GLACIER MONITORING IN SOUTH AMERICAN TROPICS USING ALOS –PRISM SATELLITE IMAGES AND PHOTOGRAMMETRIC TECHNIQUES

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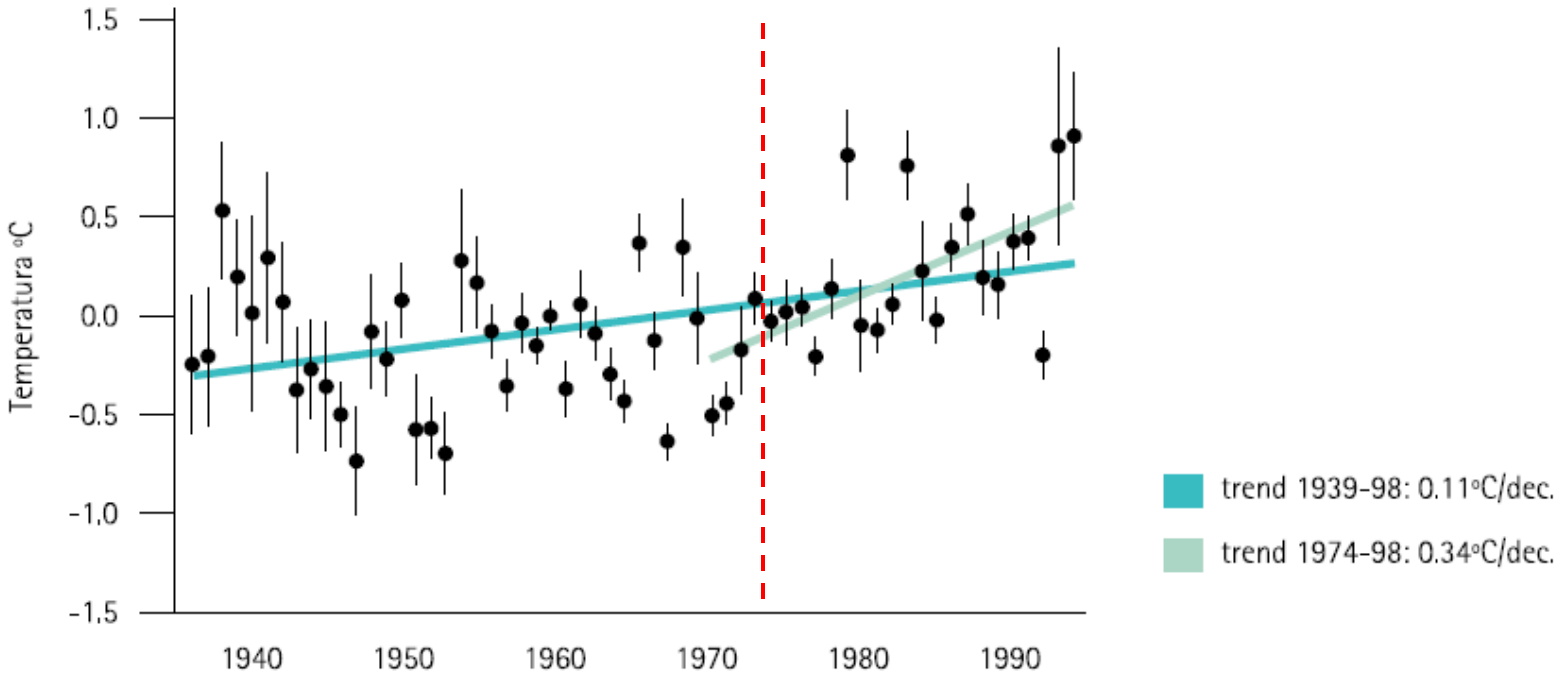
Sendai, November 2010

MOTIVATION

Andes : > 40 M inhabitants.

Source : Barnett et al., Nature 2005

- Temperature in the tropical Andes between 1939 and 1998 -

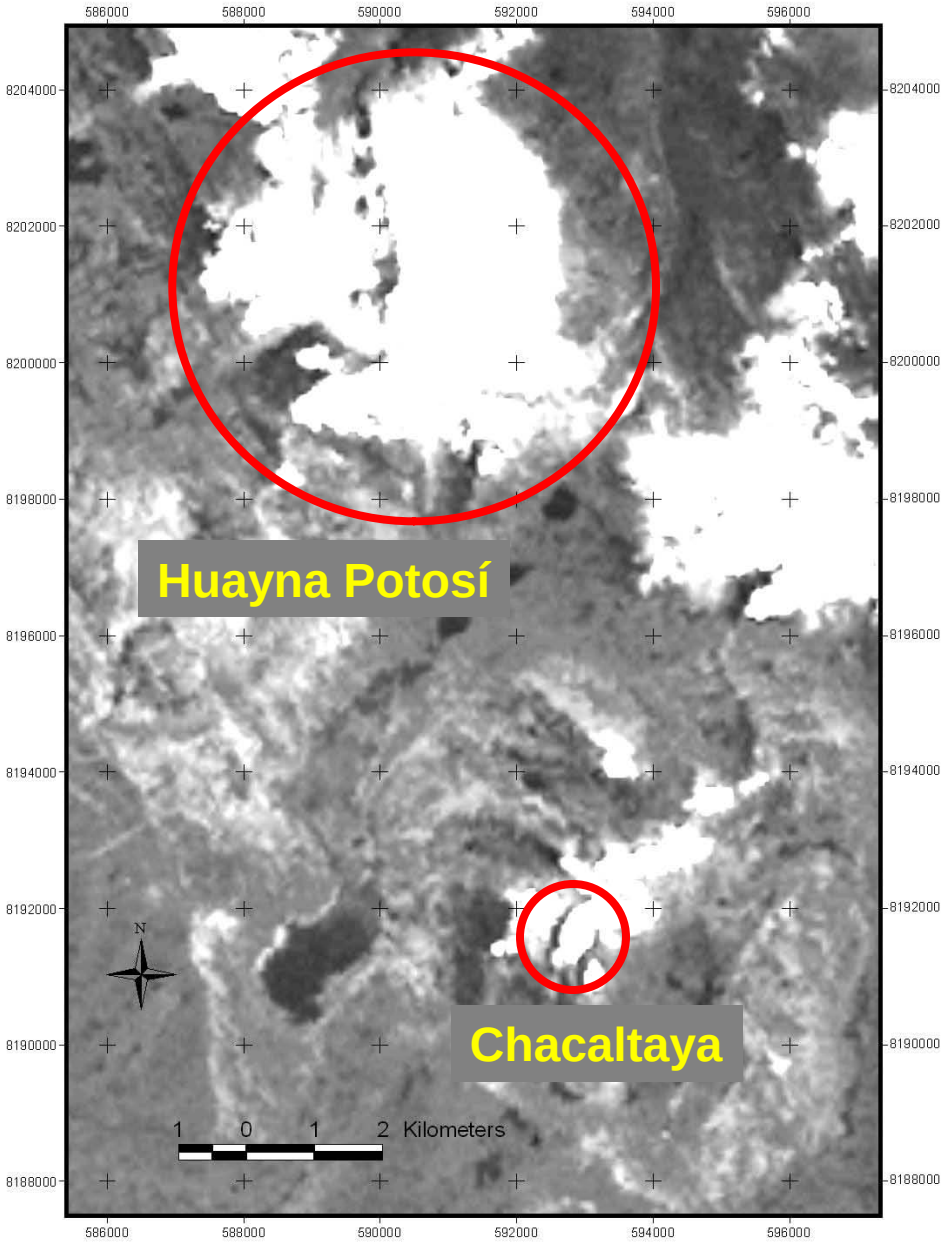


Source: Vuille and Bradley (2000)

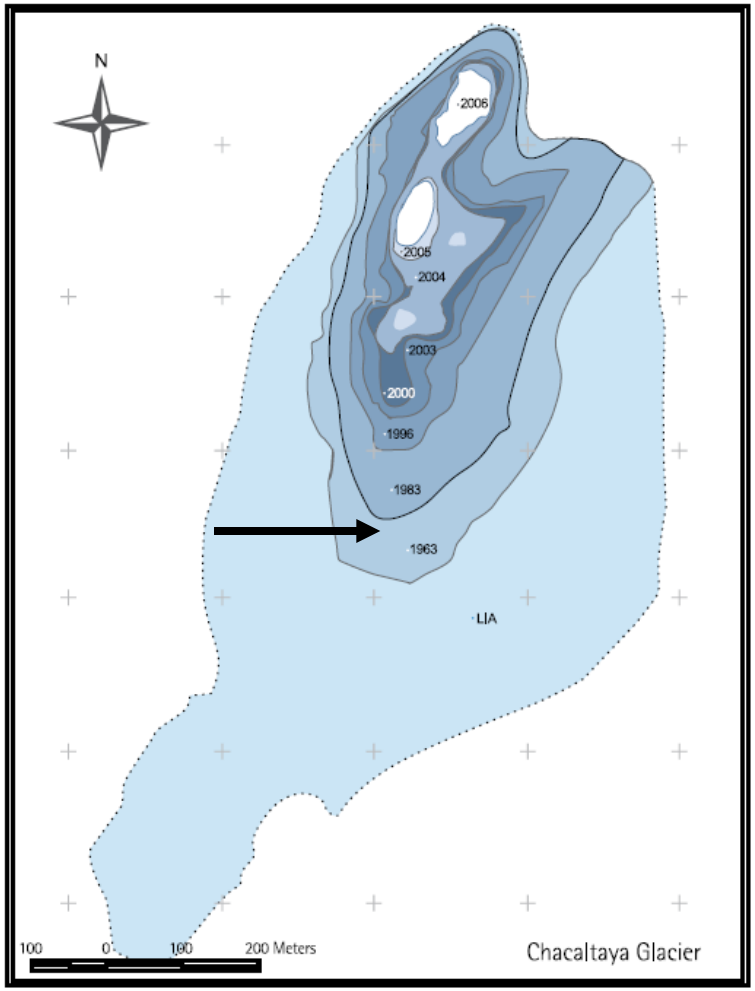
Zongo glacier - Bolivia

Hydrology

1975

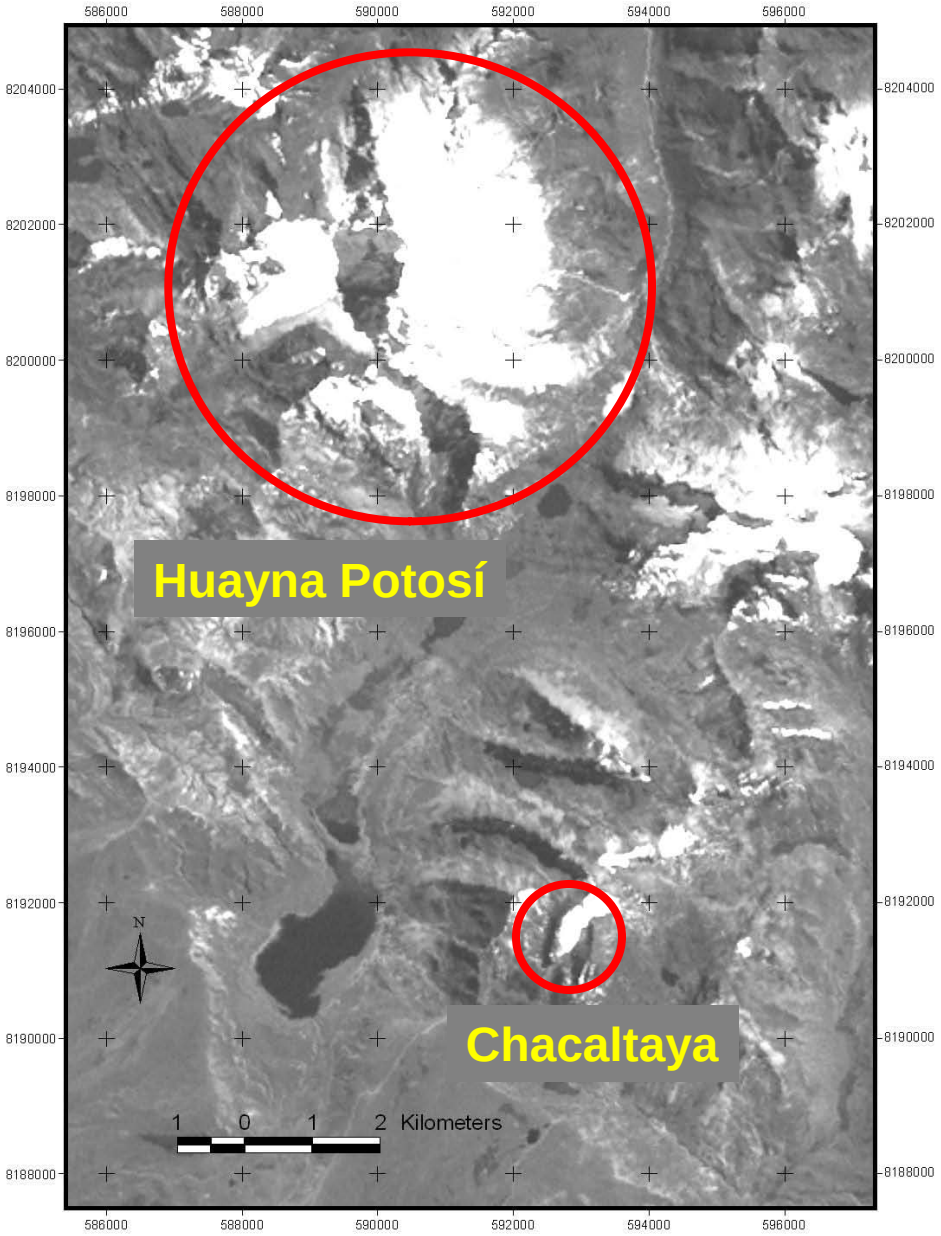


Landsat satellite image

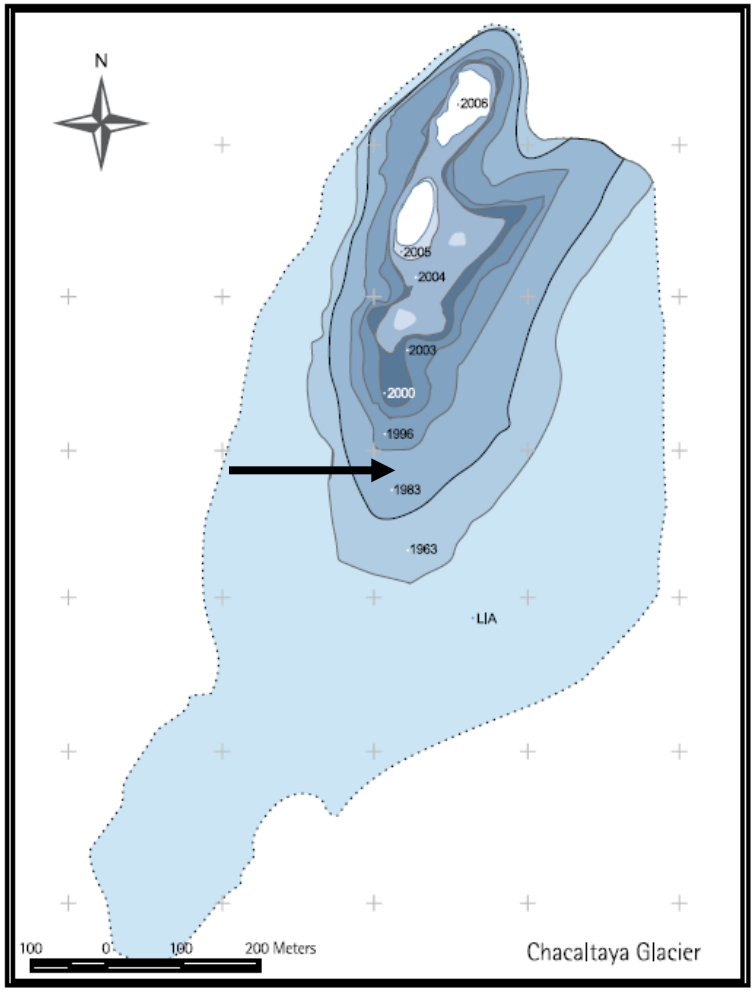


Source: (IHH-UMSA) ©

1987

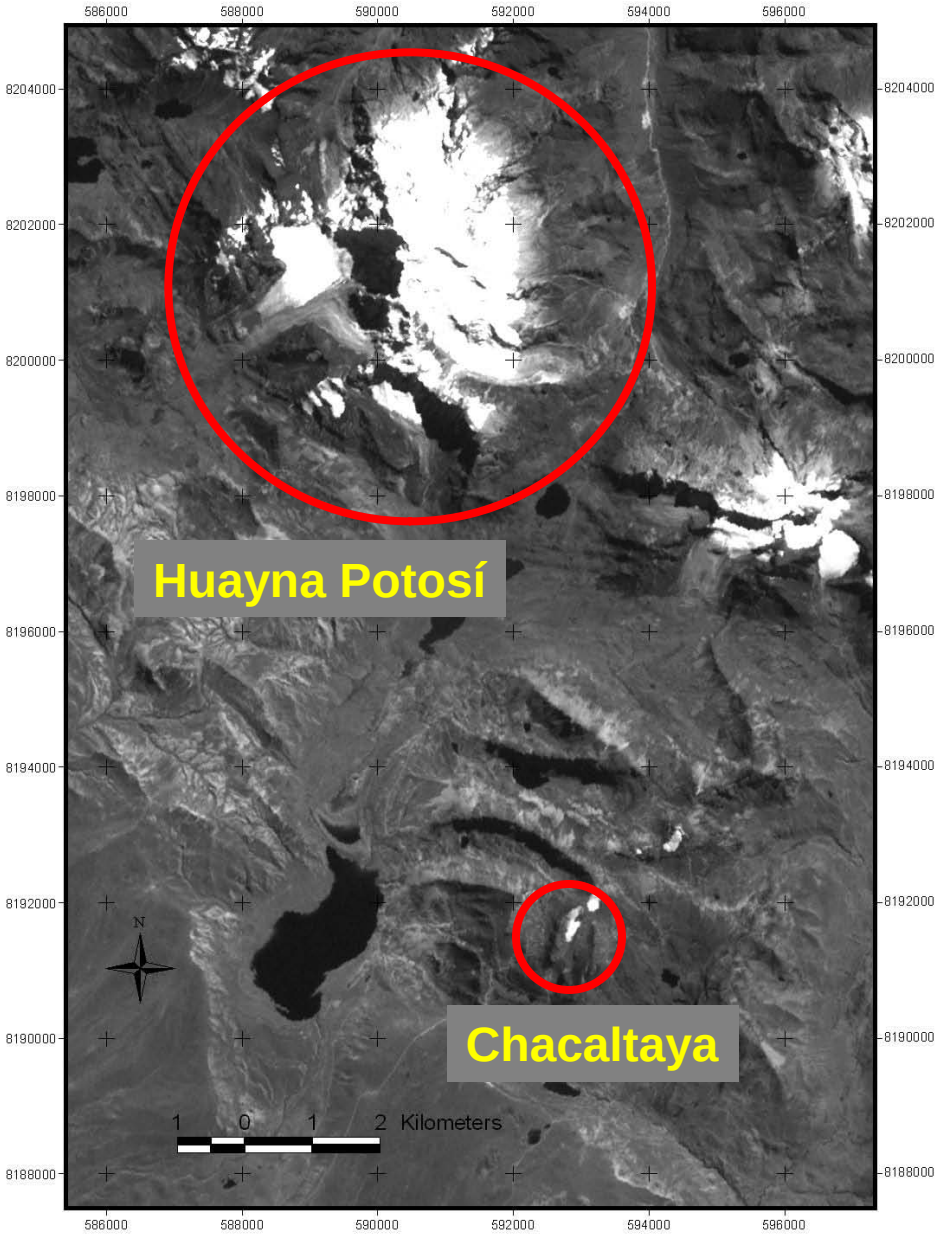


Landsat satellite image

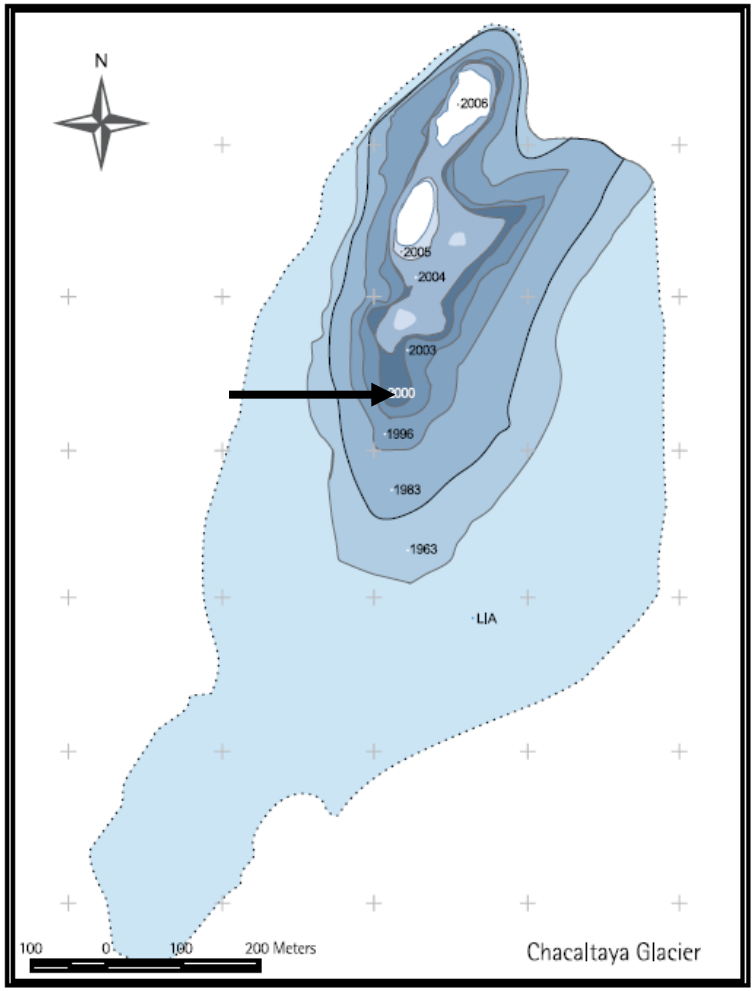


Source: (IHH-UMSA) ©

2000

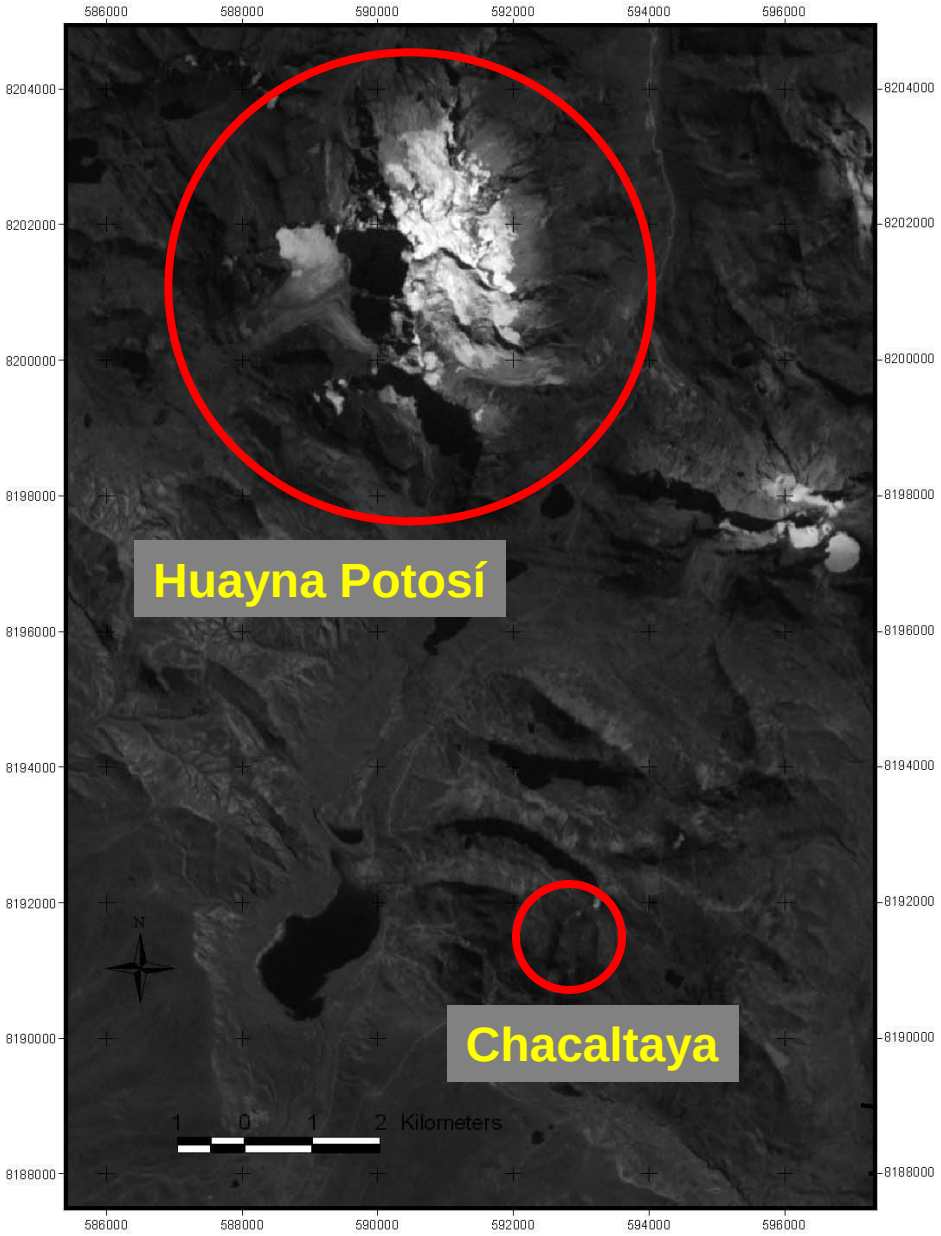


Landsat satellite image

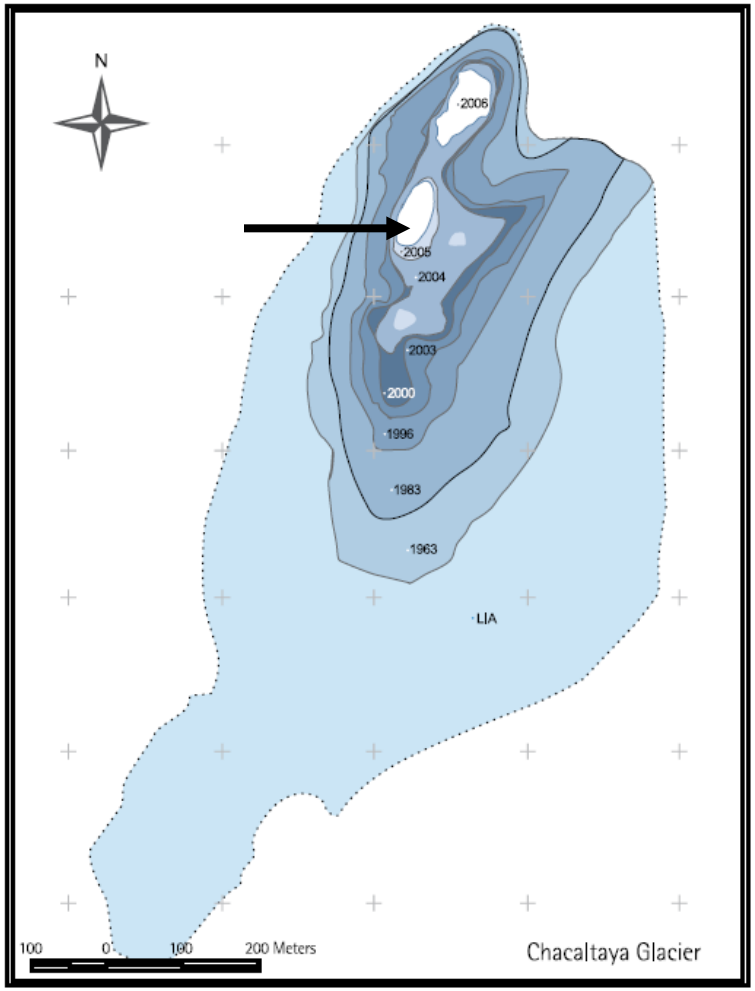


Source: (IHH-UMSA) ©

2009



Landsat satellite image

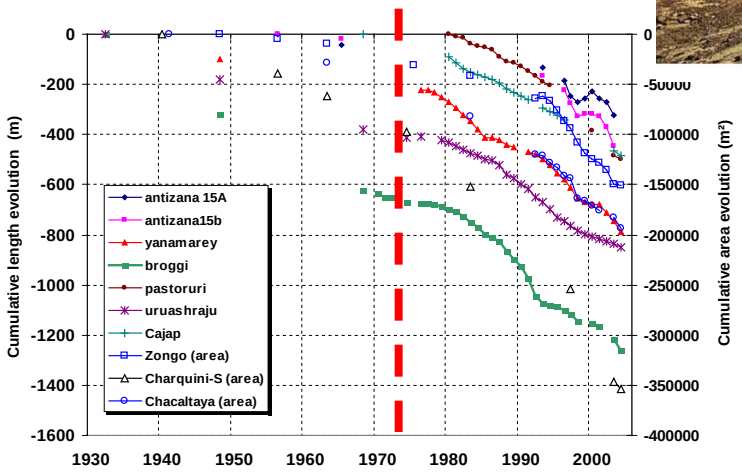


Source: (IHH-UMSA) ©

Chacaltaya Glacier

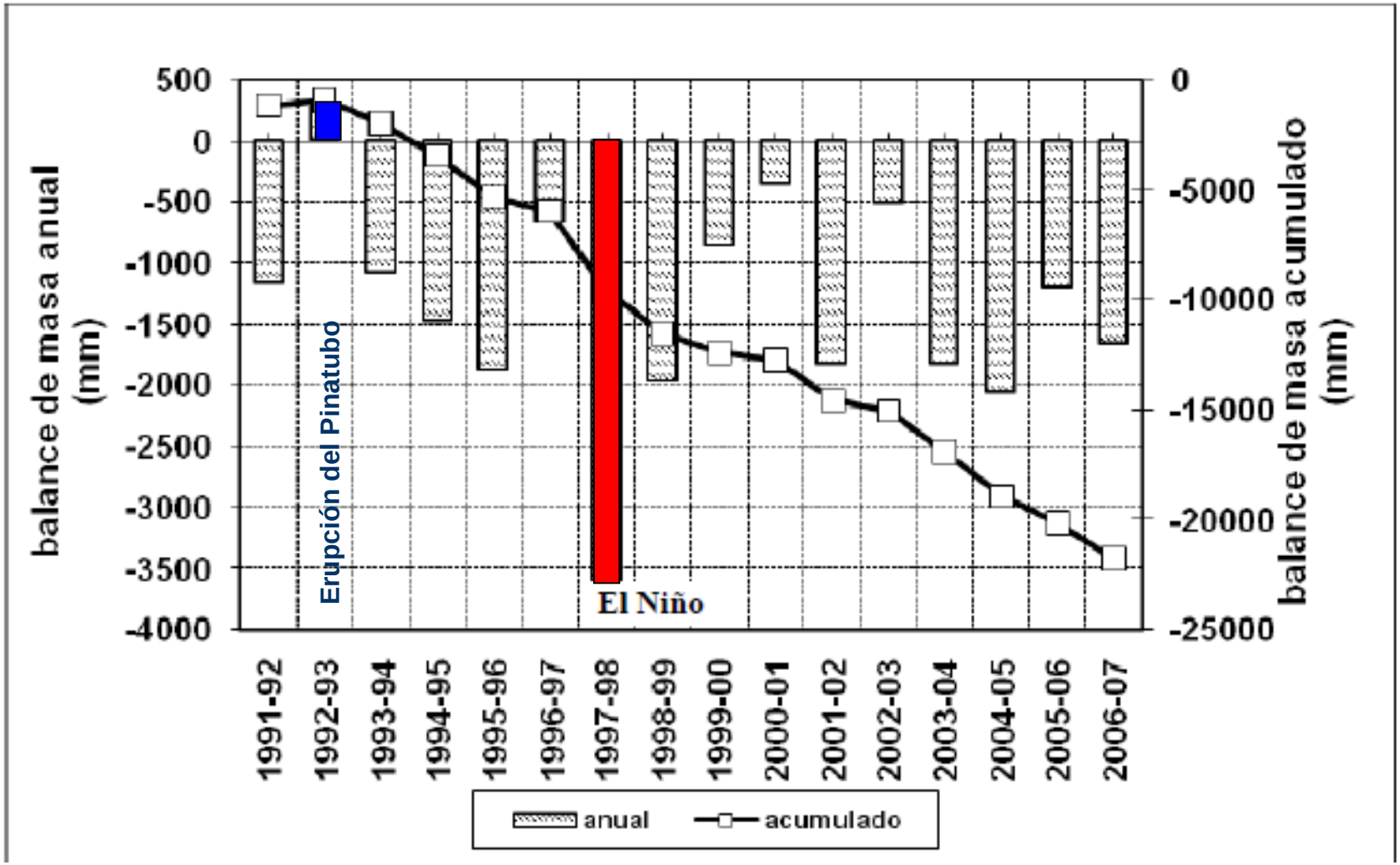
Geographical position: 16º21'S-68º07'W
Altitude range: **4700-5396 m**
Catchment area: 0.52 km^2
Glacier area in 2007: 0.003 km^2
General exposure: South

Photos:
B.Francou (IRD)©
E.Ramirez (IHH-UMSA) ©



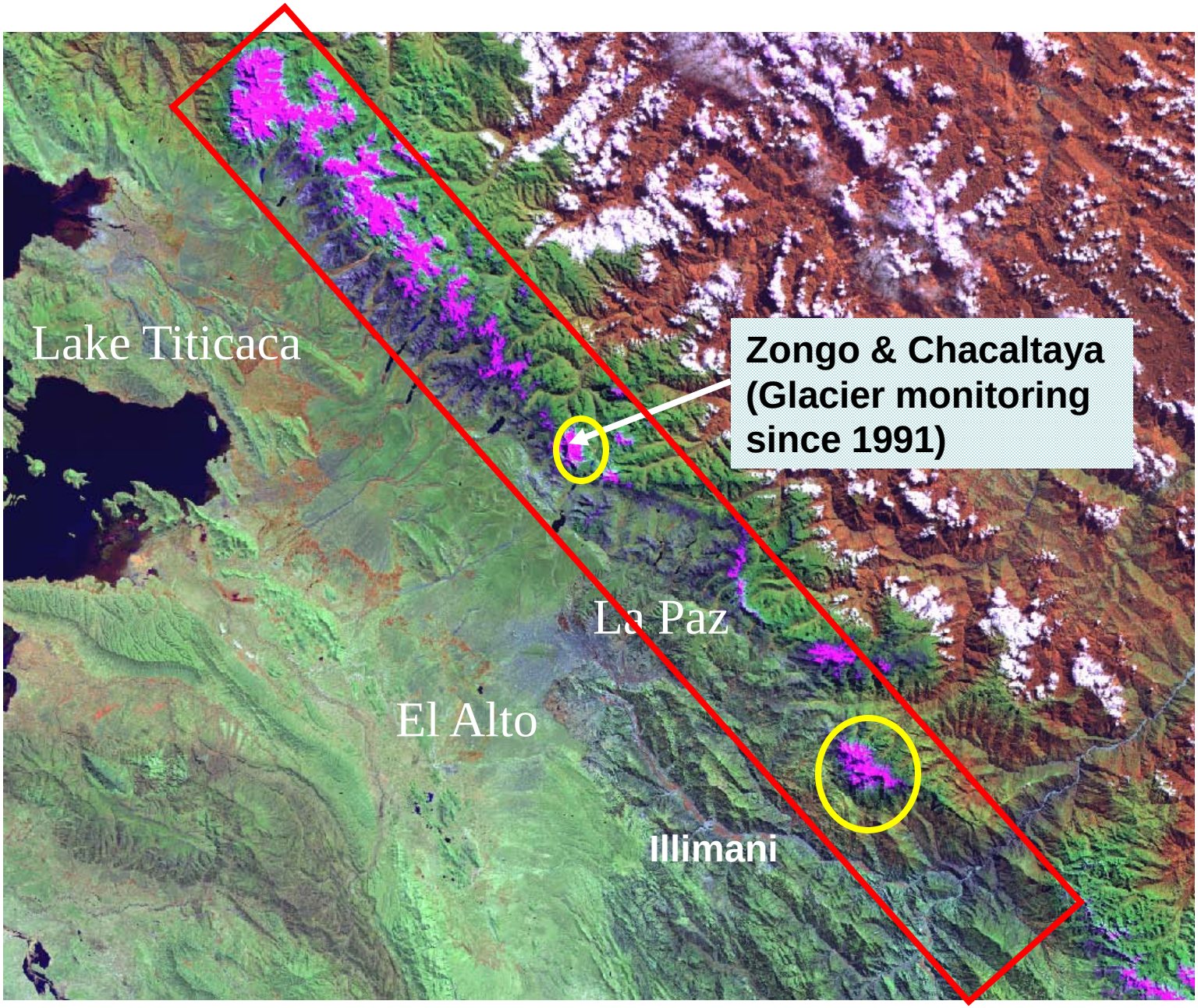
Ramirez et. al 2001; Journal of Glaciology

MASS BALANCE – CHACALTAYA GLACIER



Source: IRD-IHH

Studied glaciers in Bolivia



MAIN OBJETIVE

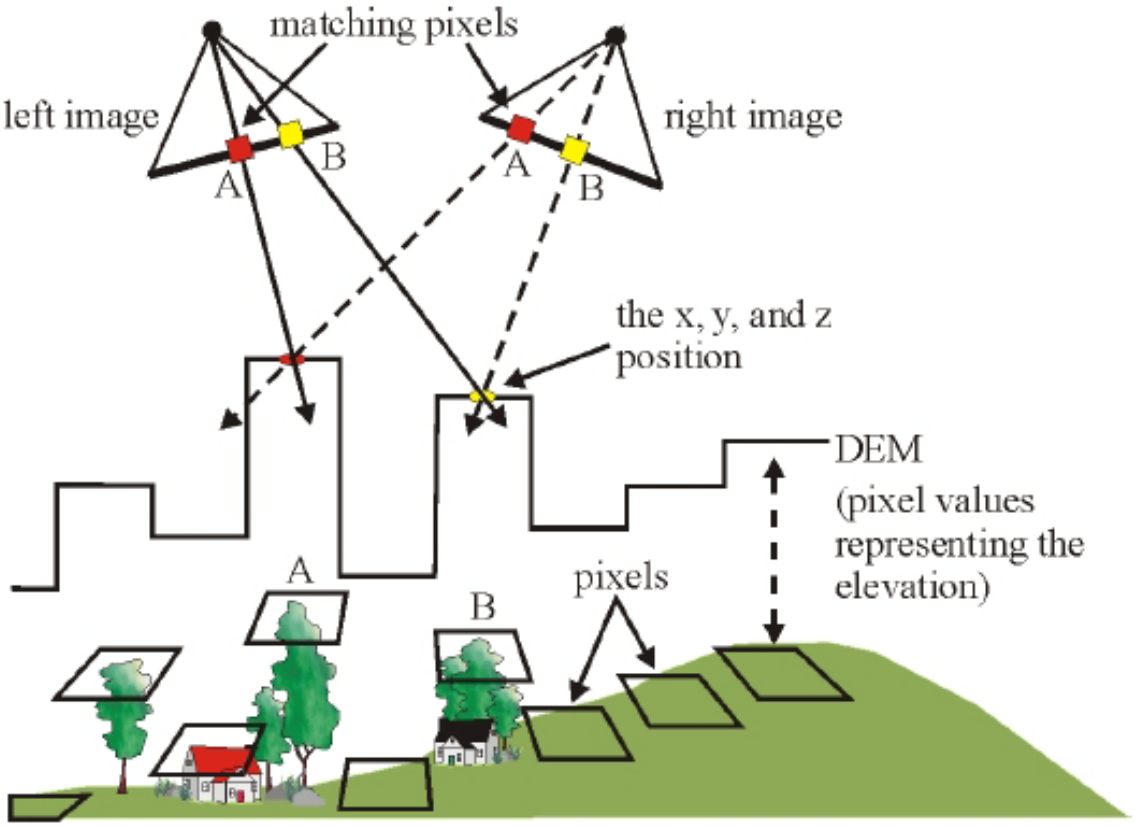
• Glacier surface reconstruction using ALOS-PRISM stereo-models capabilities.

METHODOLGY

•Using the capabilities of PRISM sensor in the stereoscopic mode made possible the acquisition of digital elevations models applying photogrammetric techniques. Two ALOS scenes were treated for the years 2007 and 2009 in order to quantify the loss of ice volume of the Illimani Mountain in Bolivia (16º39’11.42”S, 67º46’53.39”W) for this period.

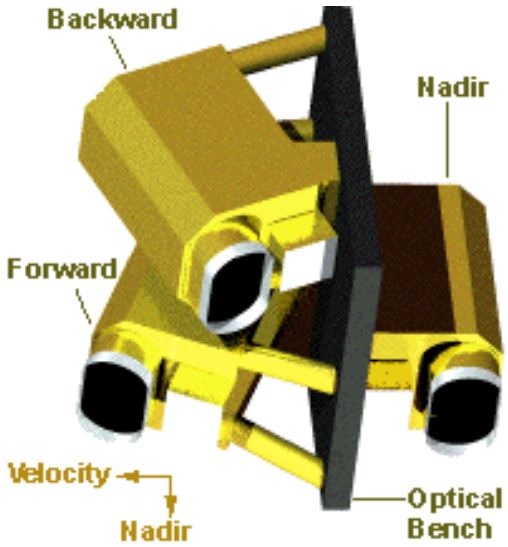
• Using a double frequency differential GPS twelve ground control points (GCP) were obtained in order to calibrate rigorous stereoscopic models. A permanent GPS base of bolivian army was used to relate with absolute values or orthometric heights.

Creating a DEM from stereo pairs



Photogrammetry techniques uses image correlation to extract matching pixels in the two images and then uses the sensor geometry from the computed math model to calculate x, y, and z positions.

Source: PCI-Gematica user manual



•ALOS-PRISM Satellite Images (Triplet Mode: Nadir, Backward, Forward) 2007 and 2009 provided by RESTEC and ASF.

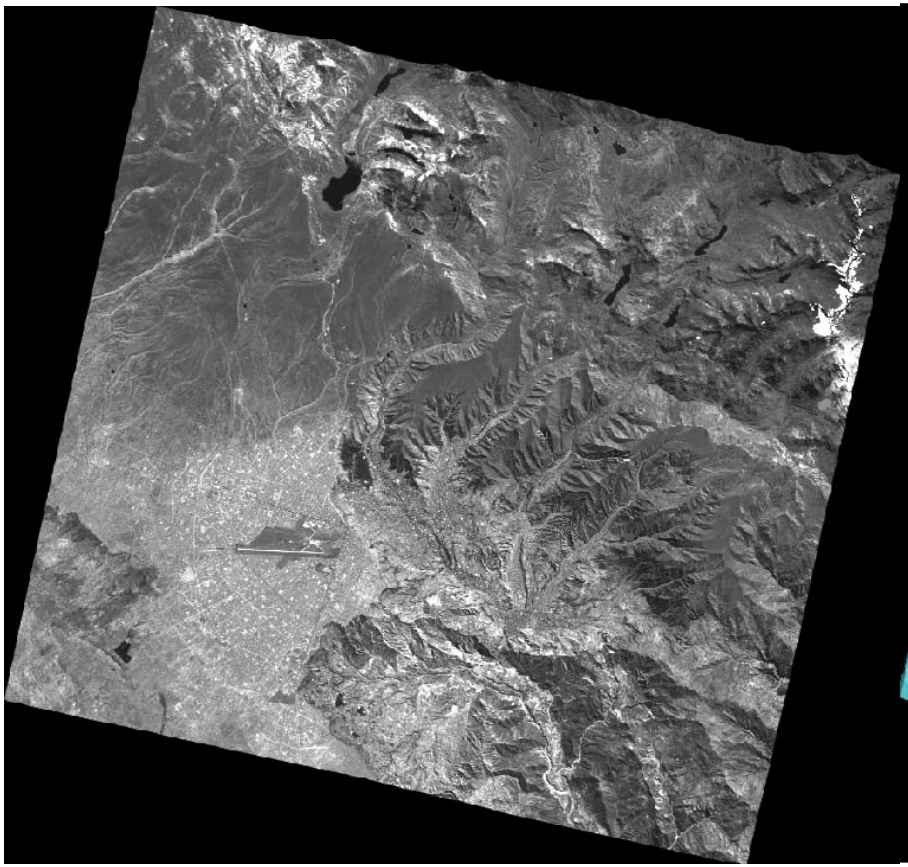
• DGPS L2 (THALES Z-max)

•Photogrammetric Software (LPS).

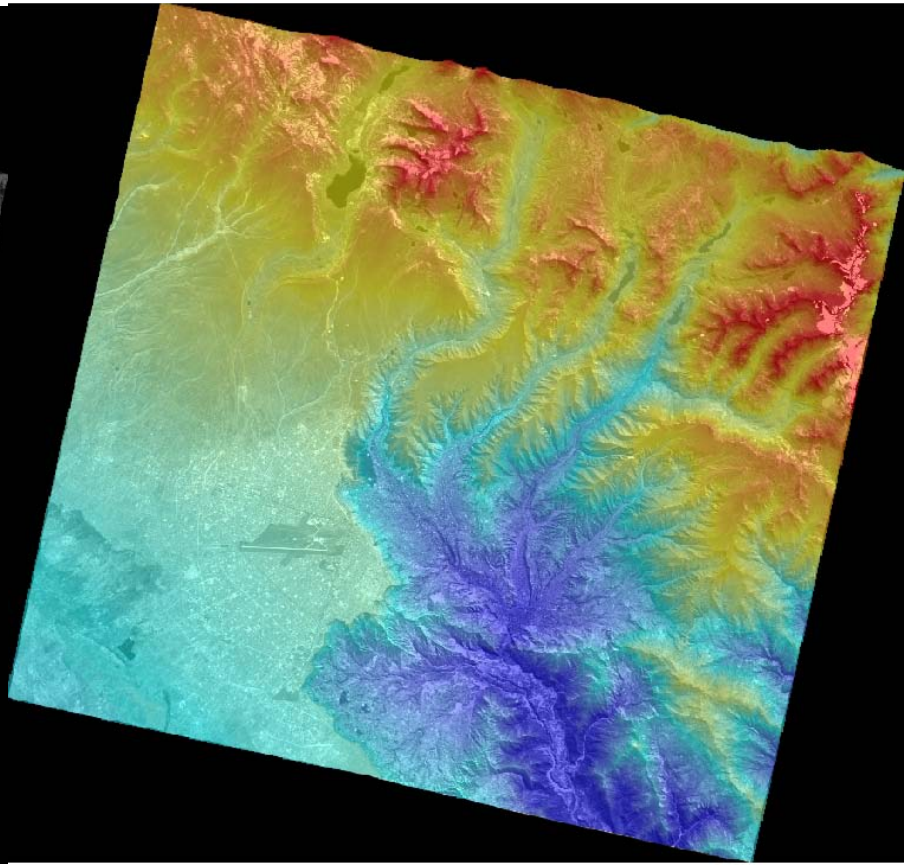
• PLANAR System (LCD Screen).

AUTOMATIC DEM EXTRACCTION FOR NON GLACIATED REGIONS

CITY OF LA PAZ - BOLIVIA



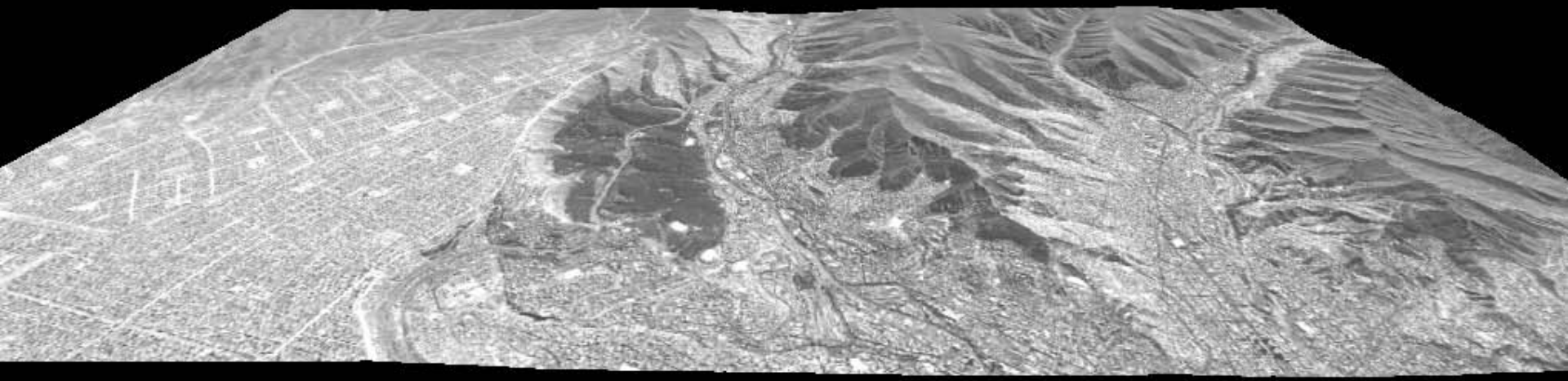
ALOS-PRISM Satellite Image



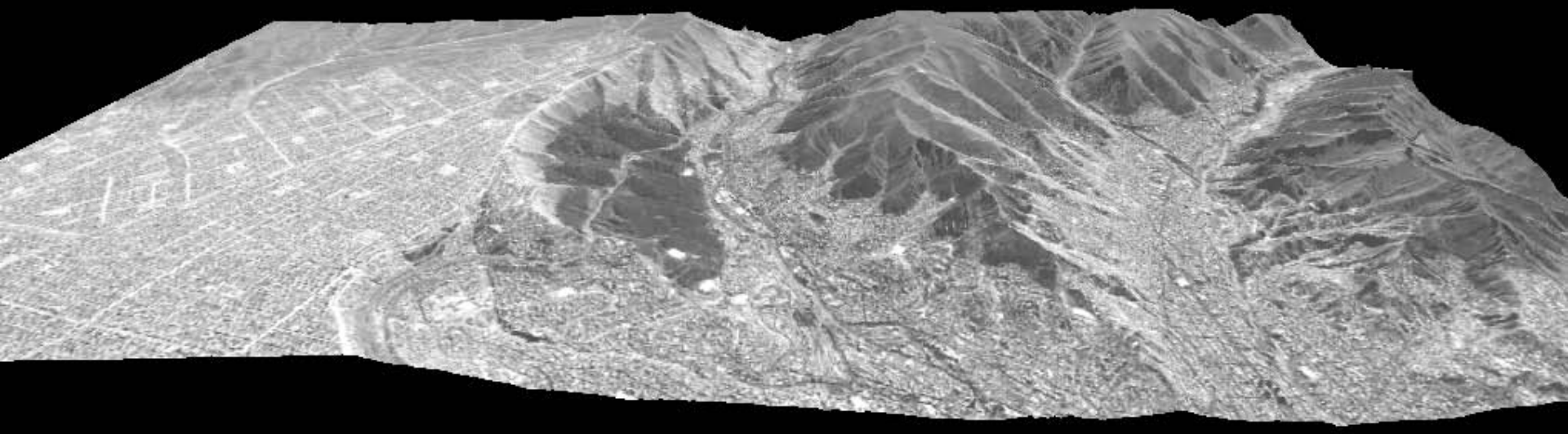
Associated DEM (Triplet mode)

Pixel DEM Resolution: 7.5 m

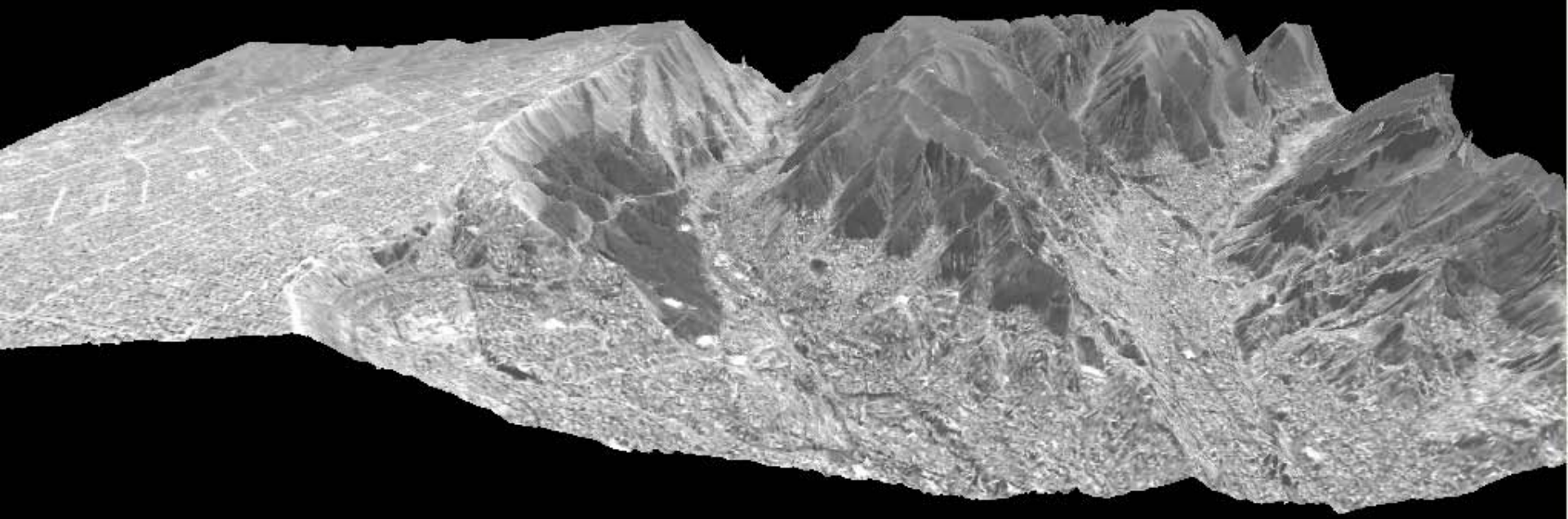
Digital Elevation Model from ALOS-Satellite for the city of La Paz

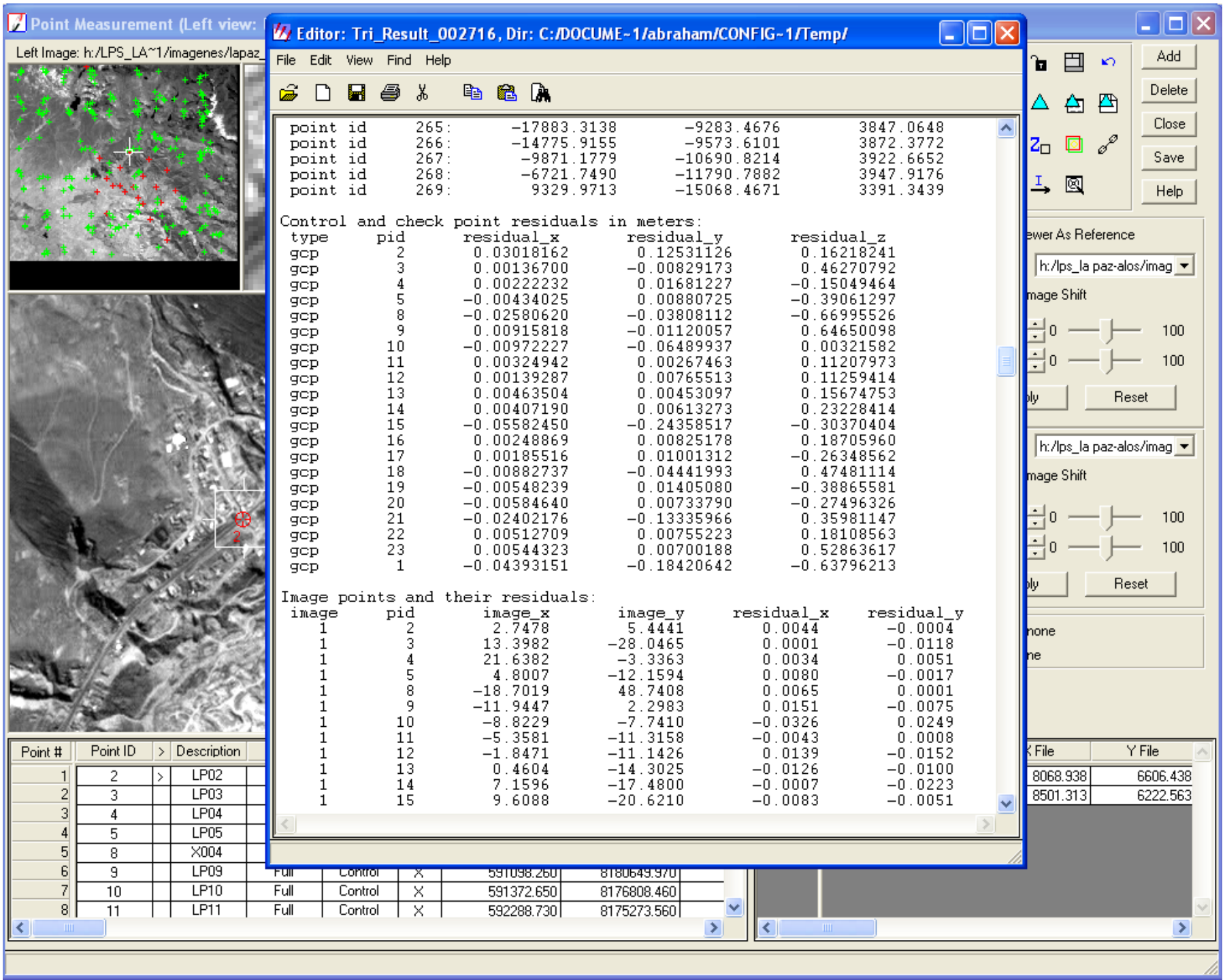


Digital Elevation Model from ALOS-Satellite for the city of La Paz

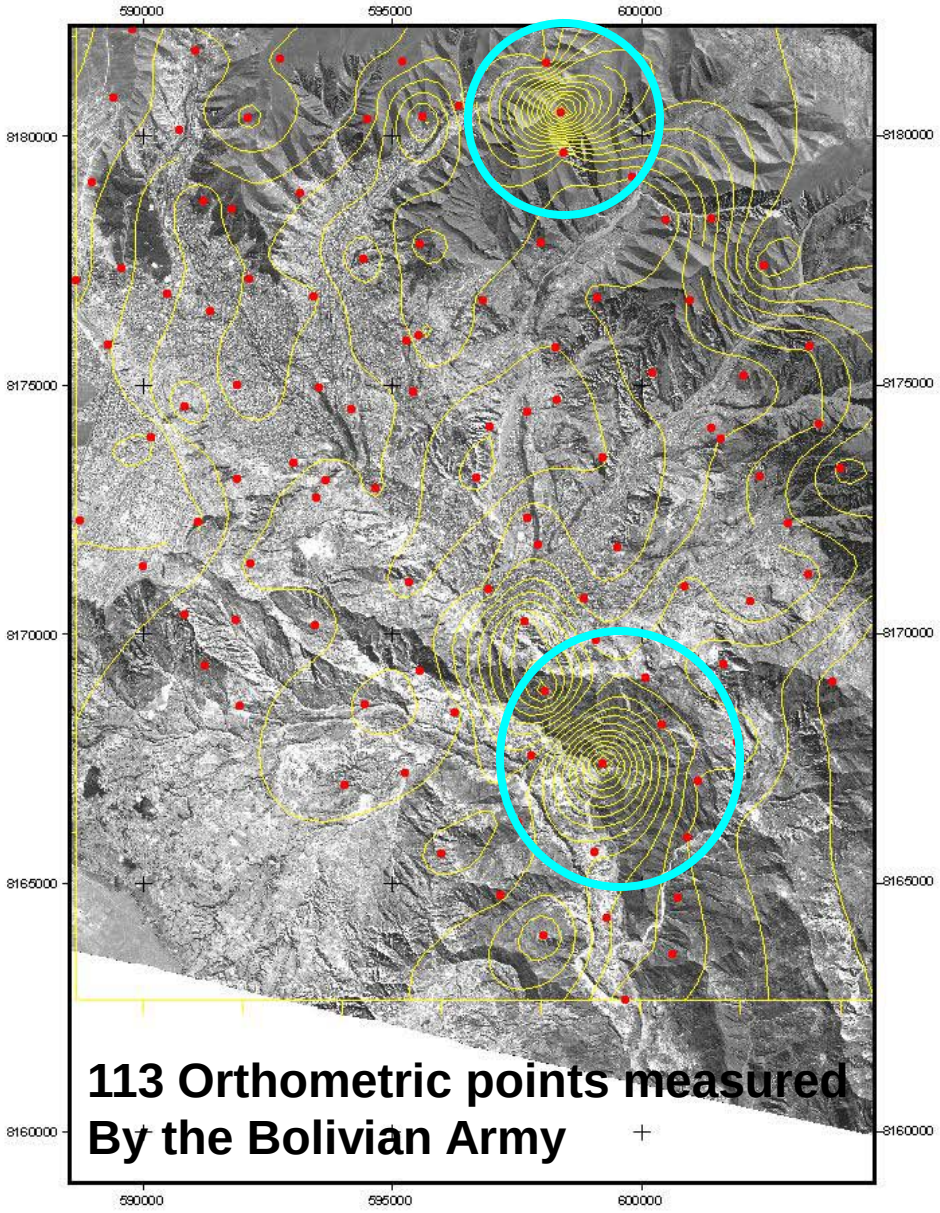


Digital Elevation Model from ALOS-Satellite for the city of La Paz



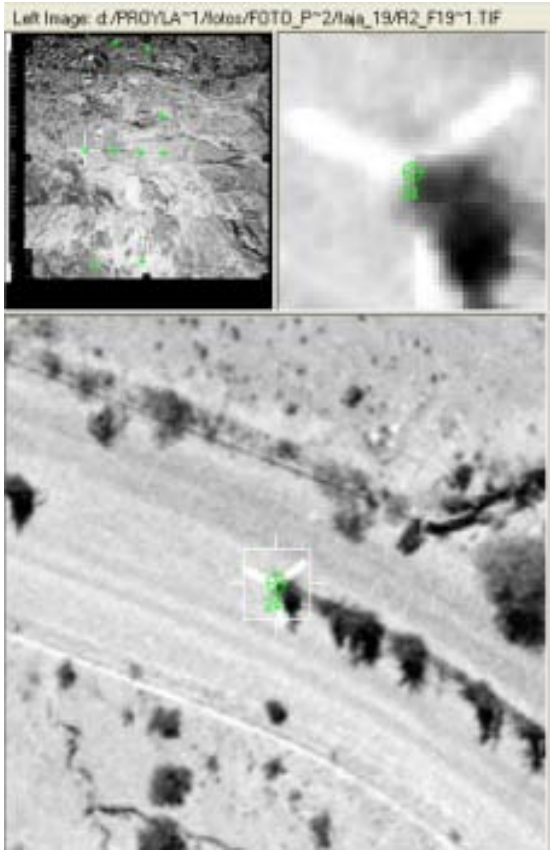

Point Measurement (Left view:
Left Image: h:/LPS_LA~1/imagenes/lapaz_
Editor: Tri_Result_002716, Dir: C:/DOCUME~1/abraham/CONFIG~1/Temp/
File Edit View Find Help
point id 265: -17883.3138 -9283.4676 3847.0648
point id 266: -14775.9155 -9573.6101 3872.3772
point id 267: -9871.1779 -10690.8214 3922.6652
point id 268: -6721.7490 -11790.7882 3947.9176
point id 269: 9329.9713 -15068.4671 3391.3439
Control and check point residuals in meters:
type pid residual_x residual_y residual_z
gcp 2 0.03018162 0.12531126 0.16218241
gcp 3 0.00136700 -0.00829173 0.46270792
gcp 4 0.00222232 0.01681227 -0.15049464
gcp 5 -0.00434025 0.00880725 -0.39061297
gcp 8 -0.02580620 -0.03808112 -0.66995526
gcp 9 0.00915818 -0.01120057 0.64650098
gcp 10 -0.00972227 -0.06489937 0.00321582
gcp 11 0.00324942 0.00267463 0.11207973
gcp 12 0.00139287 0.00765513 0.11259414
gcp 13 0.00463504 0.00453097 0.15674753
gcp 14 0.00407190 0.00613273 0.23228414
gcp 15 -0.05582450 -0.24358517 -0.30370404
gcp 16 0.00248869 0.00825178 0.18705960
gcp 17 0.00185516 0.01001312 -0.26348562
gcp 18 -0.00882737 -0.04441993 0.47481114
gcp 19 -0.00548239 0.01405080 -0.38865581
gcp 20 -0.00584640 0.00733790 -0.27496326
gcp 21 -0.02402176 -0.13335966 0.35981147
gcp 22 0.00512709 0.00755223 0.18108563
gcp 23 0.00544323 0.00700188 0.52863617
gcp 1 -0.04393151 -0.18420642 -0.63796213
Image points and their residuals:
image pid image_x image_y residual_x residual_y
1 2 2.7478 5.4441 0.0044 -0.0004
1 3 13.3982 -28.0465 0.0001 -0.0118
1 4 21.6382 -3.3363 0.0034 0.0051
1 5 4.8007 -12.1594 0.0080 -0.0017
1 8 -18.7019 48.7408 0.0065 0.0001
1 9 -11.9447 2.2983 0.0151 -0.0075
1 10 -8.8229 -7.7410 -0.0326 0.0249
1 11 -5.3581 -11.3158 -0.0043 0.0008
1 12 -1.8471 -11.1426 0.0139 -0.0152
1 13 0.4604 -14.3025 -0.0126 -0.0100
1 14 7.1596 -17.4800 -0.0007 -0.0223
1 15 9.6088 -20.6210 -0.0083 -0.0051
Add
Delete
Close
Save
Help
ewer As Reference
h:/lps_la paz-alos/imag
mage Shift
Reset
Point # Point ID > Description
1 2 > LP02
2 3 LP03
3 4 LP04
4 5 LP05
5 8 X004
6 9 LP09
7 10 LP10
8 11 LP11
Full Control X 591098.260 8180649.970
Full Control X 591372.650 8176808.460
Full Control X 592288.730 8175273.560
X File
Y File
8068.938 6606.438
8501.313 6222.563

RESIDUALS

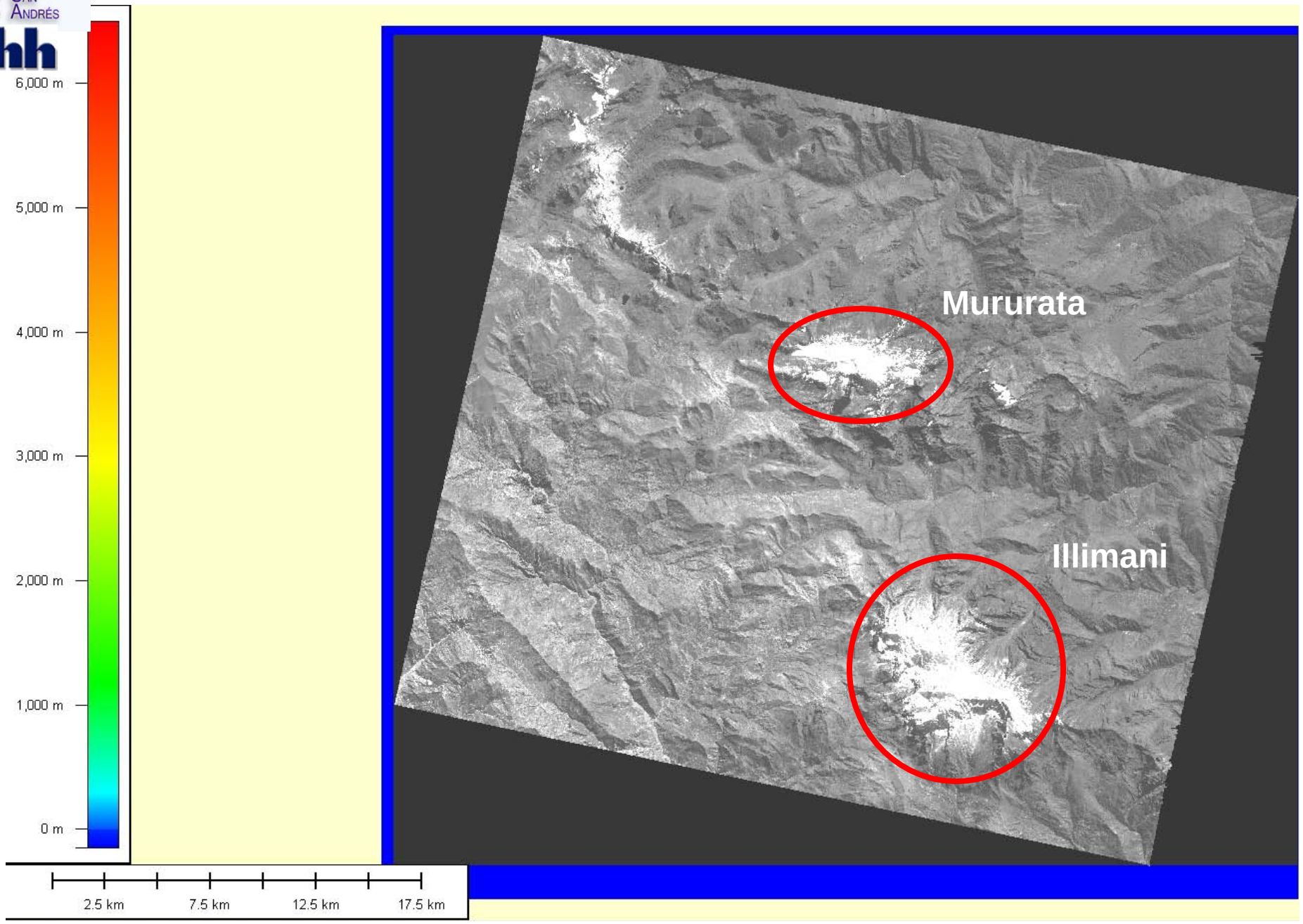


113 Orthometric points measured By the Bolivian Army

Vertical accuracy: ±5m

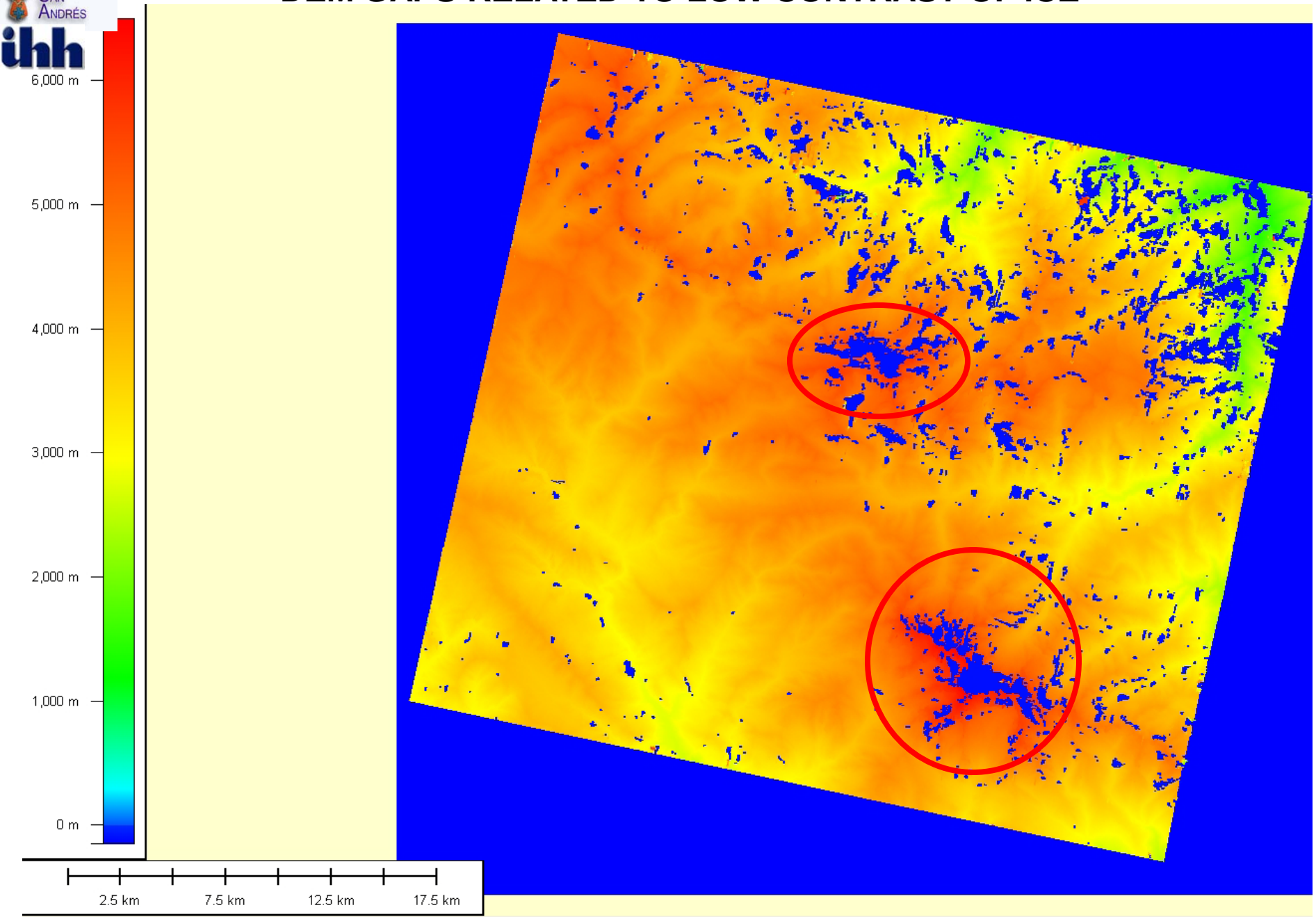


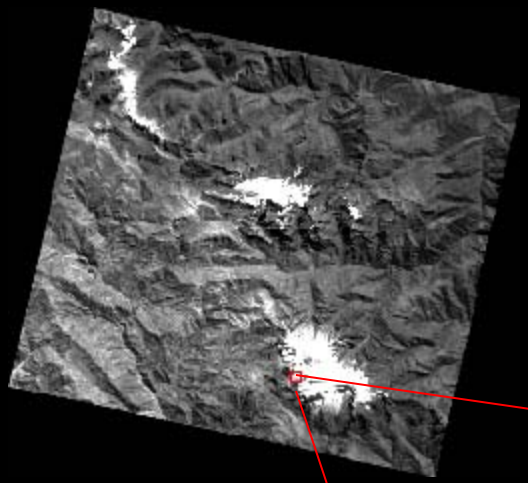
AUTOMATIC DEM EXTRACCTION FOR GLACIATED REGIONS



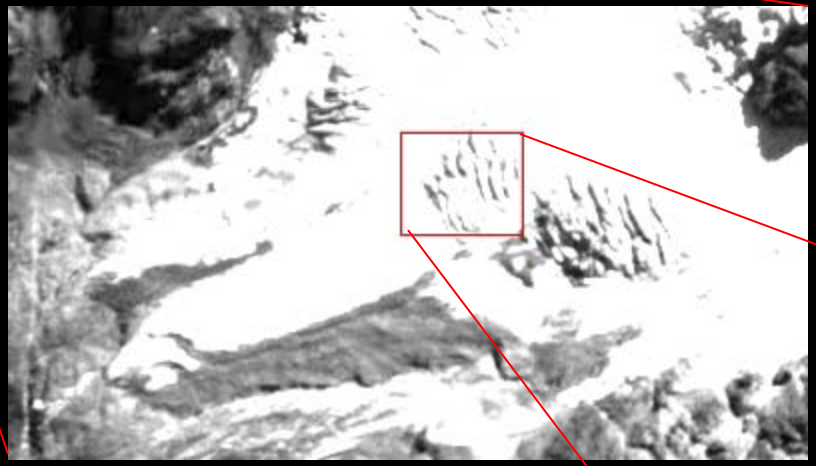
ALOS-PRISM

DEM GAPS RELATED TO LOW CONTRAST OF ICE





Use of phtogrammetric techniques measuring small details observed on the glacier surface.



Internal orientation:

•Focal Length (mm) = 1939.0

•Principal Point x0 (mm) = 0.0000

•Principal Point y0 (mm) = 0.0000

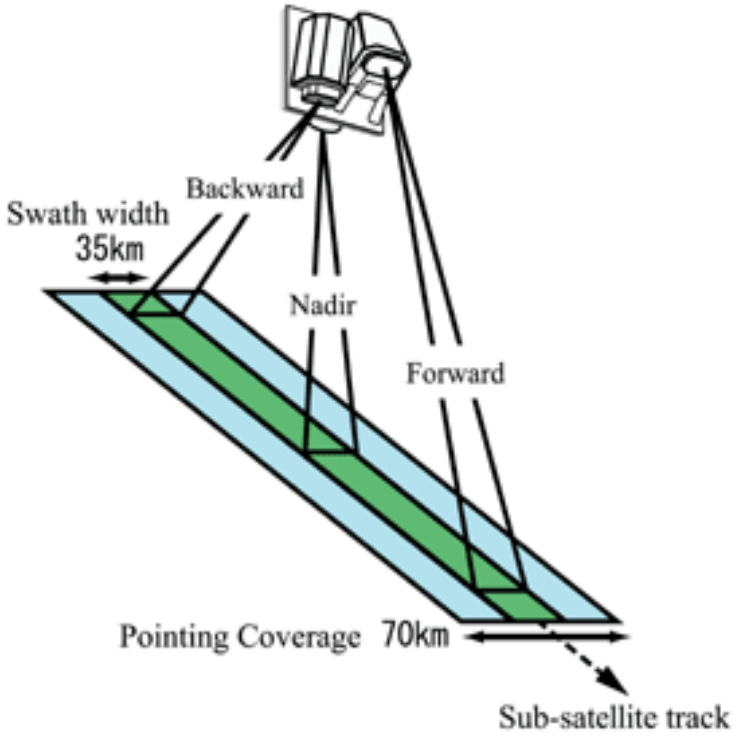
•Xpixel Size (mm) = 0.007

•Ypixel Size (mm) = 0.007

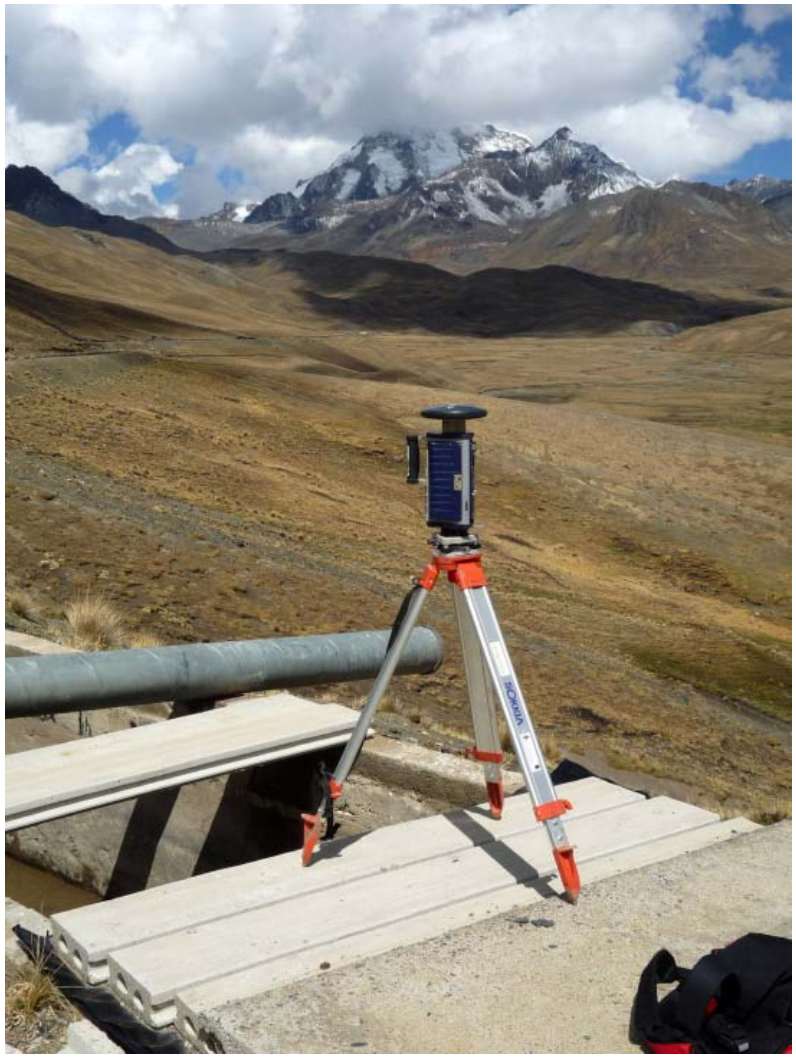
•Incidence Angle Along Track = 0.0˚ at Nadir / 23.8˚ (Backward) / -23.8˚ (Forward)

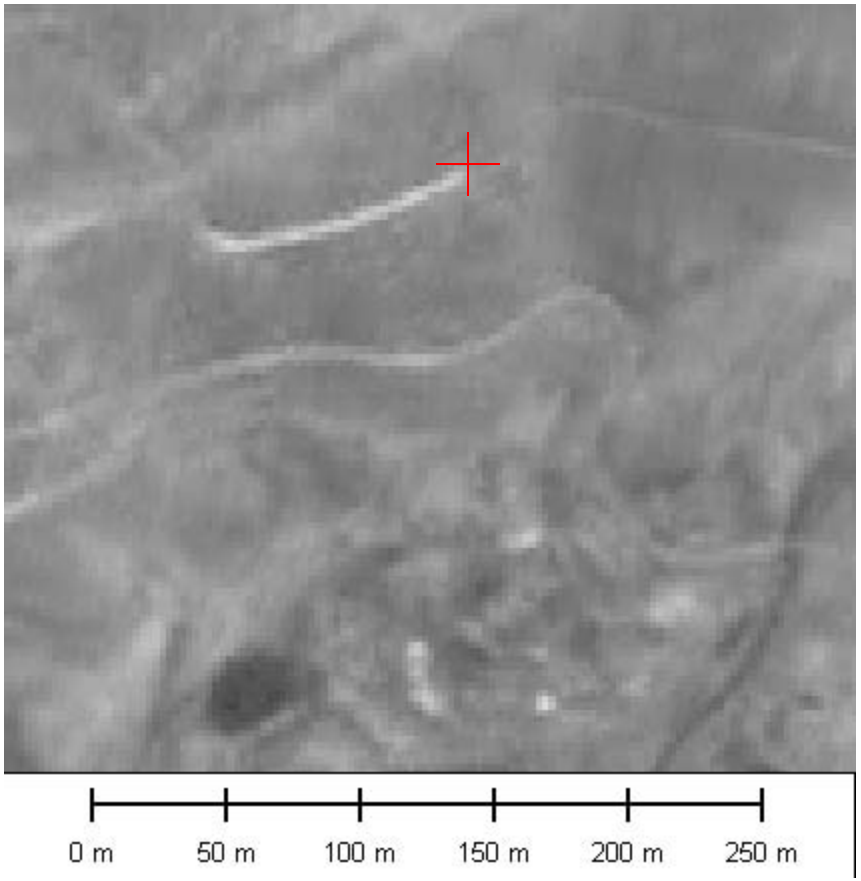
•Incidence Angle Across Track = 0.0˚

•Sensor Line Along Axis = X

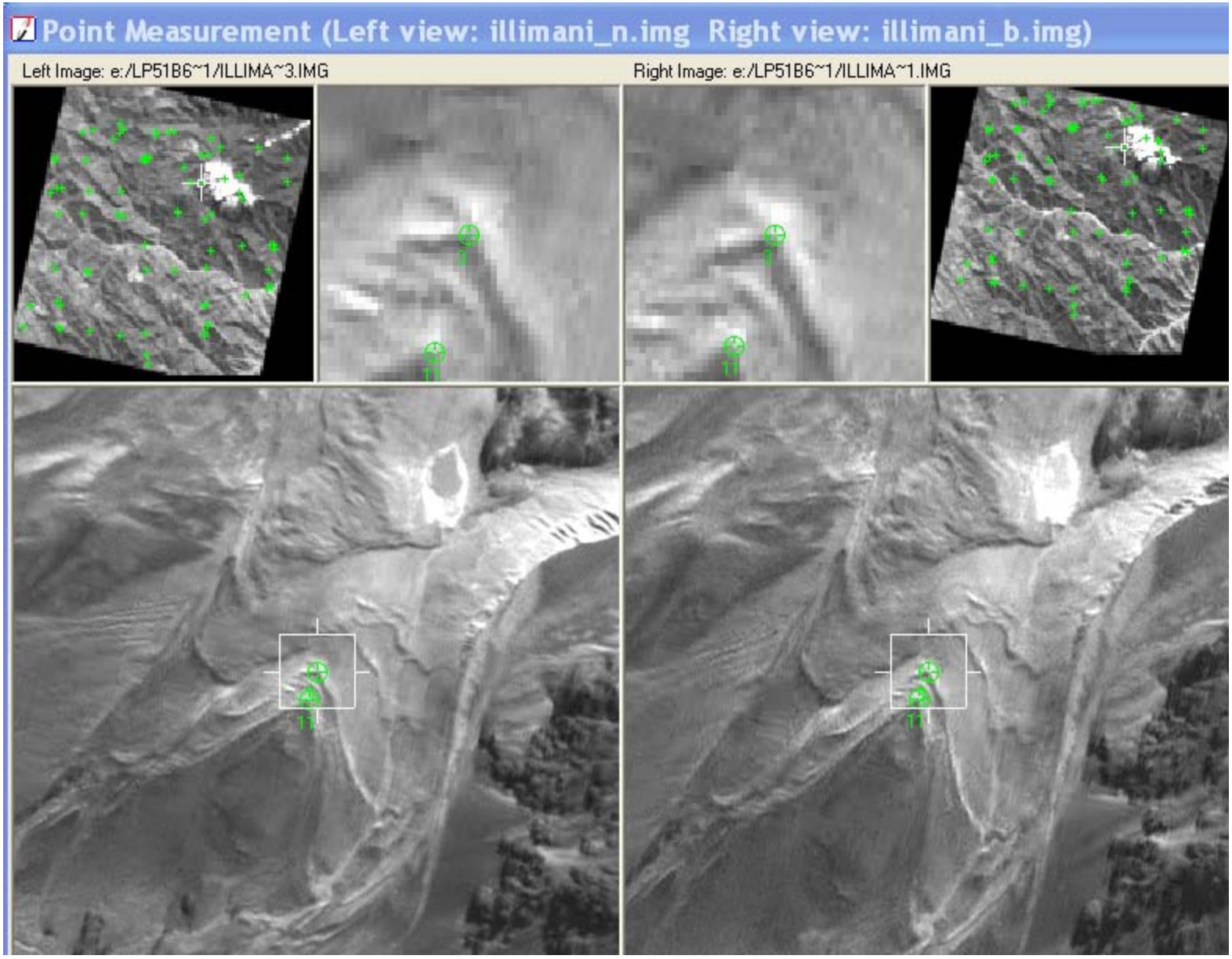


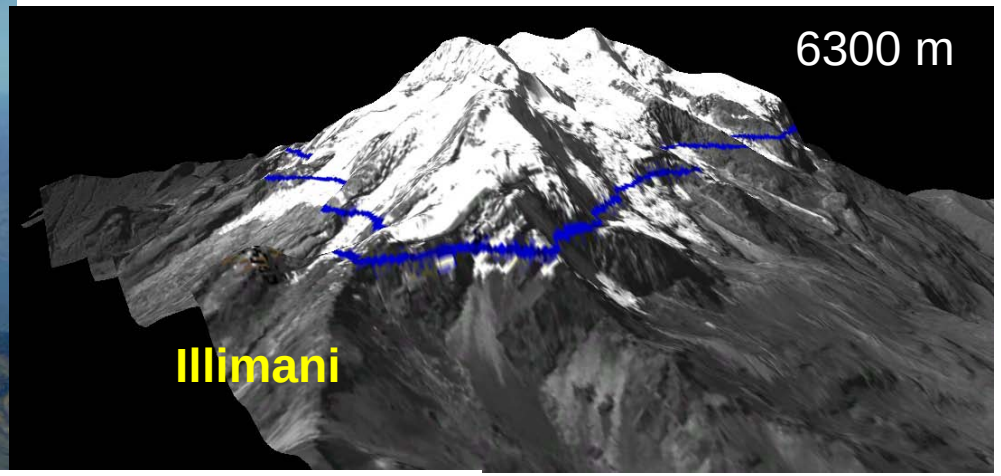
EXTERNAL ORIENTATION





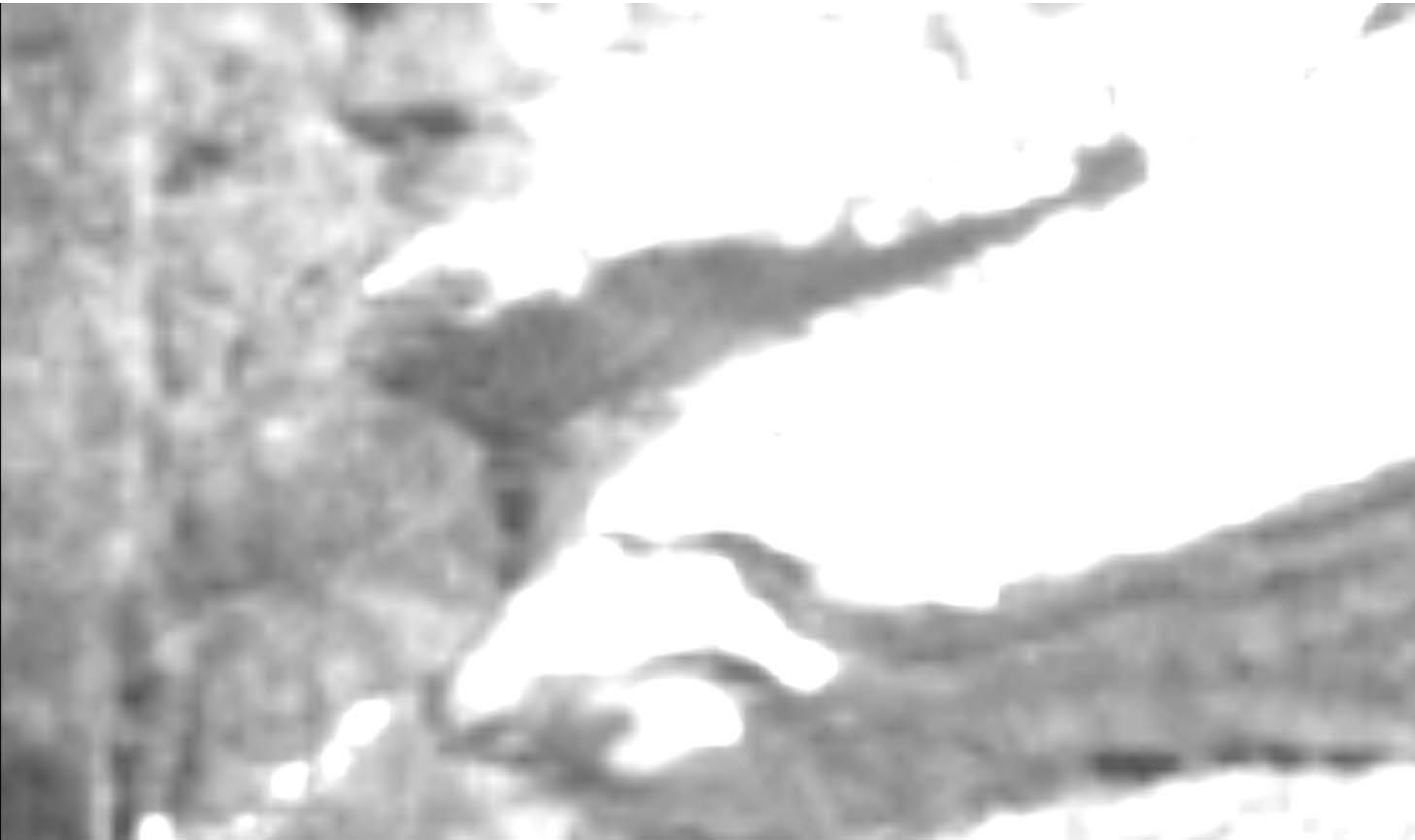
* 12 GCP were obtained with a DGPS L2 THALES Z-max.
•Time of acquisition: 1 hour.
• Orthometric elevations related with a permanent DGPS of Bolivian Army.


Point Measurement (Left view: illimani_n.img Right view: illimani_b.img)
Left Image: e:/LP51B6~1/ILLIMA~3.IMG
Right Image: e:/LP51B6~1/ILLIMA~1.IMG


6300 m
Illimani

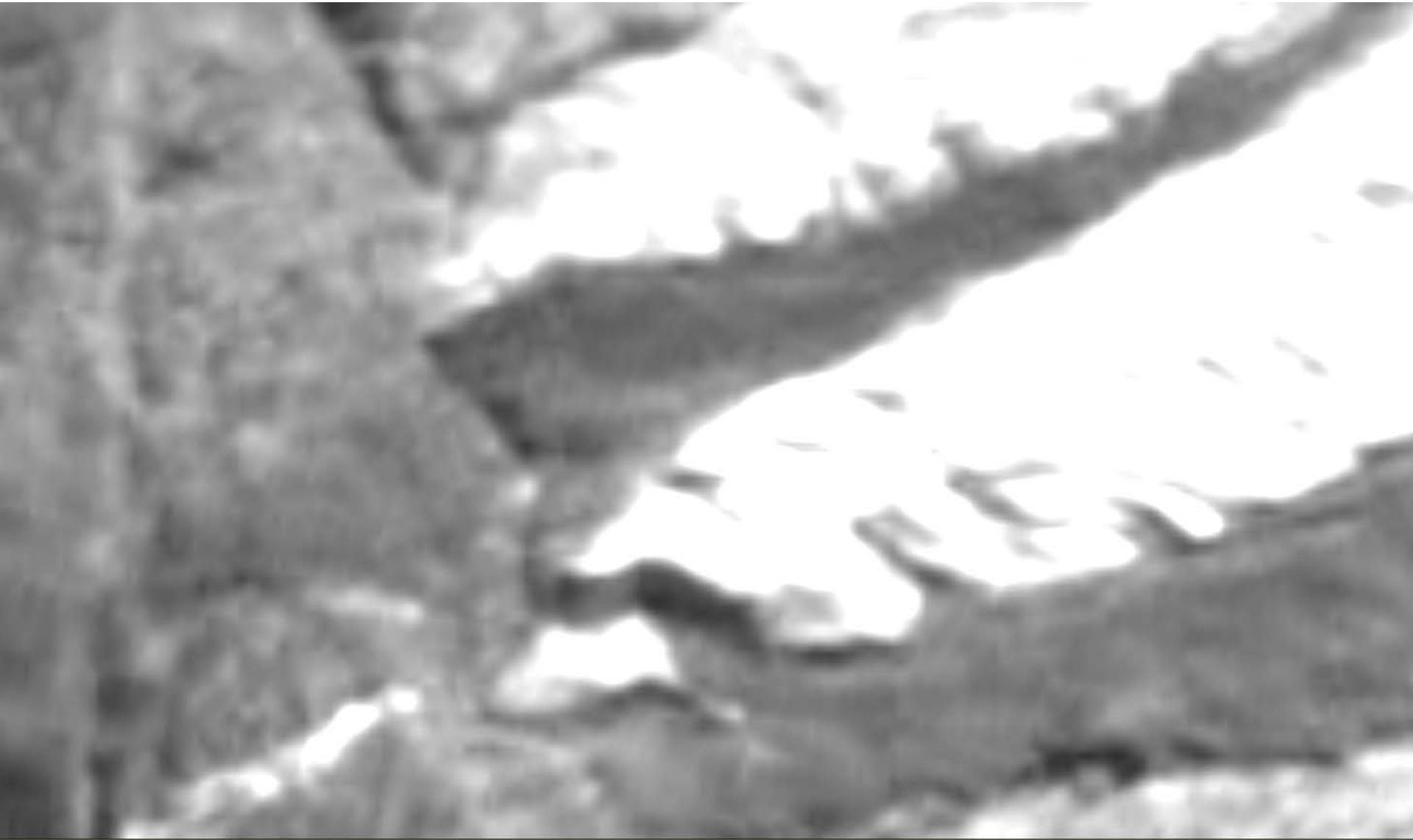
ALOS-PRISM Satellite Image

2007

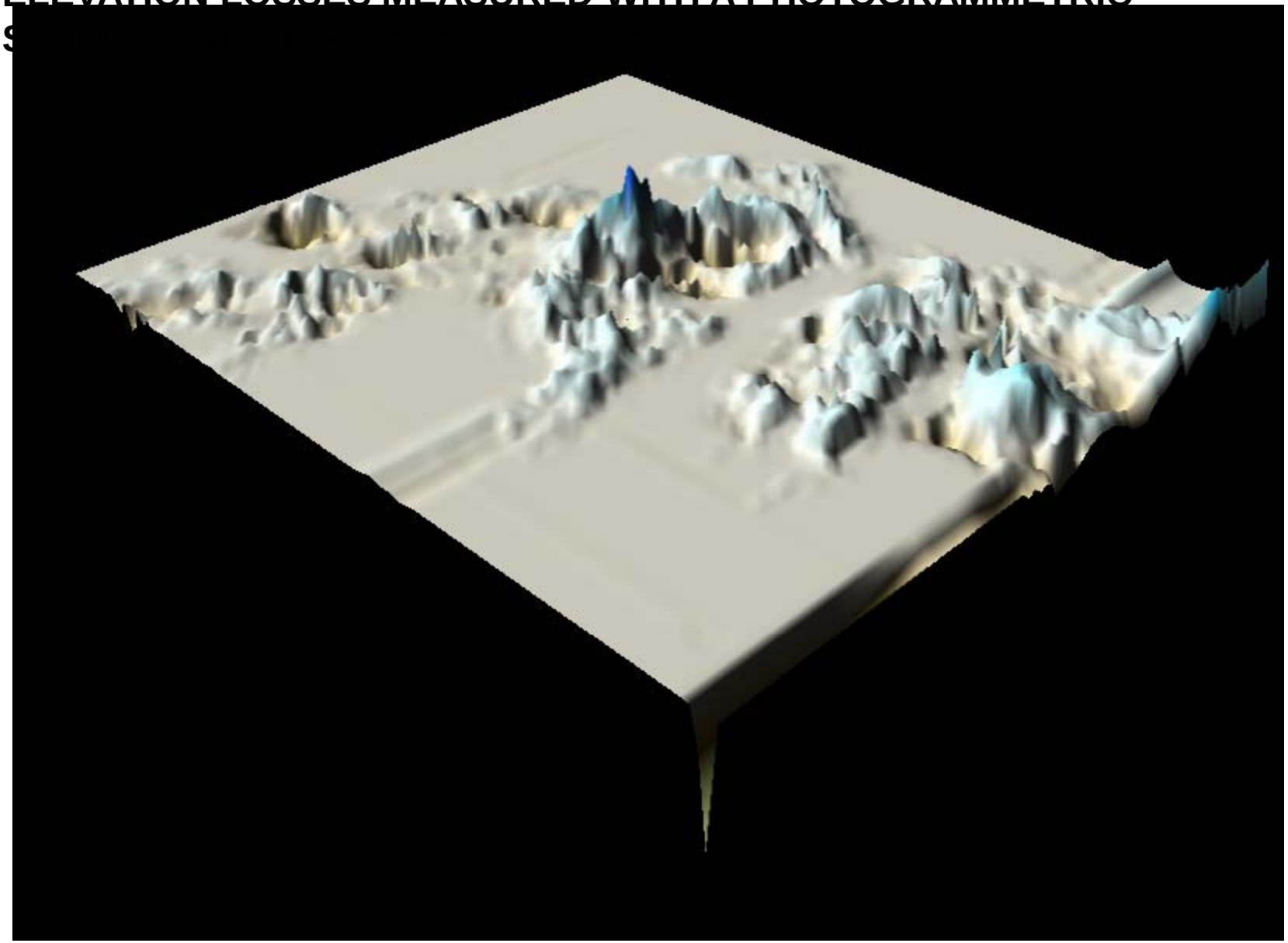


ALOS-PRISM Satellite Image

2009



ELEVATION LOSSES MEASURED WITH A PHOTOGRAMMETRIC S



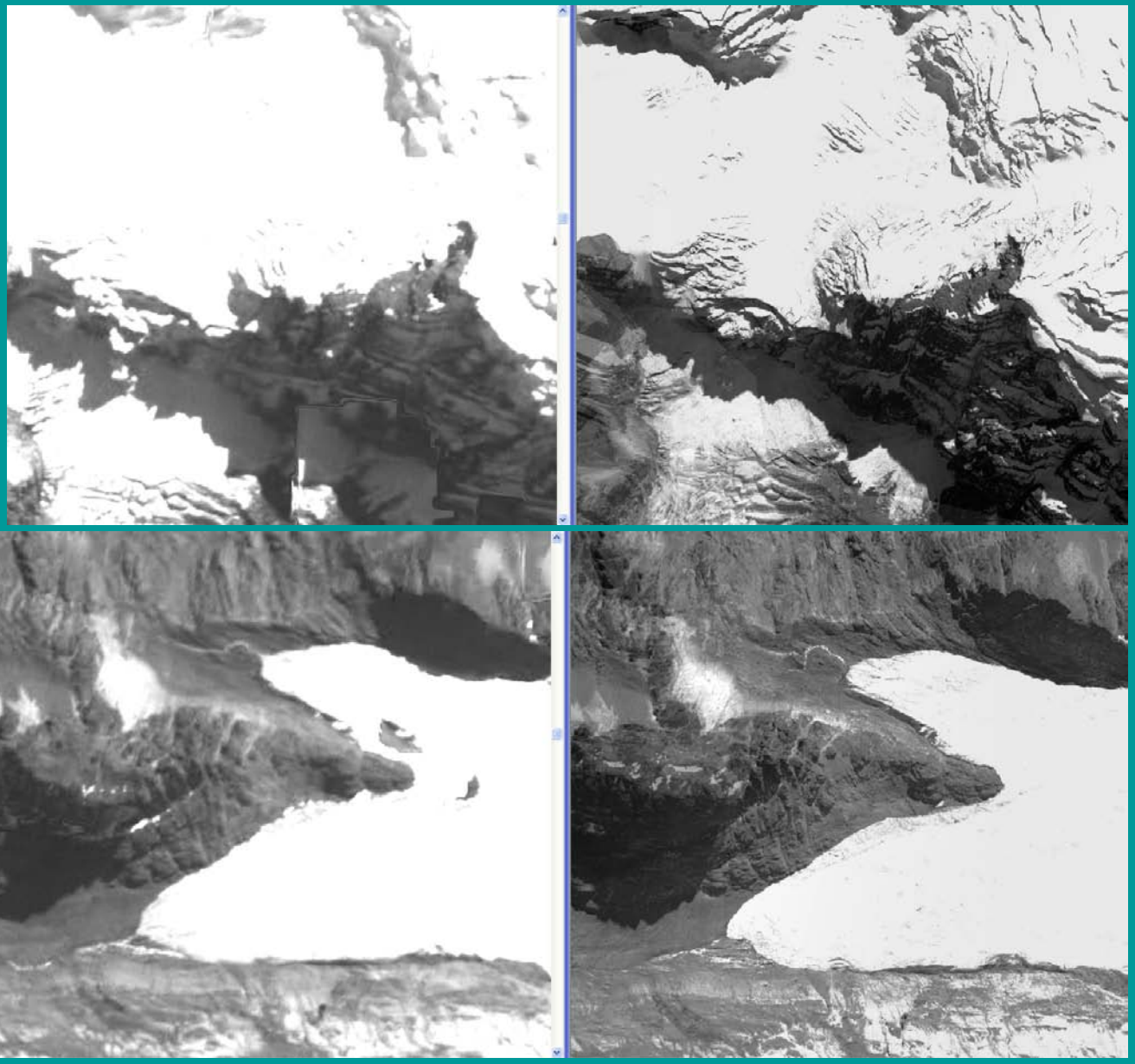
FIELD VALIDATION

Very realistic for glacier boundaries but maybe not enough for volume.

COMPARISON BETWEEN ALOS-PRISM IMAGES AND AERIAL PHOTOGRAPHS OBTEINED AT THE SAME PEROD.

A photogrammetric flight carried out at the same time ,in 2009 by the Bolivian Air Force have allowed to make a comparison between the use of aerial photographs and stereoscopic high resolution satellite images.

COMPARISON BETWEEN ALOS IMAGES AND AERIAL PHOTOGRAPHS



ALOS - PRISM

Aerial Photograph

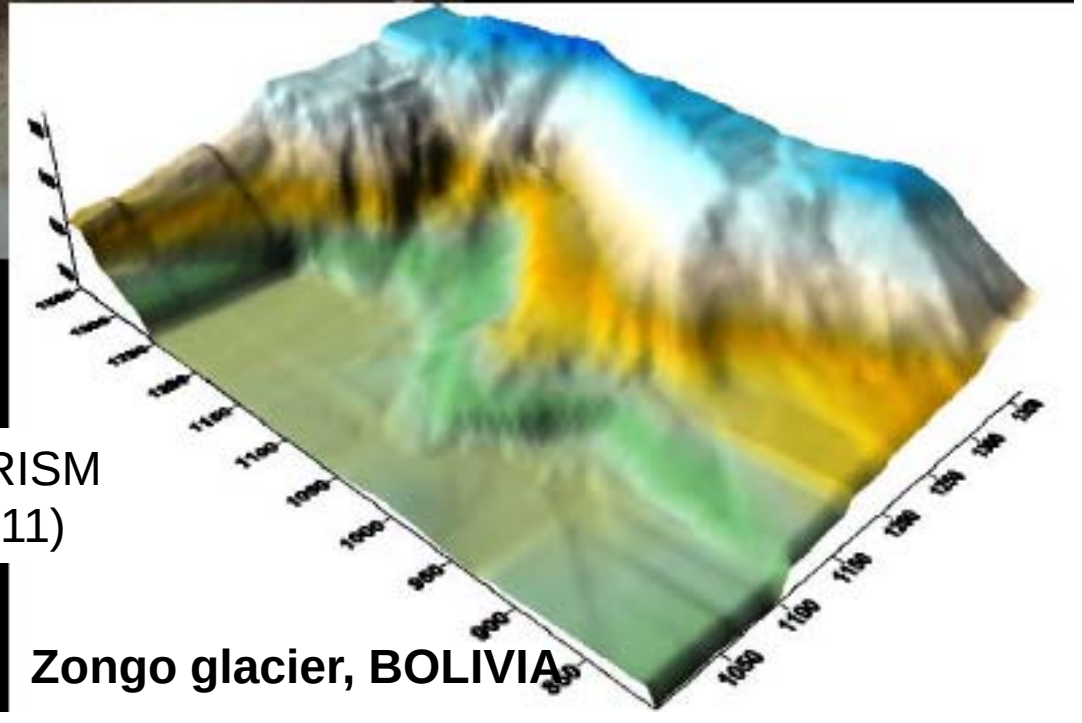
CONCLUSIONS

•Since the middle of the 70's the glacier retreat increase about three times compared with precedent years according to glaciological studies in the Andes.

• It is important to improve the glacier – monitoring network for mass-balance quantification, however classical methods are difficult to apply mainly because de accessibility and high cost.

• For non glaciated zones, the application of DEM extraction using ALOS-PRISM images is possible with an accuracy about ±5m, however it is related with optimal contrast of the image and the slope.
• For glaciated zones it is not recommended to use an automatic DEM extraction.
• For glacier surface reconstruction using PRISM sensor it is recommended to apply photogrammetric techniques considering very accurate GCP and orthorectified points using photogrammetric stations. The elevation accuracy obtained is 3-5m, however it depends also of the visual sensitivity of the operator.
• ALOS-PRISM images are a good alternative mainly for glacier inventories, but at the moment it is not enough for mass balance quantification in the case of small glaciers.

FUTURE ACTIVITIES FOR 2011



- Application of terrestrial LIDAR & PRISM
- Glacier inventory up-grade (may 2011)

Zongo glacier, BOLIVIA

Thank you very much for your attention.

Photo: E.Ramirez