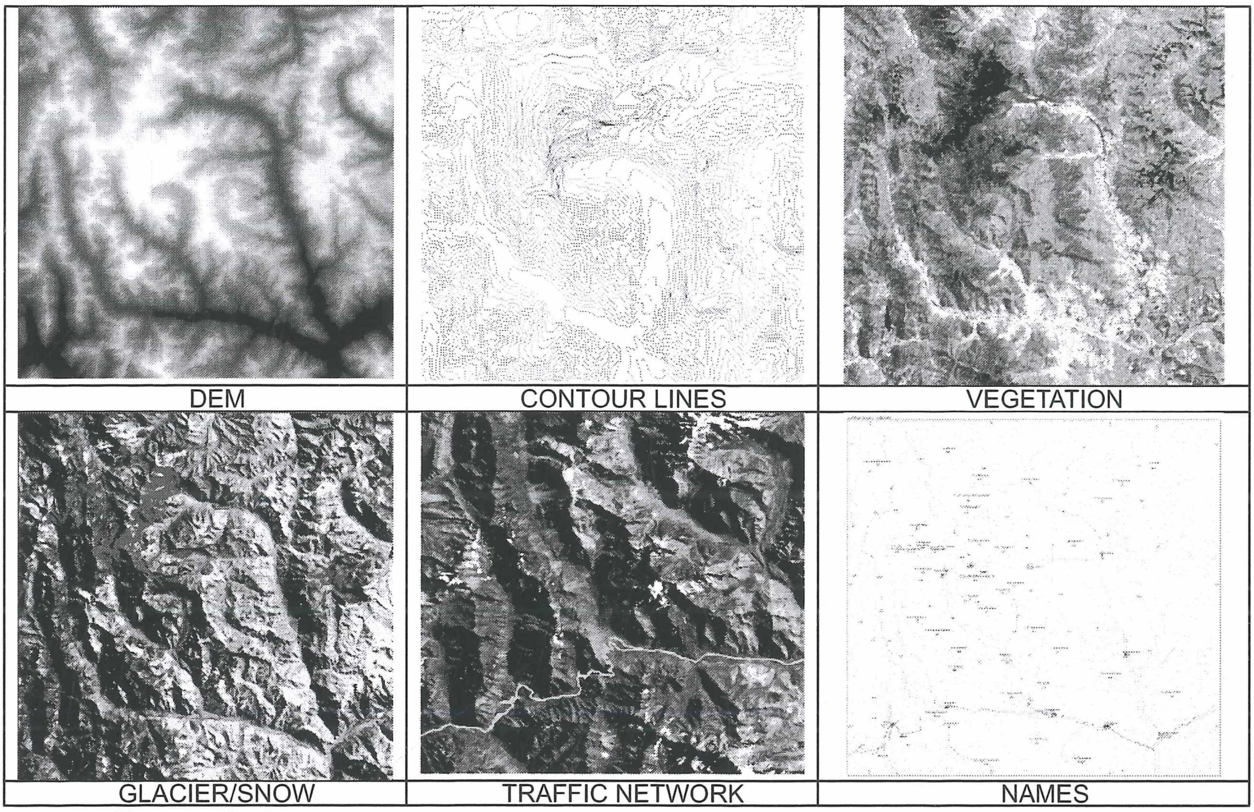


Figure 11: Different map layer.

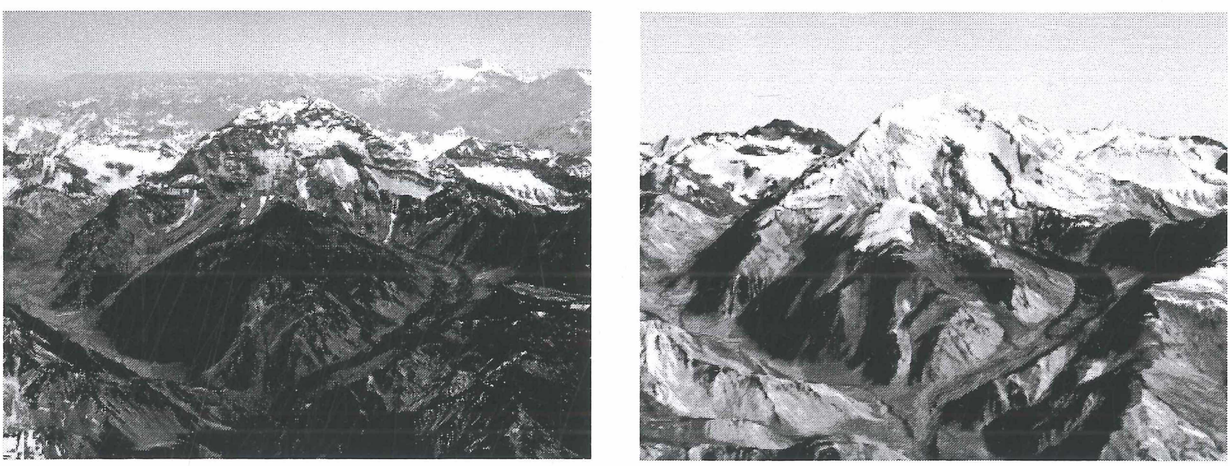


Figure 12: Glacier Surge of the Horcones Inferior glacier (left: photograph of 1/2006 by Deutscher/Hirschmugl; right: perspective view with ASTER data of 1/2004).

3. Preliminary Results and further investigations

The aim of this project is to provide a basic data base for the generation of a map at scale 1:100.000. The most suitable way for the map creation is a balanced relationship between time/costs and the achieved quality of the results. This has been done by means of a multisensoral (ASTER/SRTM/LANDSAT) and multitemporal (1989-2004) data set. The presented study must be seen as an intermediate result. Figure 6 shows a sketch of the map in the area of Mt. Aconcagua and the Horcones Inferior Glacier with some mistakes, which will be refit in the next processing step.

The compilation (preprocessing, merging, raster to vector conversation, evaluation, etc.) of the geodata is most suitable for the generation of a (topographic) SAT-MAP 1:100.000. Further investigations/work are to finalize a digital compilation for printing and to create a WEB MAP.

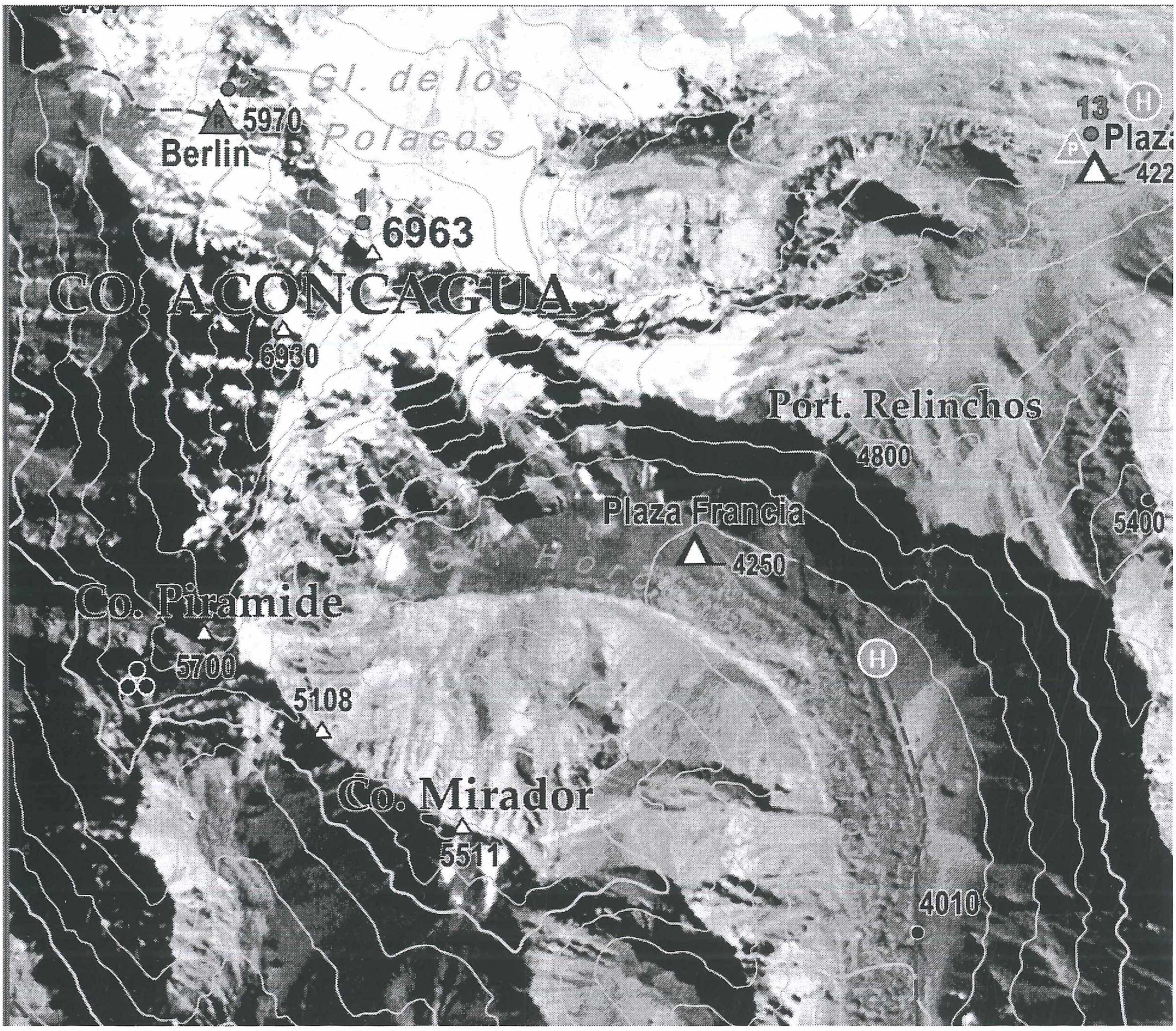


Figure 13: Preliminary result of the Map (sketch).

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