INVENTARIO DE GLACIARES, CUERPOS DE AGUA Y BOFEDALES DE LA CORDILLERA REAL DE BOLIVIA

Edson Ramírez Ph.D.

eeramirez@umsa.bo

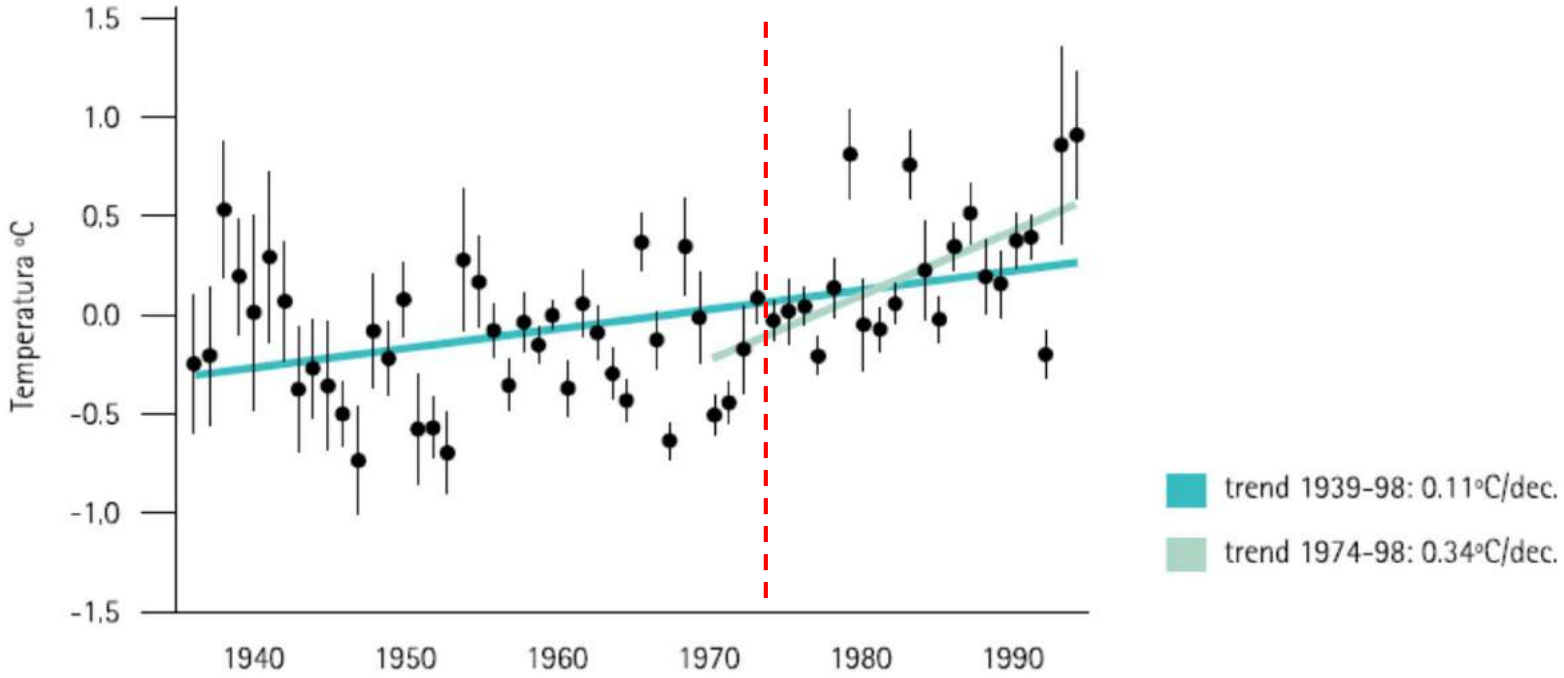
Instituto de Hidráulica e Hidrología,
Universidad Mayor de San Andrés (UMSA, Bolivia)

Octubre 2021

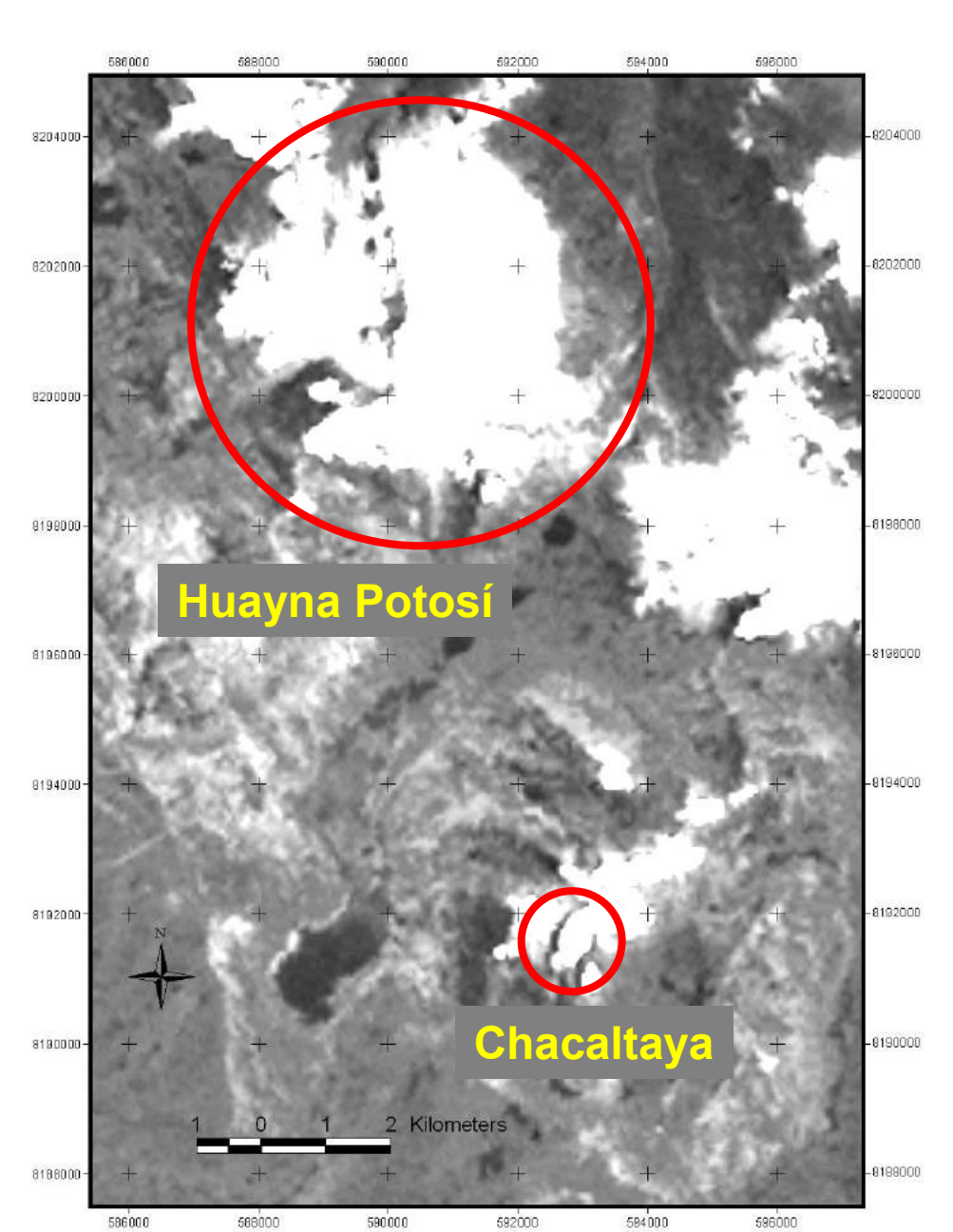
Foto: E.Ramirez ©

ANTECEDENTES

- Temperature in the tropical Andes between 1939 and 1998 -

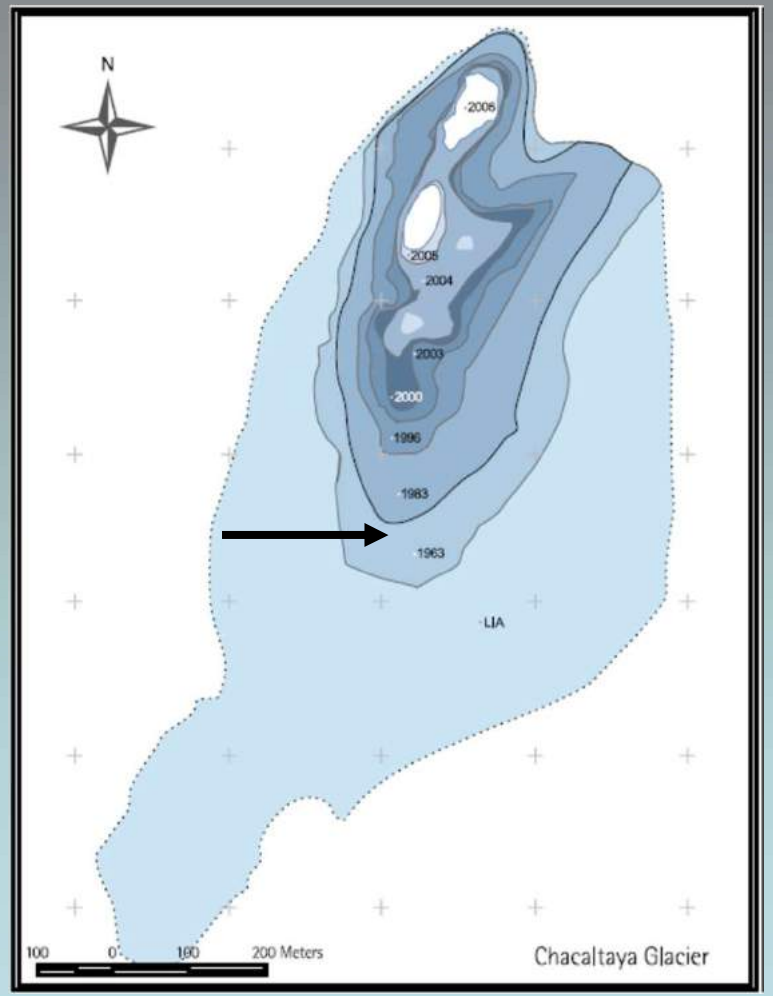


Source: Vuille and Bradley (2000)



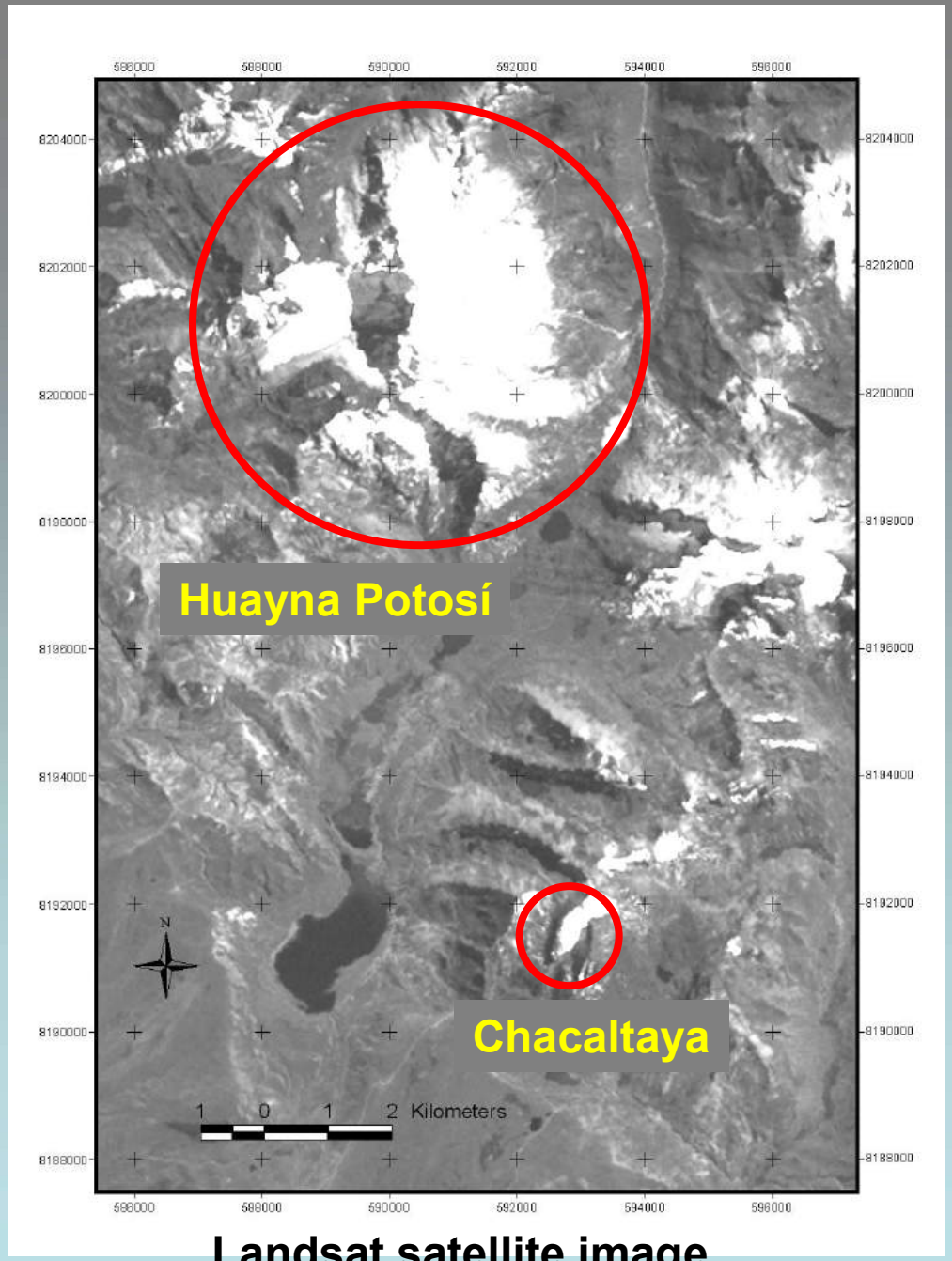
Landsat satellite image

1975

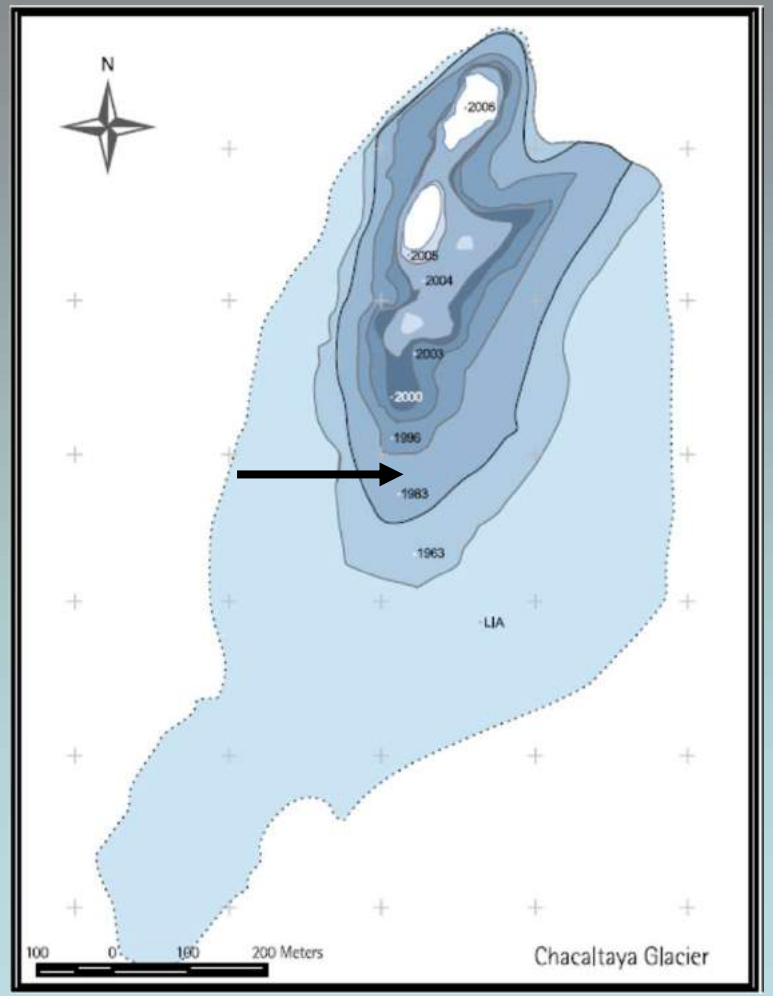


Fuente: (IHH-UMSA) ©

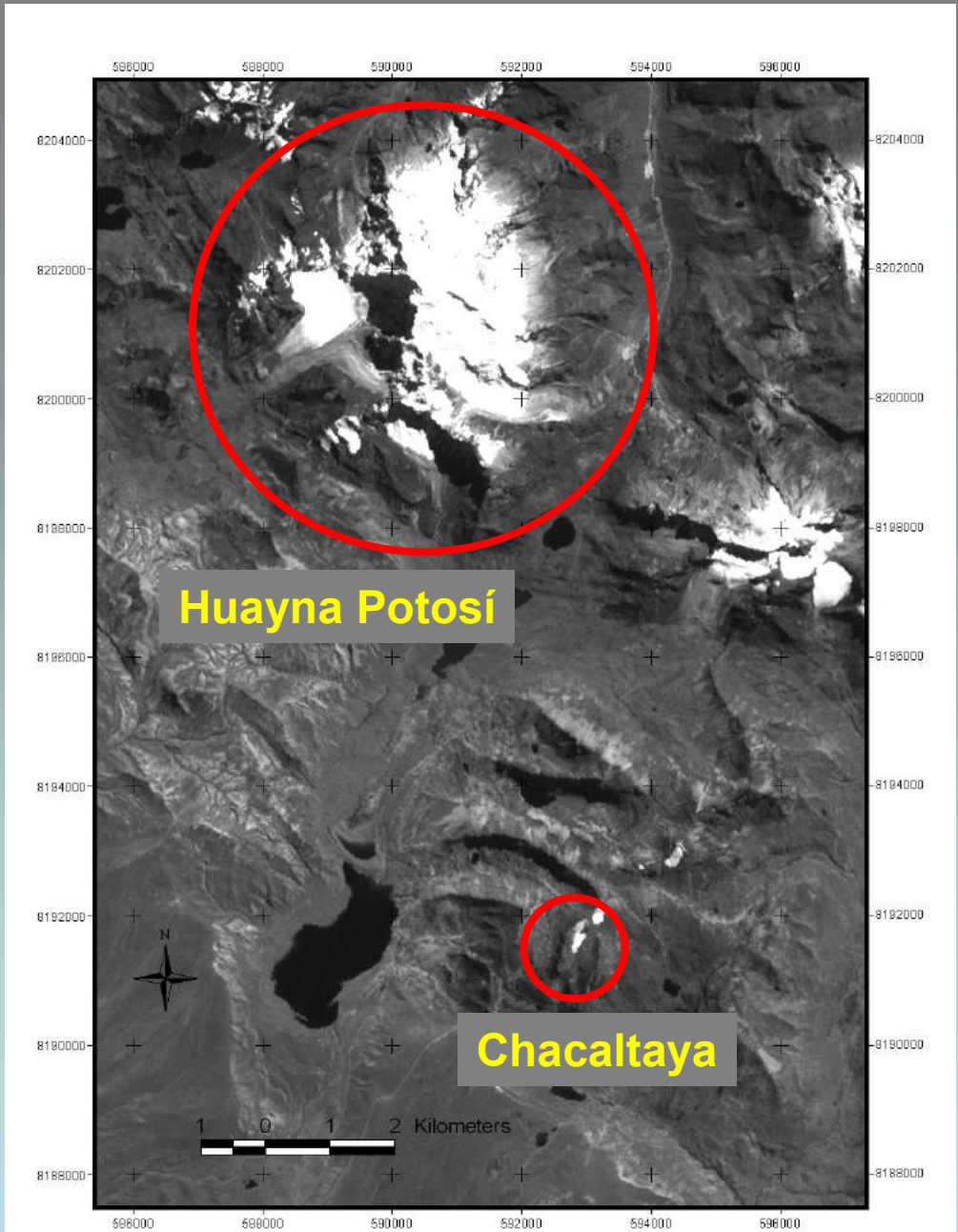
1987



Landsat satellite image

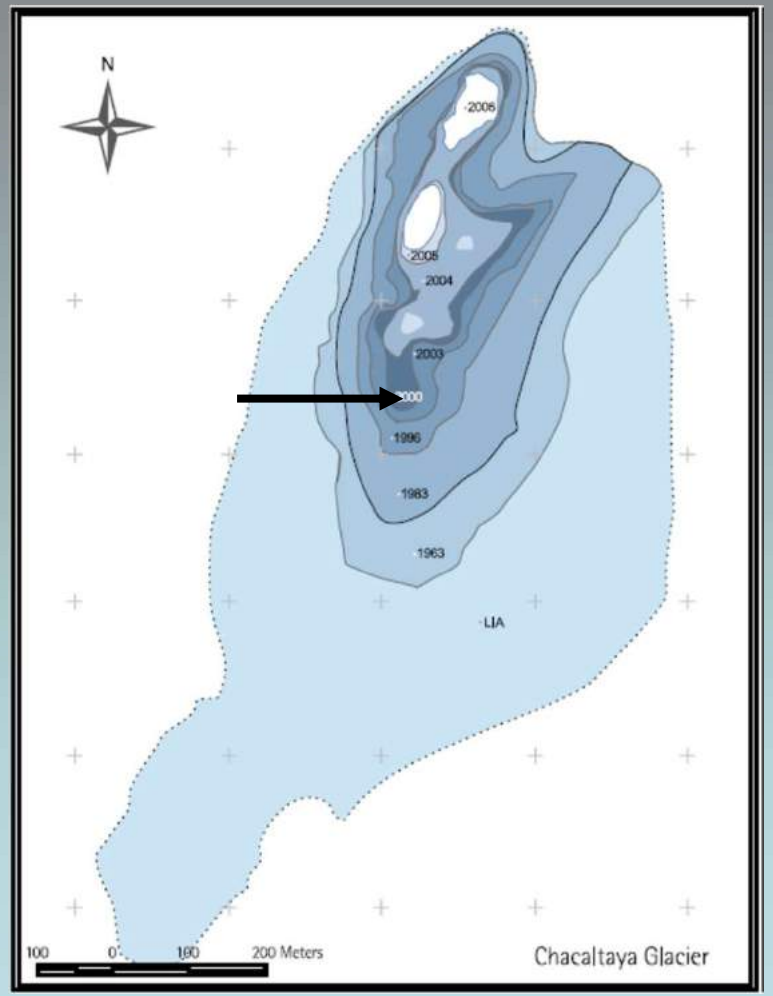


Fuente: (IHH-UMSA) ©

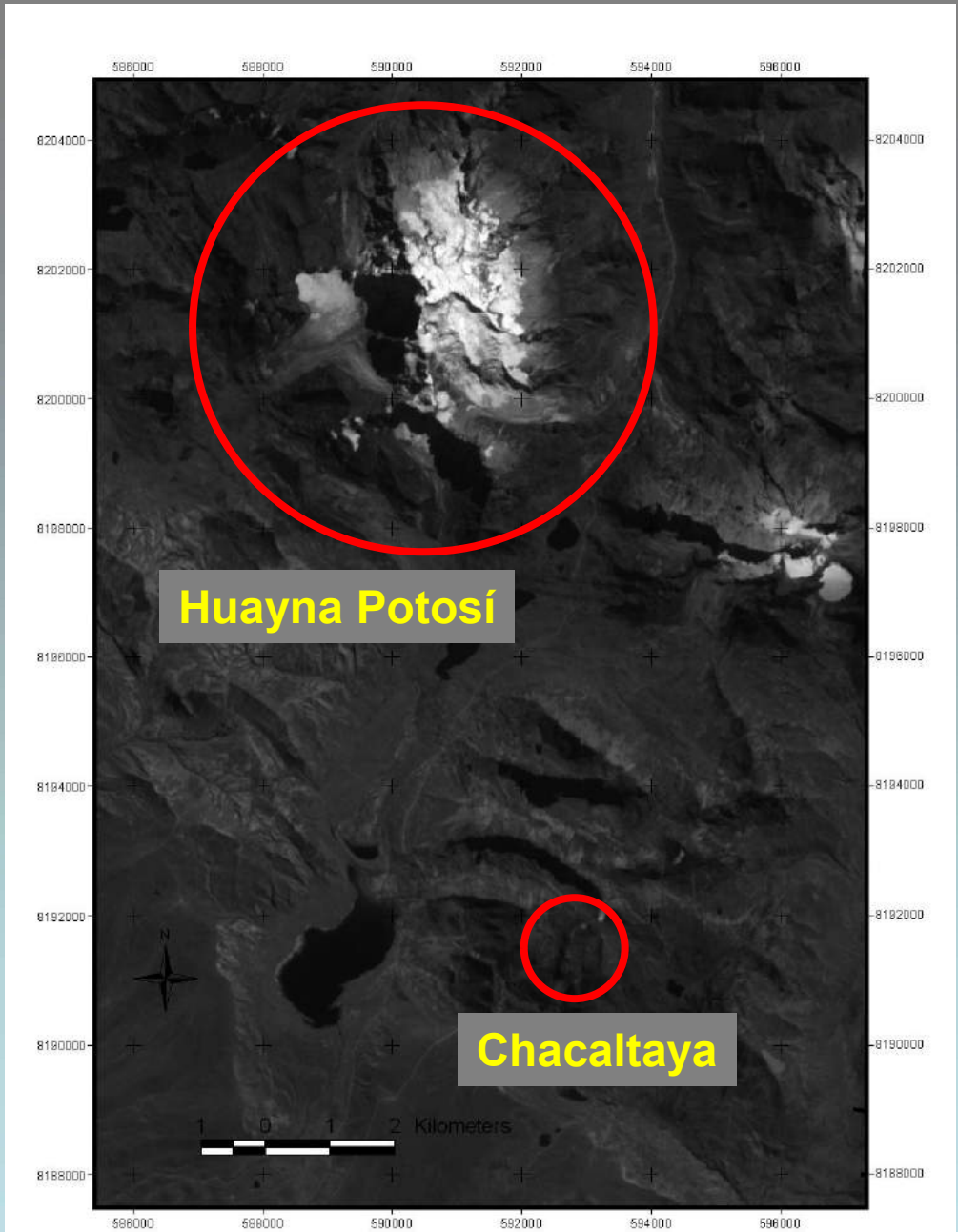


Landsat satellite image

2000

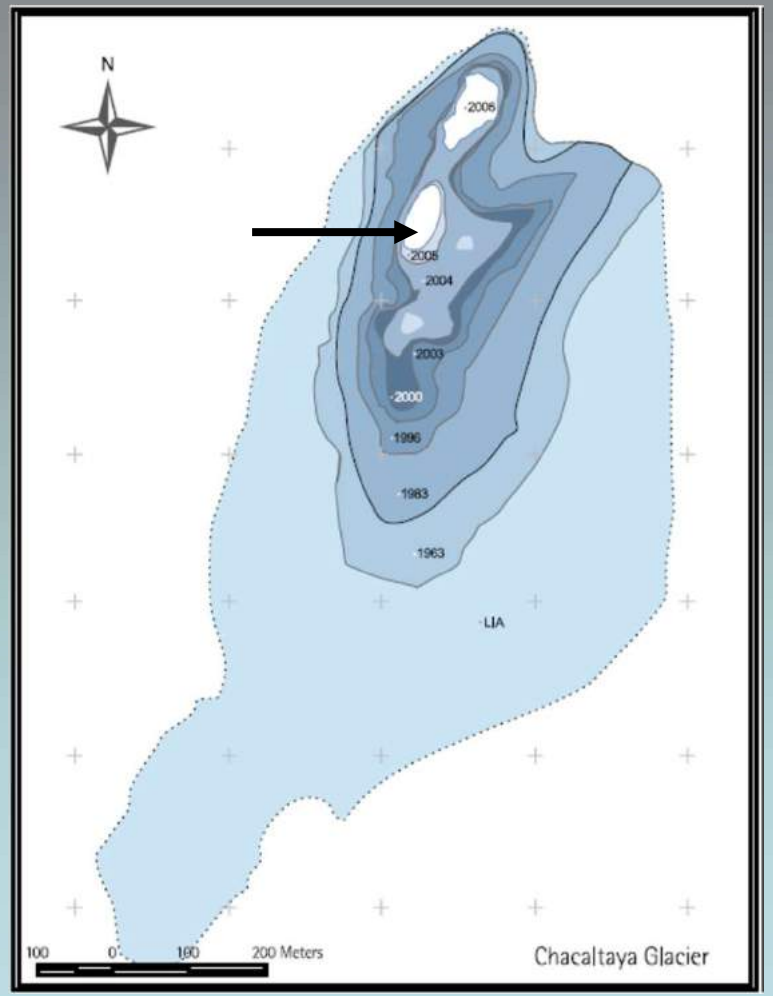


Fuente: (IHH-UMSA) ©



Landsat satellite image

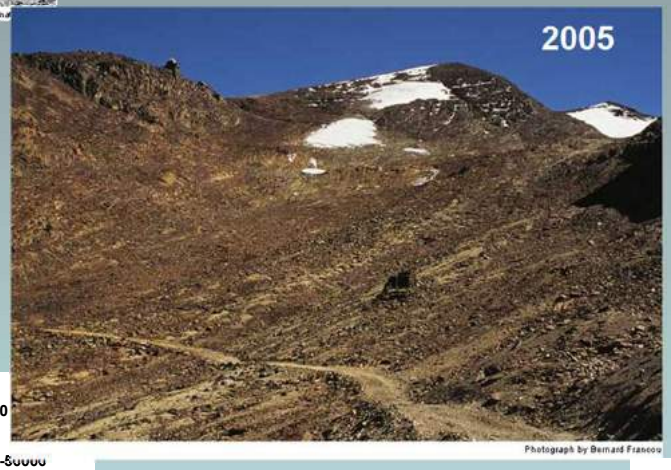
2009



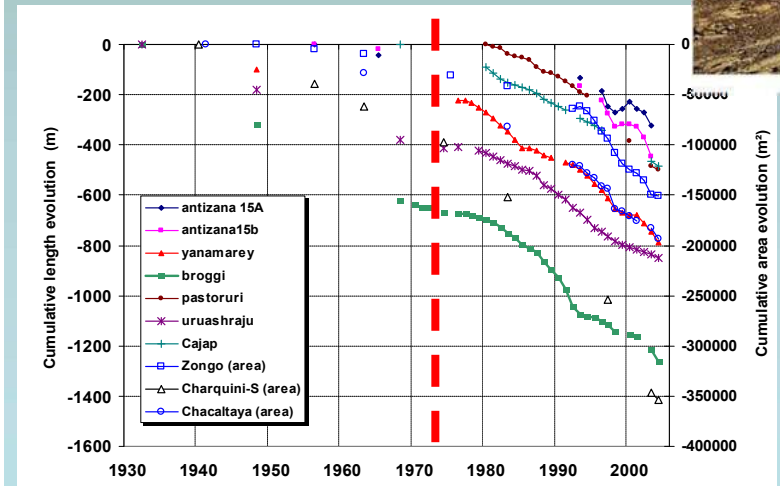
Fuente: (IHH-UMSA) ©

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

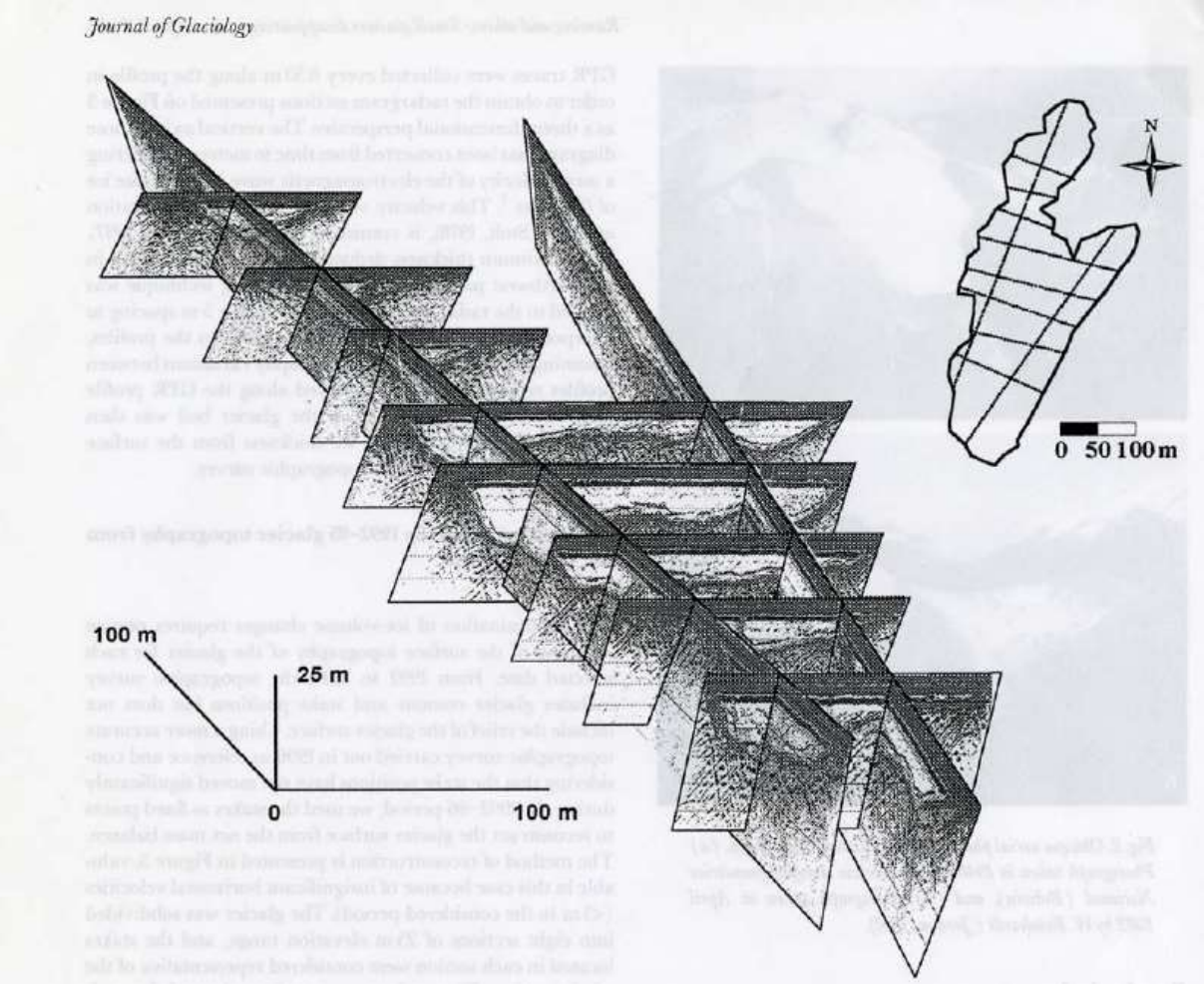


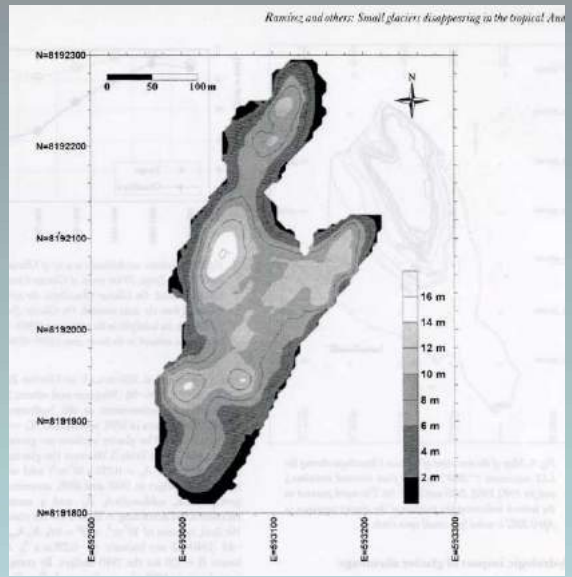
Photos:
B.Francou (IRD)©
E.Ramirez (IHH-UMSA) ©



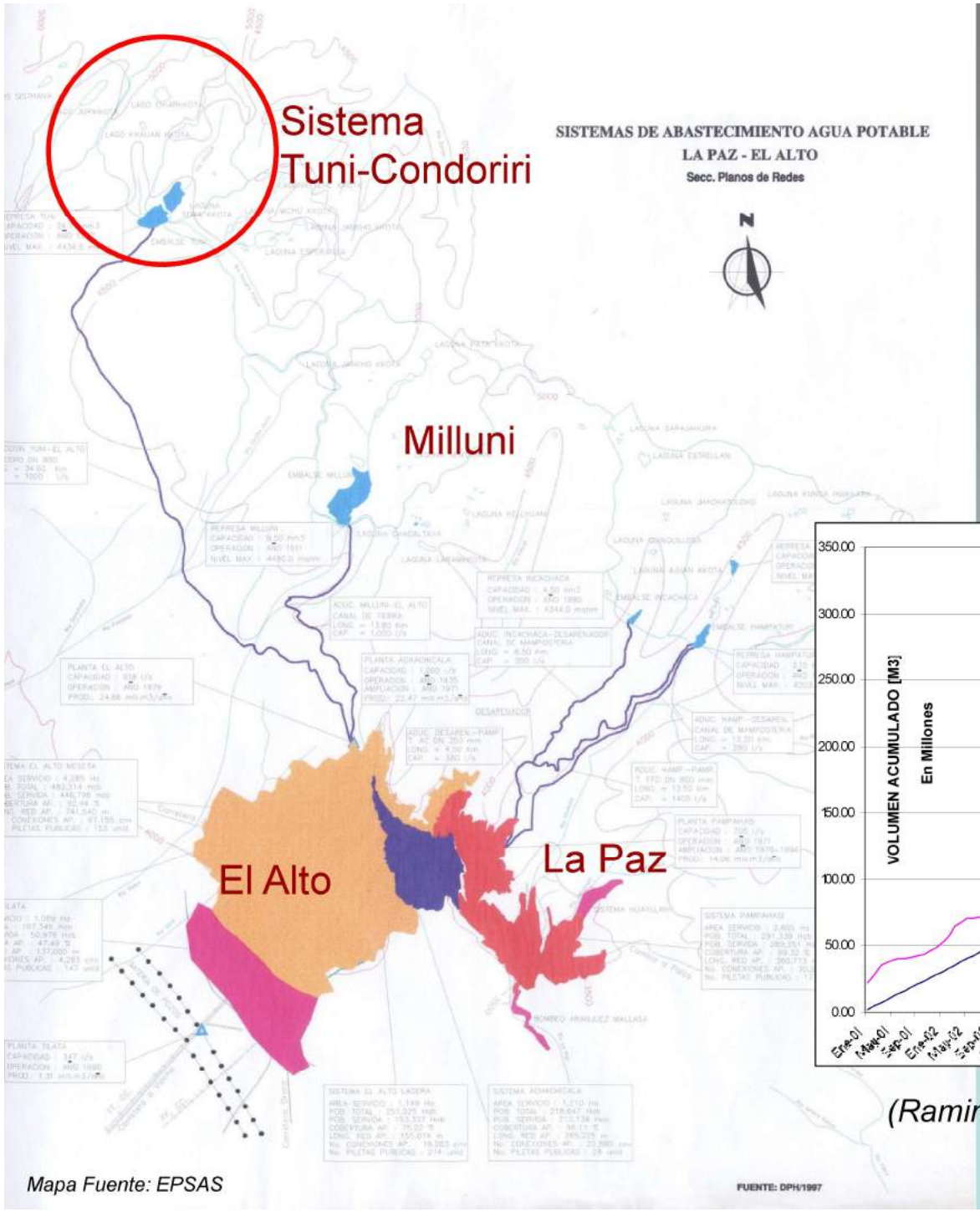
Ramirez et al., 2001; Journal of Glaciology

El caso del Glaciar Chacaltaya

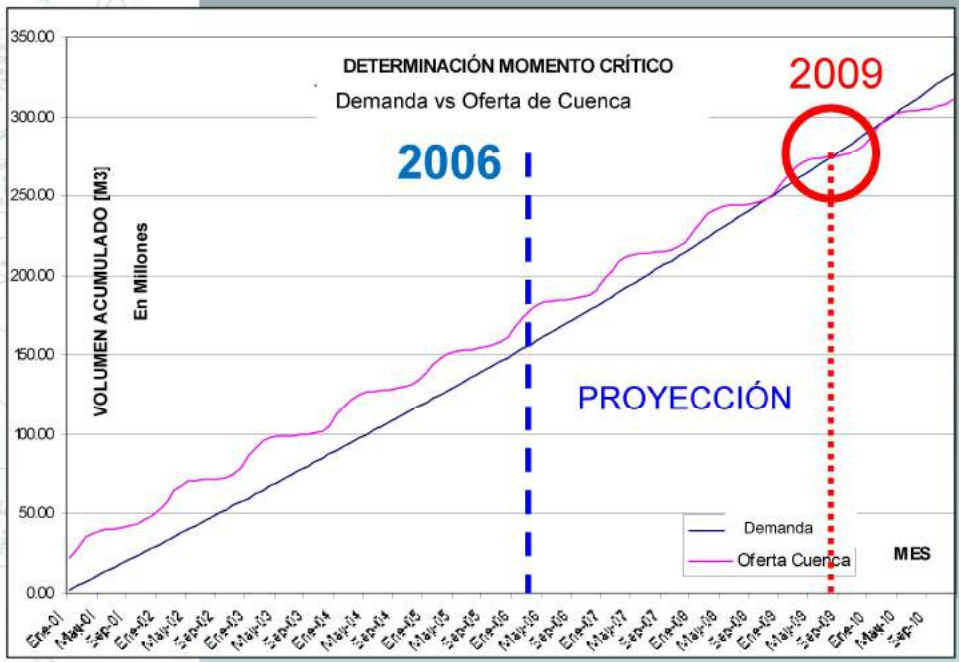




Fuente: Ramírez et al., 2003, *Journal of Glaciology*

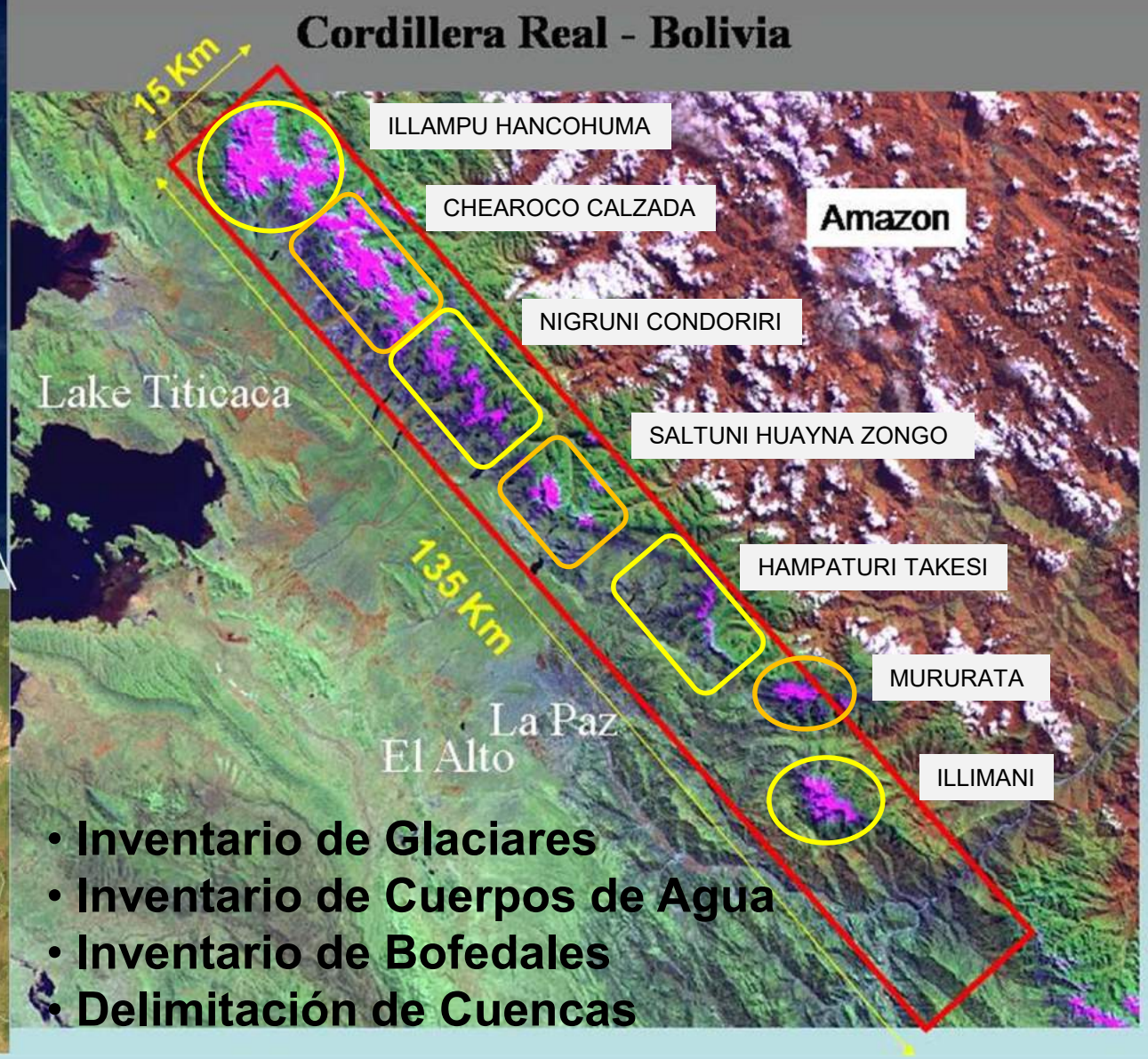


Mapa Fuente: EPSAS



(Ramirez & Olmos, 2006)

OBJETIVOS



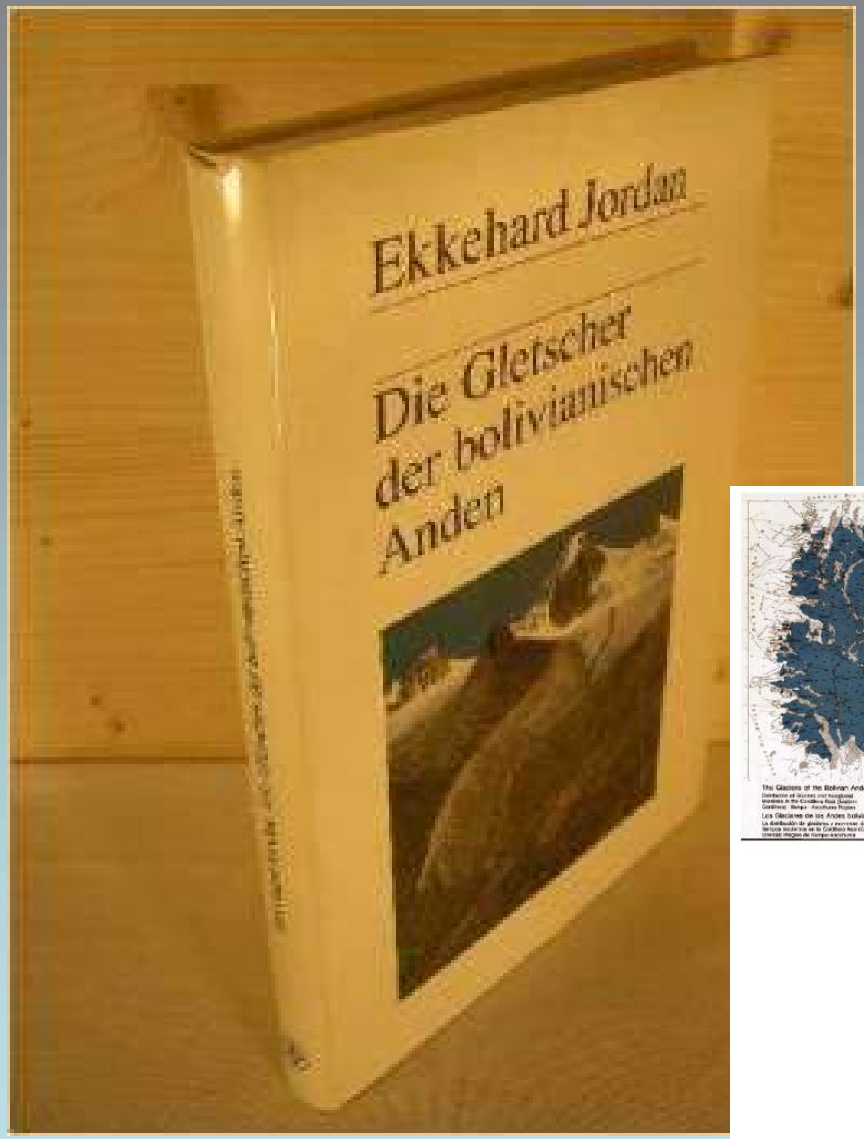
- **Inventario de Glaciares**
- **Inventario de Cuerpos de Agua**
- **Inventario de Bofedales**
- **Delimitación de Cuencas**

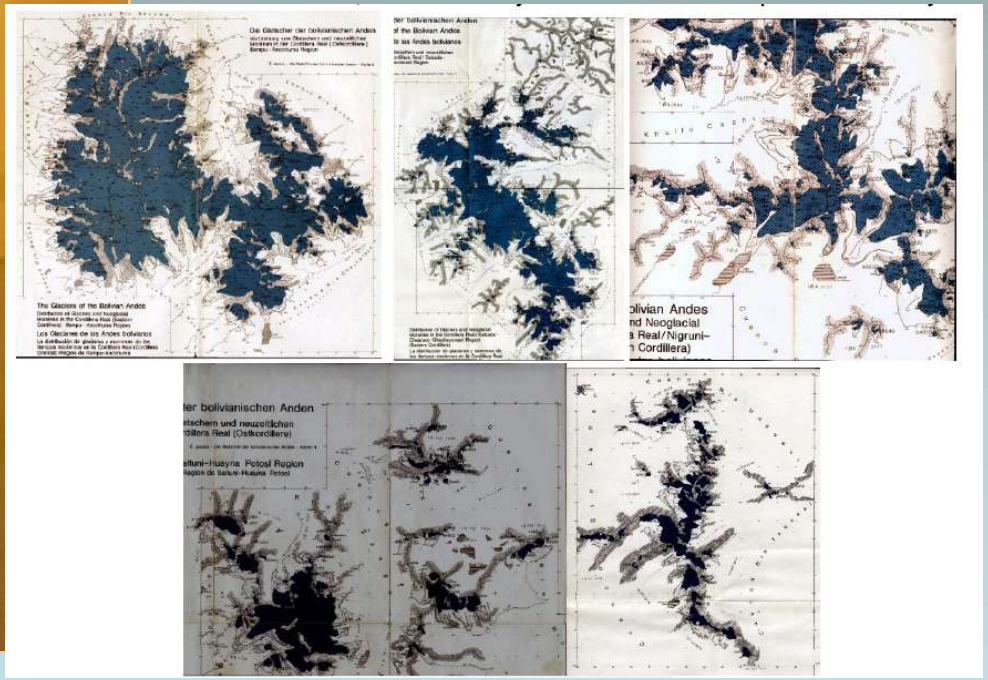
Foto: E.Ramírez ©

Foto: E.Ramírez ©

Foto: E.Ramírez ©

El Primer Inventario Nacional de Glaciares

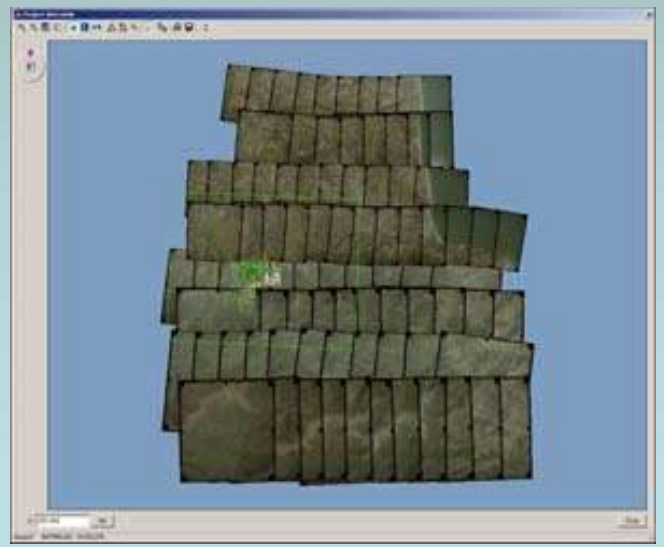


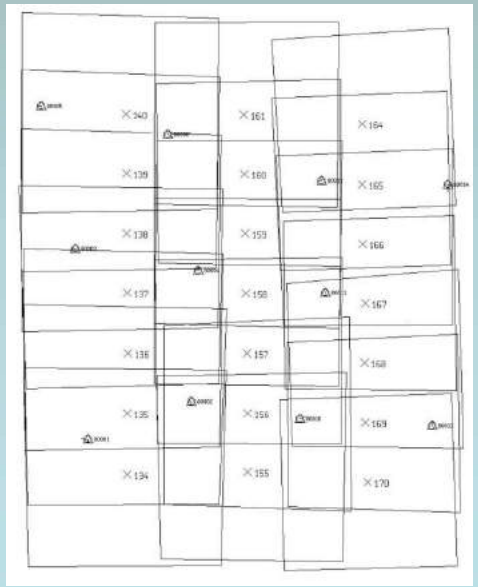


Fuente: Jordan, 1991

Limitantes para la elaboración de inventarios Glaciares mediante vuelos fotogramétricos

- Excesivo **costo** de un vuelo fotogramétrico.
- **Cobertura espacial** insuficiente de vuelos fotogramétricos anteriores.
- Vuelos desactualizados.
- **Temporalidad** de vuelos no homogénea.
- Alturas, escalas y direcciones de vuelo no homogéneas.
- Excesiva **cantidad de fotografías aéreas** para el proceso de aerotrinagulación y colocación de **puntos de apoyo** en campo.

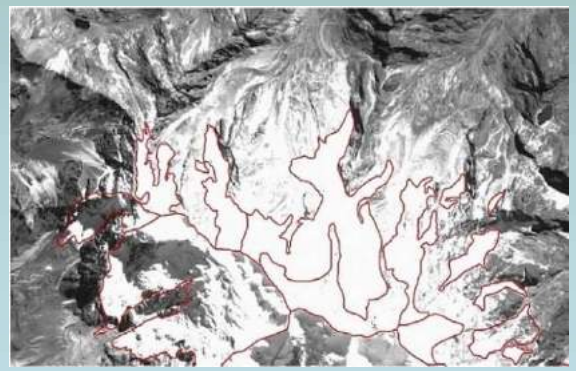




Limitantes para la elaboración de inventarios glaciares mediante imágenes satelitales convencionales

- Baja **resolución espacial** para una delimitación precisa en glaciares de pequeña extensión (< 1km^2).

- Ambigüedad en la delimitación usando 2D



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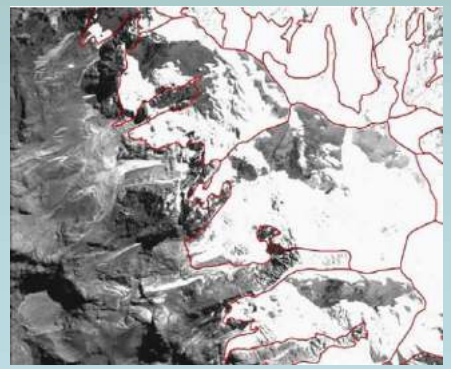
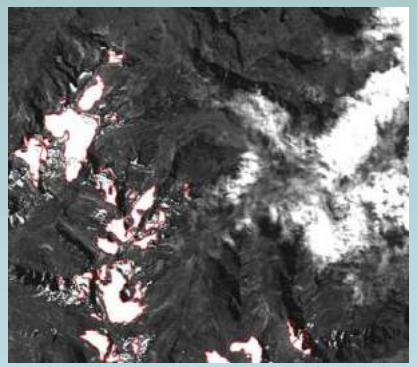


Sombra



Nubosidad

ALOS Satellite
Japan Aerospace Exploration Agency
(JAXA) Tsukuba Space Center - Japan

PRAA

COMUNIDAD ANDINA

BANCO MUNDIAL

2009 - 2012

PROYECTO REGIONAL ANDINO DE ADAPTACION AL CAMBIO CLIMÁTICO

(Bolivia, Colombia, Ecuador y Perú)

JAXA Japan Aerospace Exploration Agency

MMAyA Ministerio de Medio Ambiente y Agua

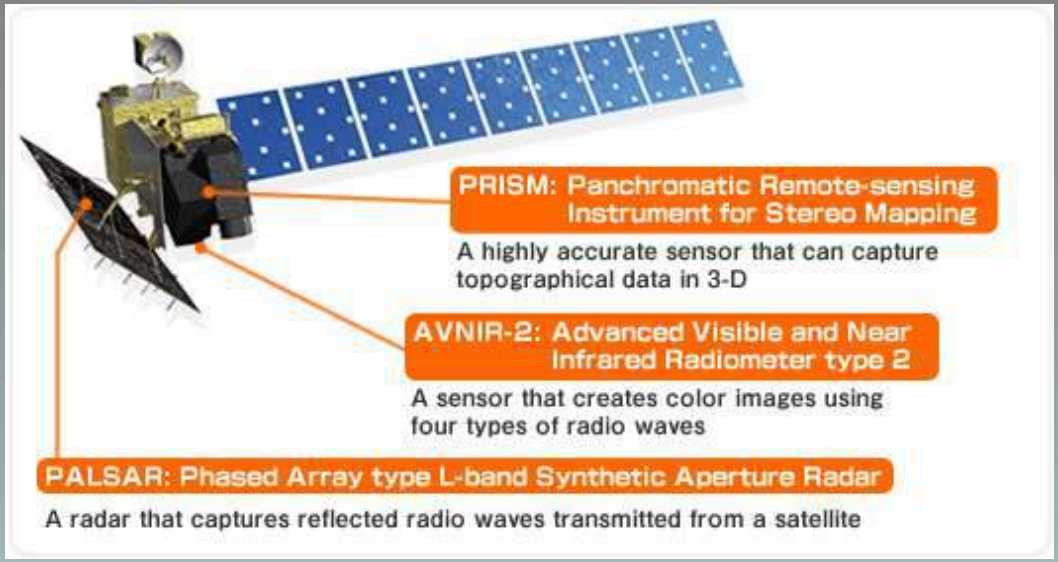
Universidad Mayor de San Andrés

ihh

INCT da CRIOSFERA

El Instrumento Tecnológico

2006



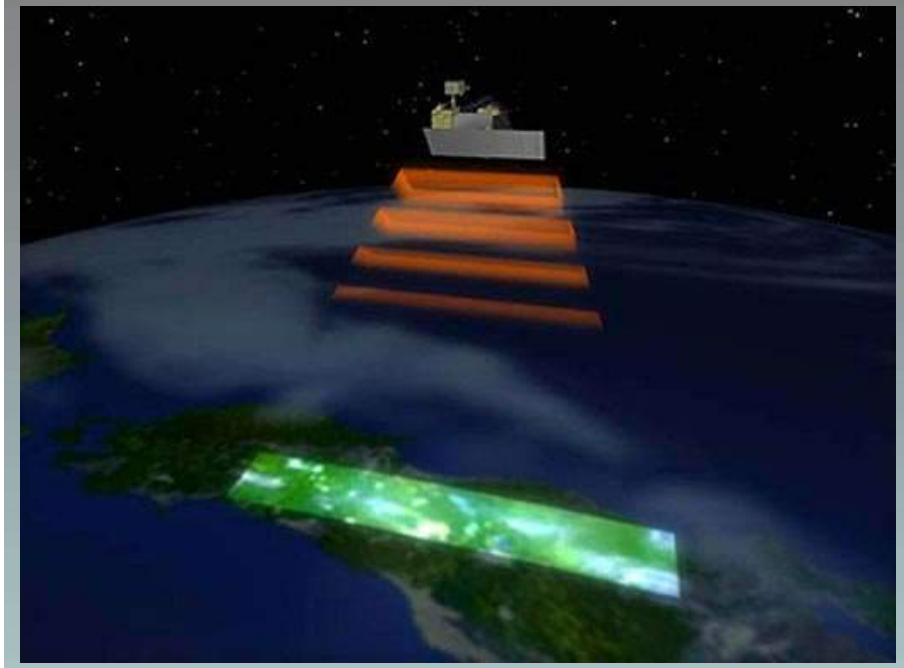
PRISM

Banda	Región de longitud de onda	Resolución (m)
PAN	0,52-0,77 µm	2,5

AVNIR-2

Banda	Región de longitud de onda	Resolución (m)
1	0,42-0,50 µm (azul)	10
2	0,52-0,60 µm (verde)	10
3	0,61-0,69 µm (rojo)	10
4	0,76-0,89 µm (cerca-IR)	10

PALSAR



El sensor **PALSAR**, es un sensor activo de RADAR, con una resolución variable de 10 a 100 metros. Este sensor permite captar escenas a través de las nubes, bruma, niebla o humo, tanto de día como de noche. Por lo tanto, es ideal para realizar estudios en áreas tropicales o polares. También son utilizadas en la geología, movimientos en masa, aplicaciones marítimas, entre otros.

Modalidad PALSAR	Resolución	Polarización	Corredor
FBS Fine Resolución	10m	Single HH	70Km
FBD Fine Resolución	20m	Dual HH+HV	70Km
SL Scan SAR	100m	Single HH	350Km
P Fine Polarimetría	30m	HH+HV+VH+VV	30Km

ALOS:

Advanced Land Observing Satellite
(Satélite Avanzado de Obervación Terrestre)

Sensor Tri-Dimensional ***PRISM***
***(*Panchromatic Remote-sensing Instrument for Stereo Mapping)**

PRISM Characteristics	
Number of Bands	1 (Panchromatic)
Wavelength	0.52 to 0.77 micrometers
Number of Optics	3 (Nadir; Forward; Backward)
Base-to-Height ratio	1.0 (between Forward and Backward view)
Spatial Resolution	2.5m (at Nadir)
Swath Width	70km (Nadir only) / 35km (Triplet mode)
S/N	>70
MTF	>0.2
Number of Detectors	28000 / band (Swath Width 70km) 14000 / band (Swath Width 35km)
Pointing Angle	-1.5 to +1.5 degrees (Triplet Mode, Cross-track direction)
Bit Length	8 bits

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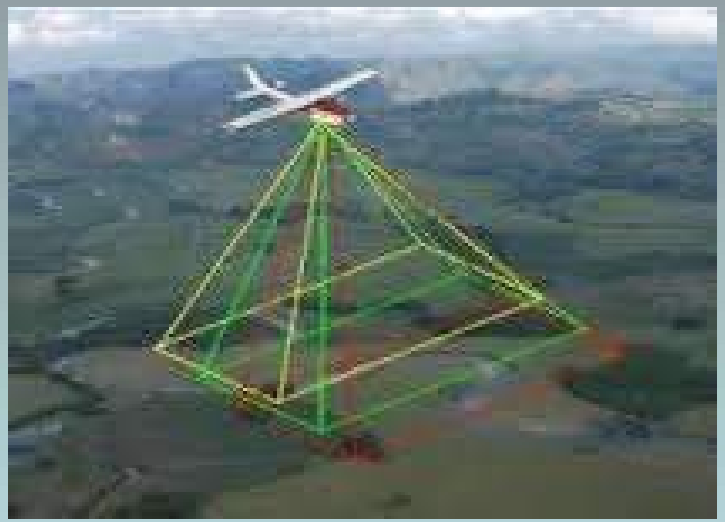

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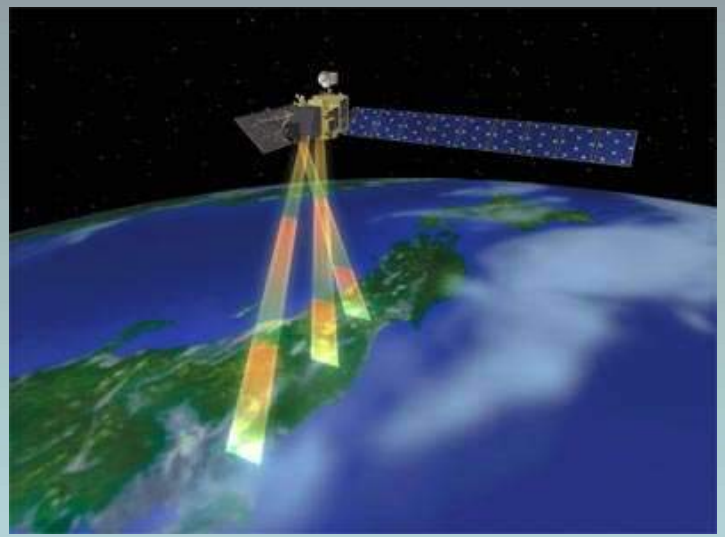

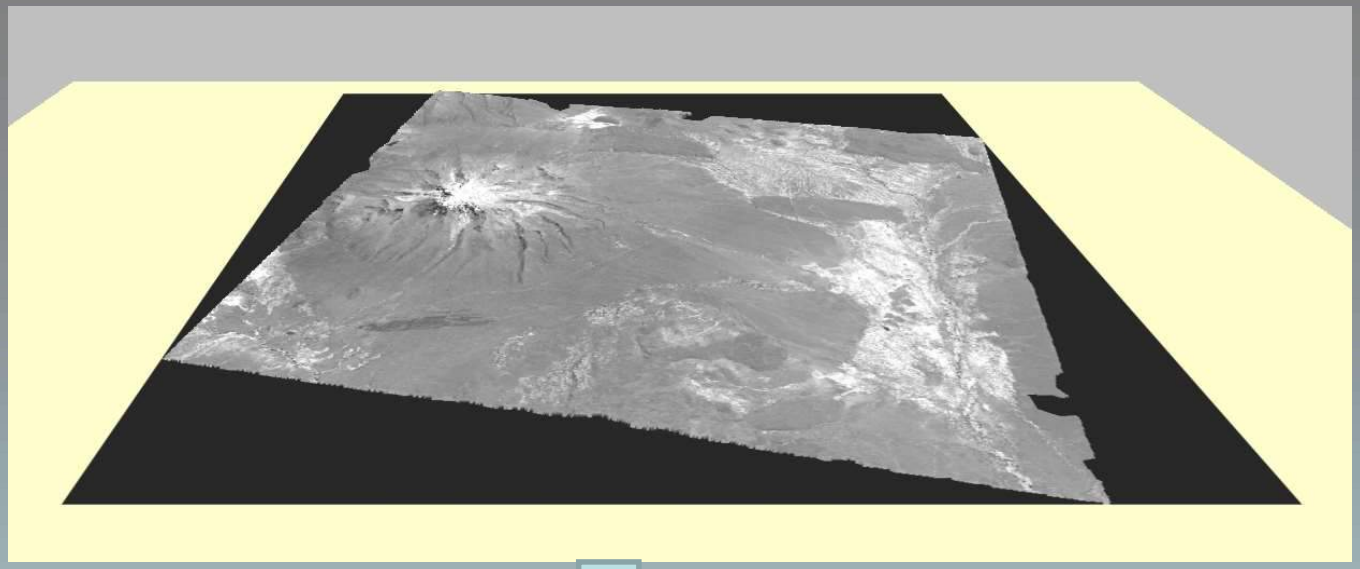

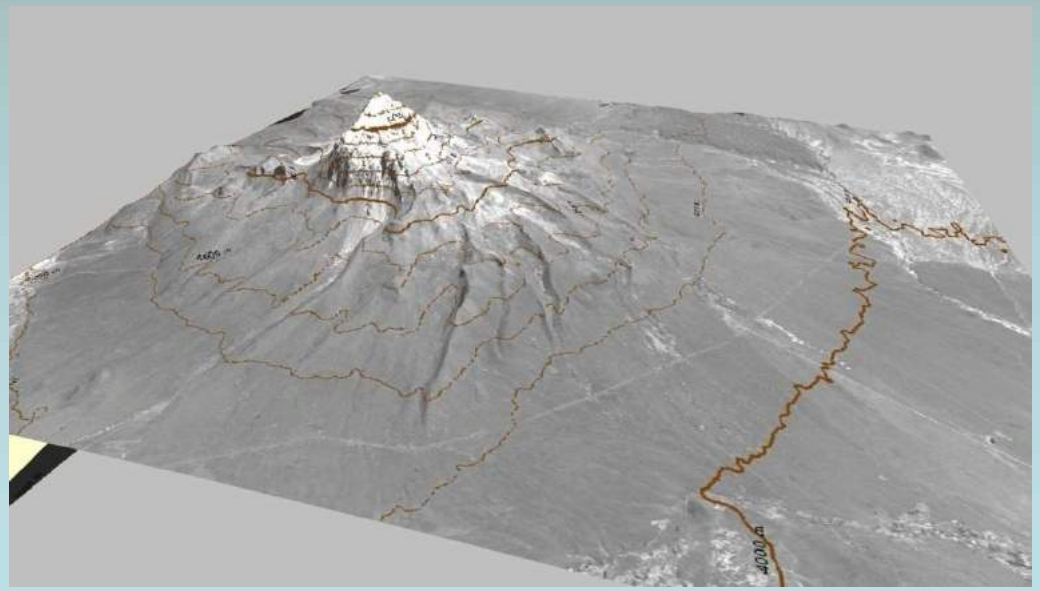

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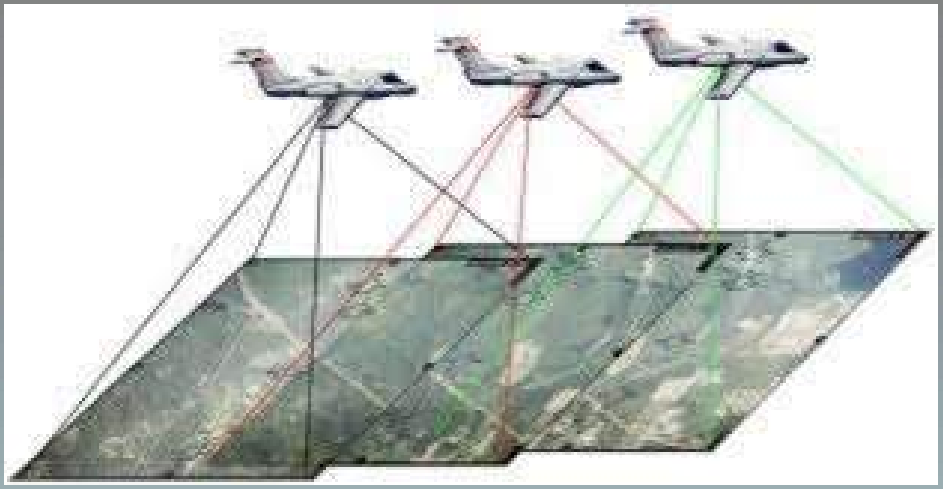
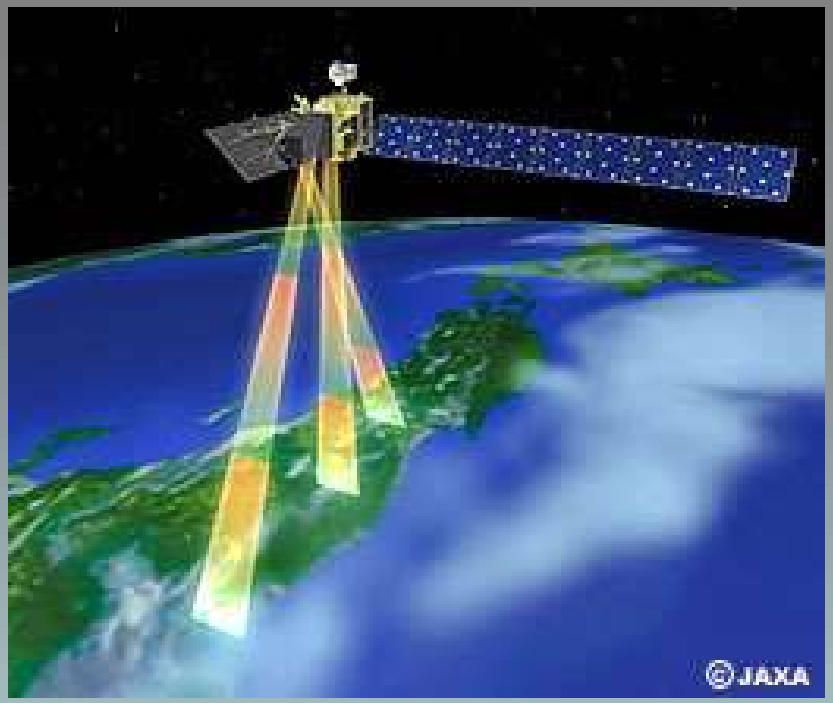
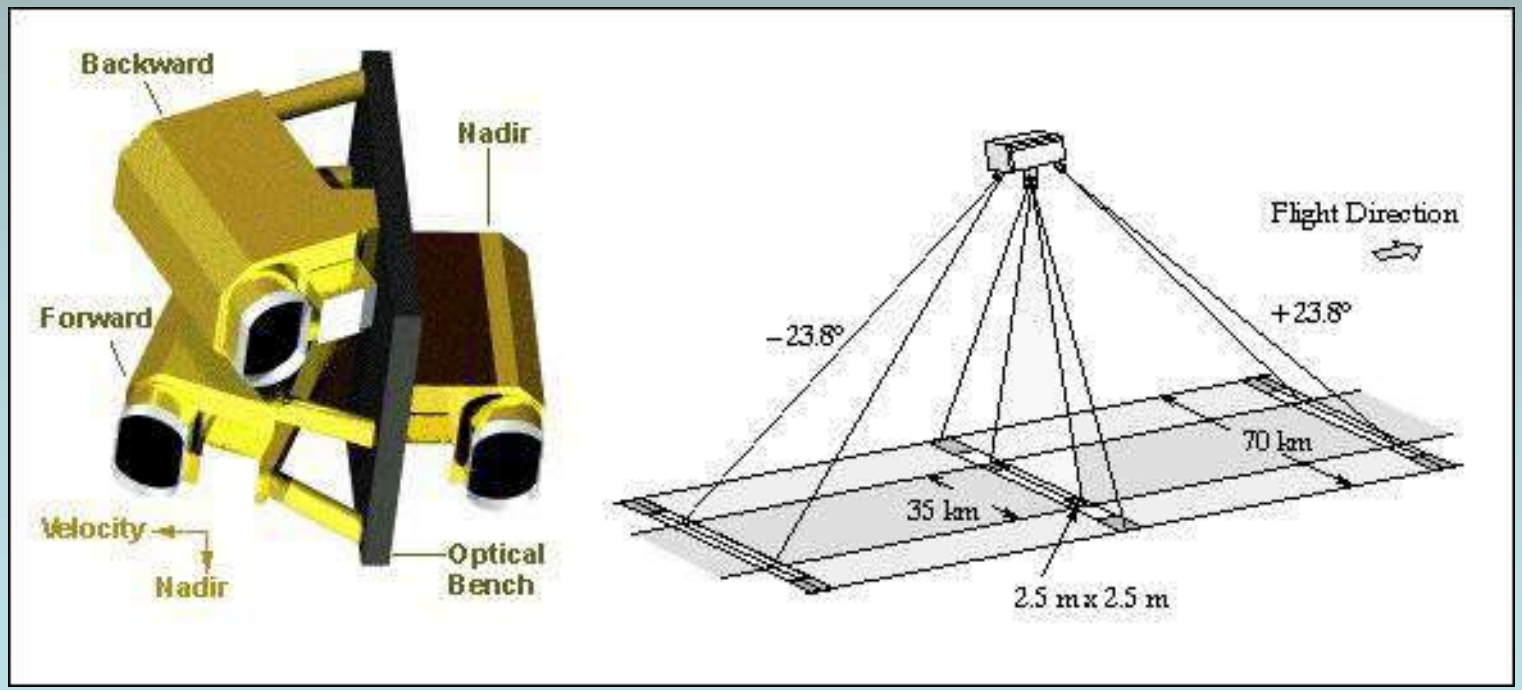
La semejanza en estereoscopía







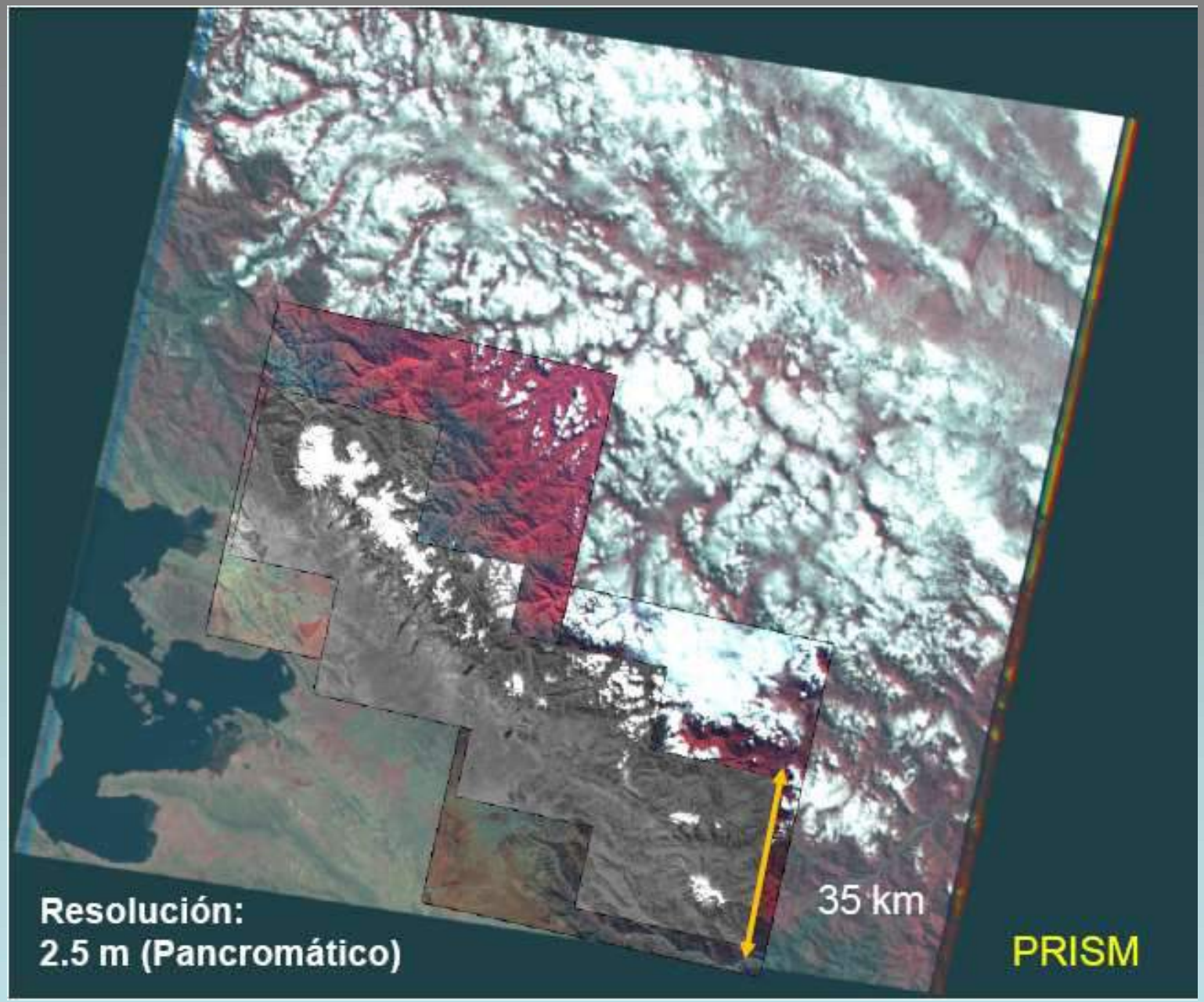

Resolución:
2.5 m (Pancromático)
35 km
PRISM

Figura 7: Punto de Control del Instituto Geográfico Militar de Bolivia (IGM). Denominación del punto: CM-338 – IGM – 1996 (Mina La Unión).

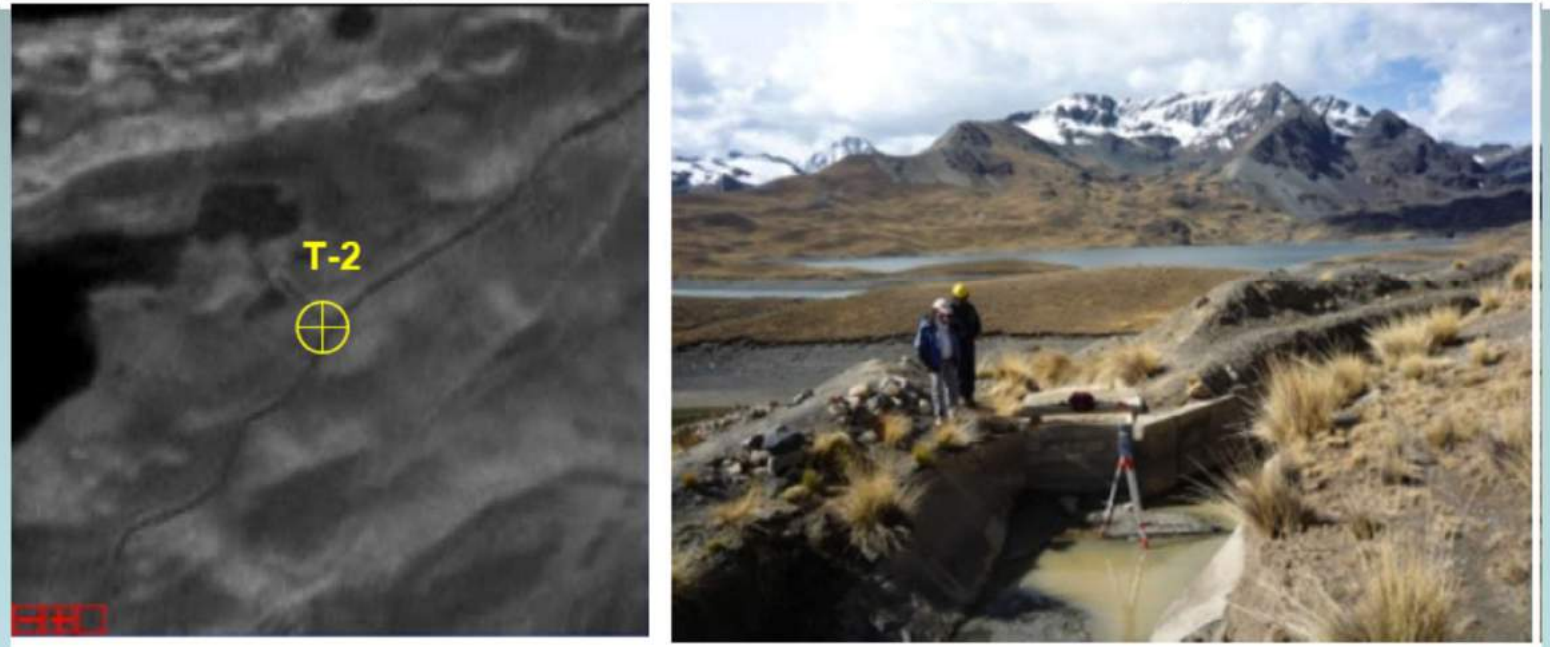


Figura 9: Punto de Control T-2 sobre imagen ALOS y en el terreno.

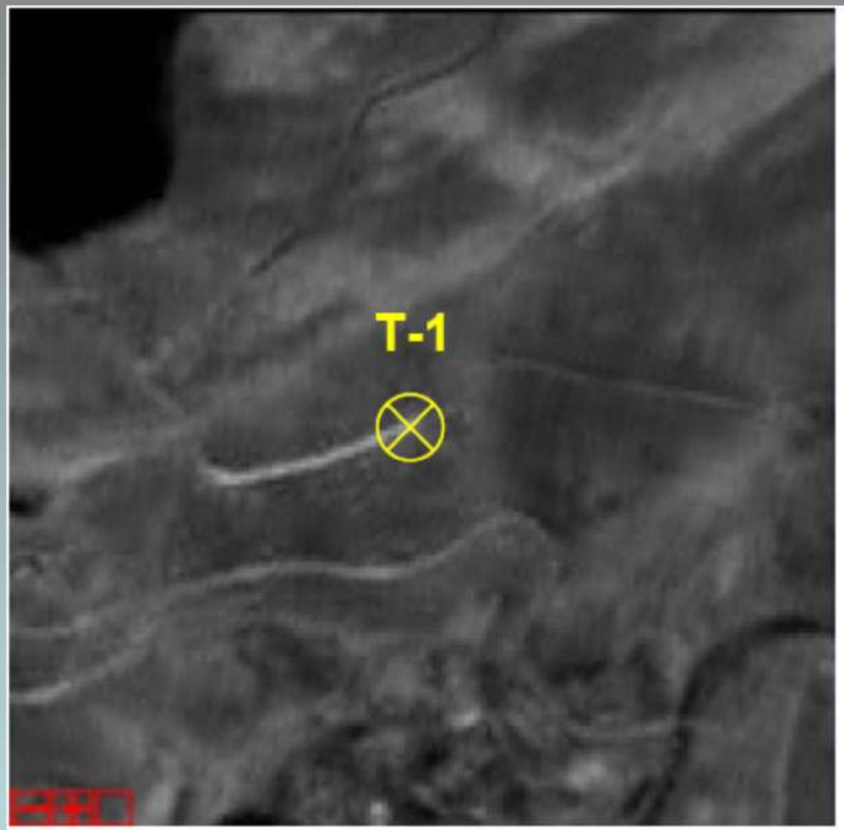


Figura 8: Punto de Control T-1 sobre imagen ALOS y en el terreno.

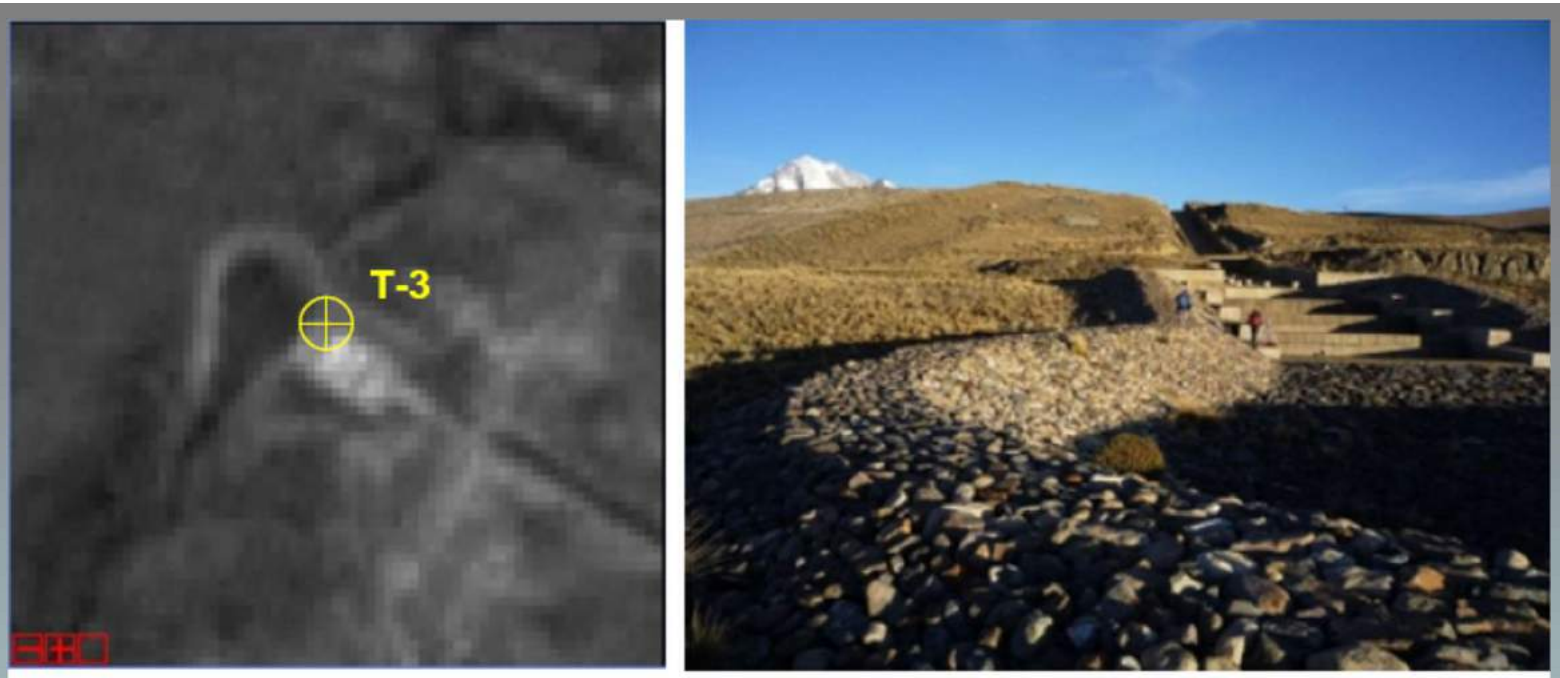


Figura 10: Punto de Control T-3 sobre imagen ALOS y en el terreno.

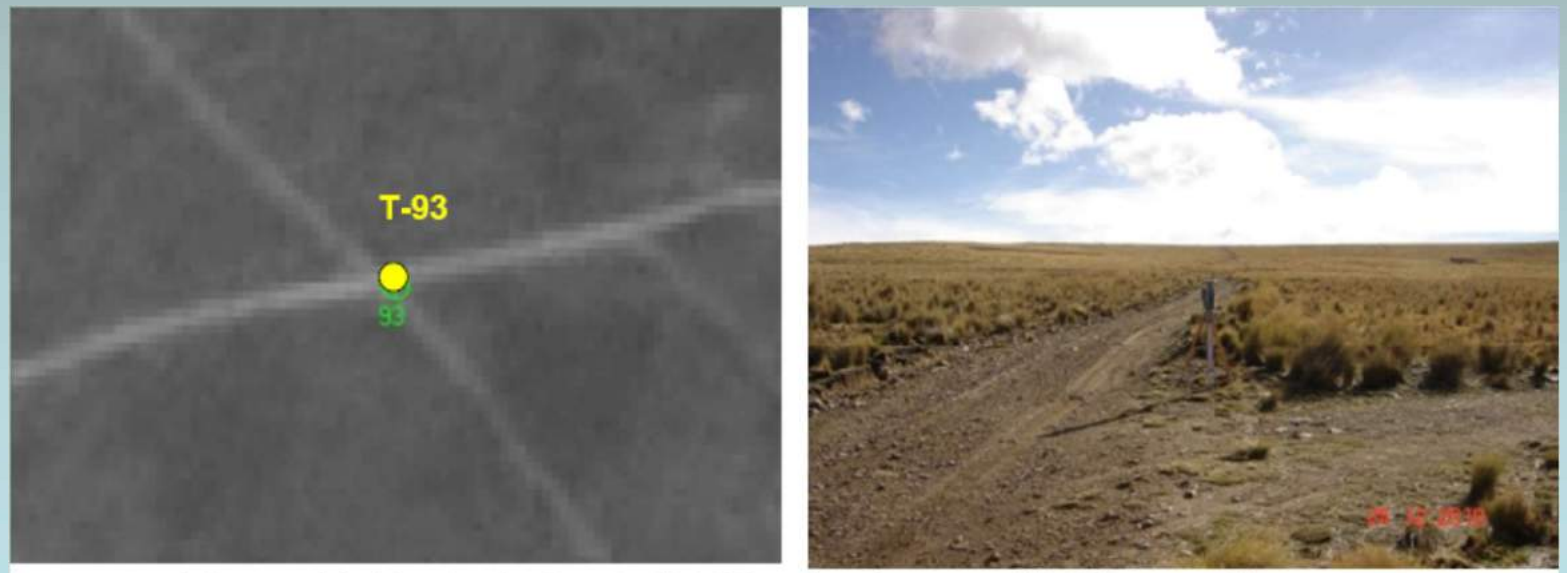


Figura 11: Punto de Control T-93 sobre imagen ALOS y en el terreno.

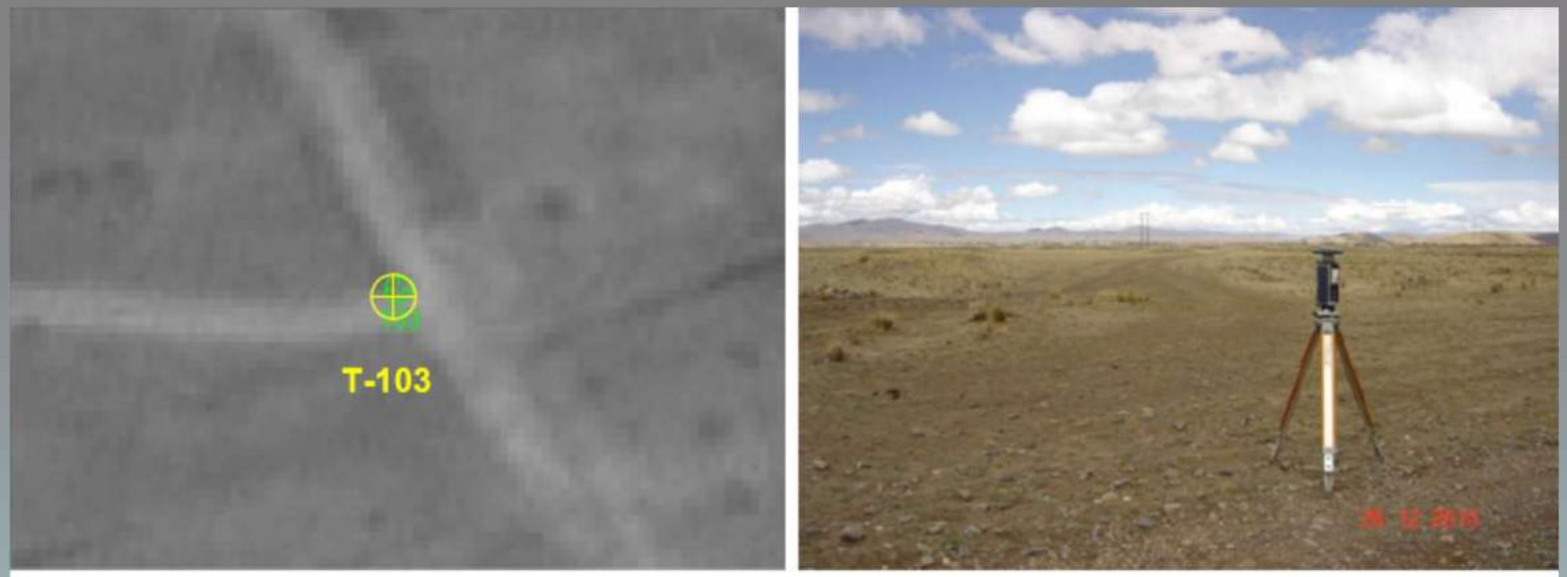


Figura 12: Punto de Control T-103 sobre imagen ALOS y en el terreno.

Figura 12: Punto de Control GCP-3 sobre imagen ALOS y en el terreno.

Antena Base: Sistema SIRGAS (IGM)
Regimiento Ingavi

Fuente: IGM

Antena Móvil: Sistema THALES Z-MAX (IHH-UMSA)

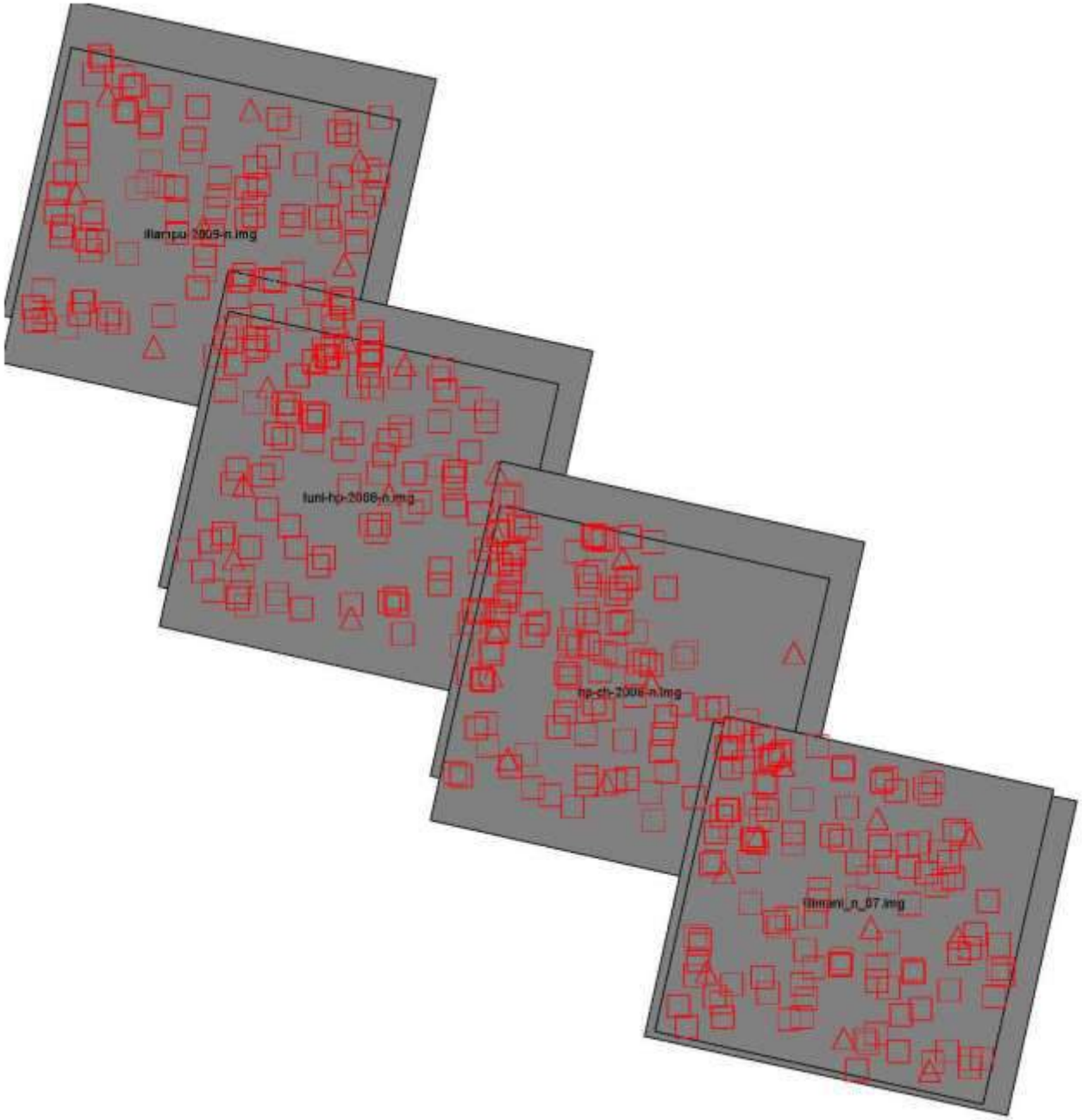
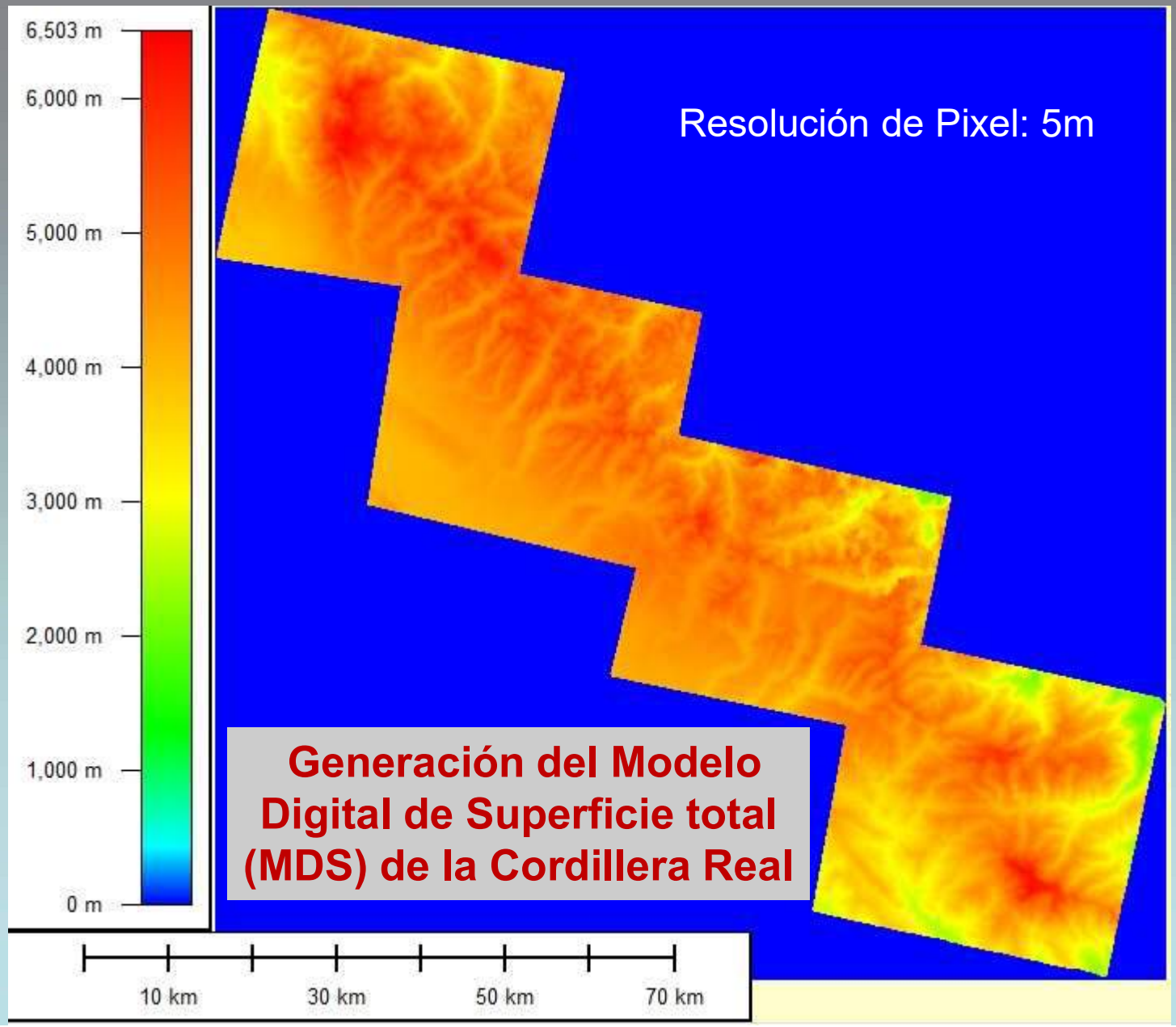


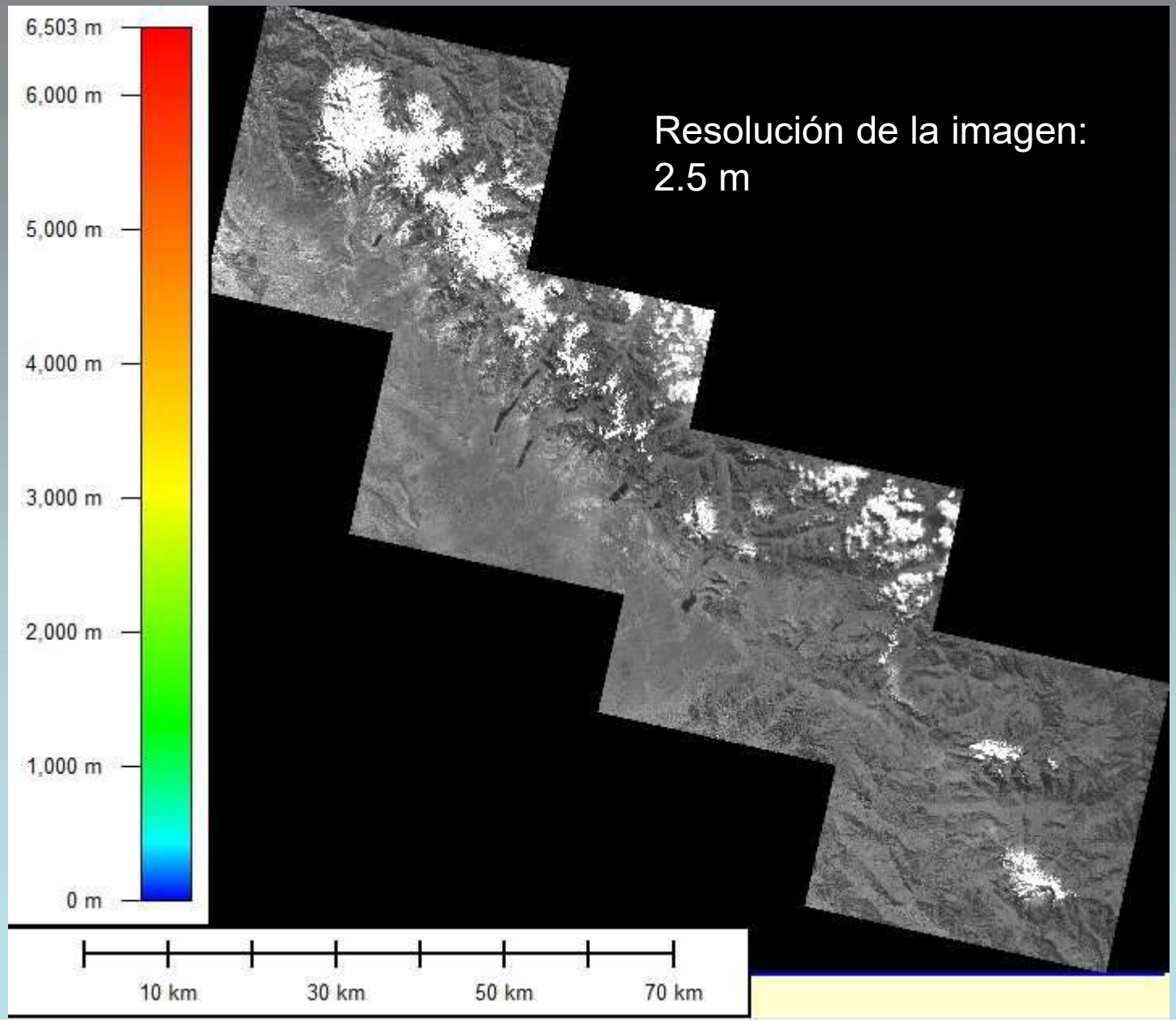
Figura 9.4: Distribución de Puntos de Control y Puntos de enlace para los cuatro estéreo modelos fotogramétricos que cubren la "Cordillera Real de Bolivia".

RESULTADOS



Generación del Modelo Digital de Superficie total (MDS) de la Cordillera Real

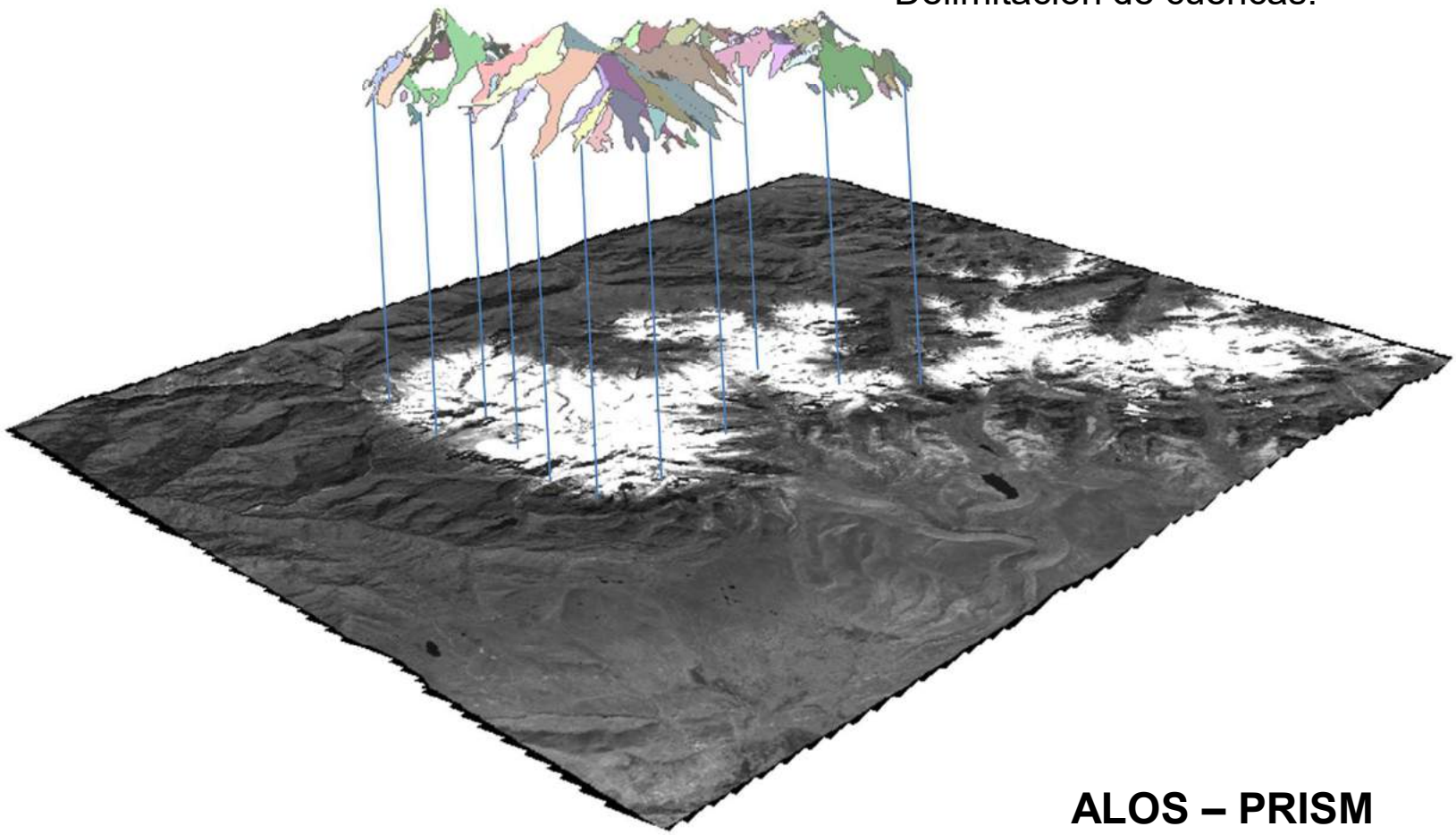
Generación del Modelo Fotogramétrico de la Cordillera Real



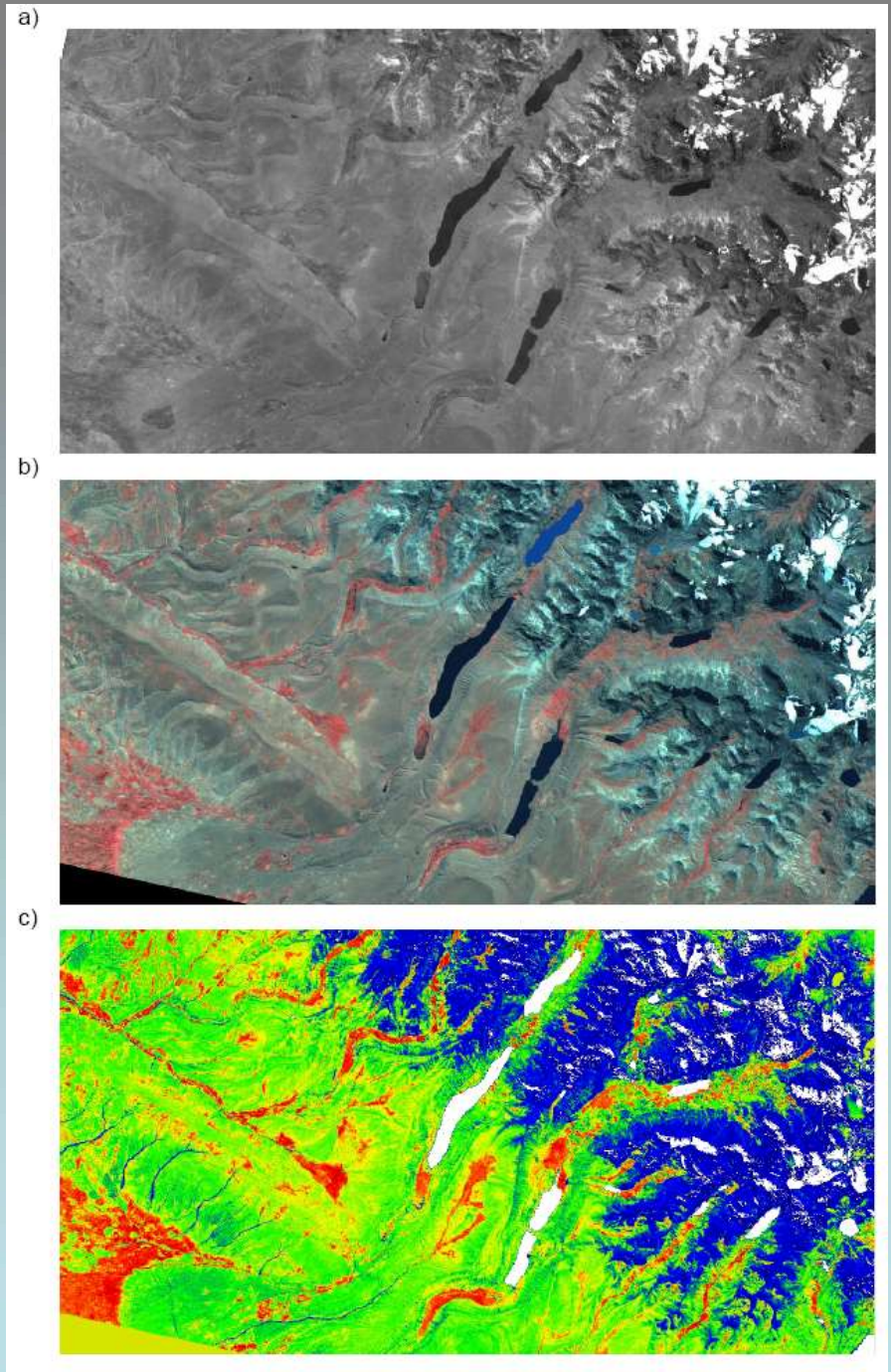
Resolución de la imagen:
2.5 m

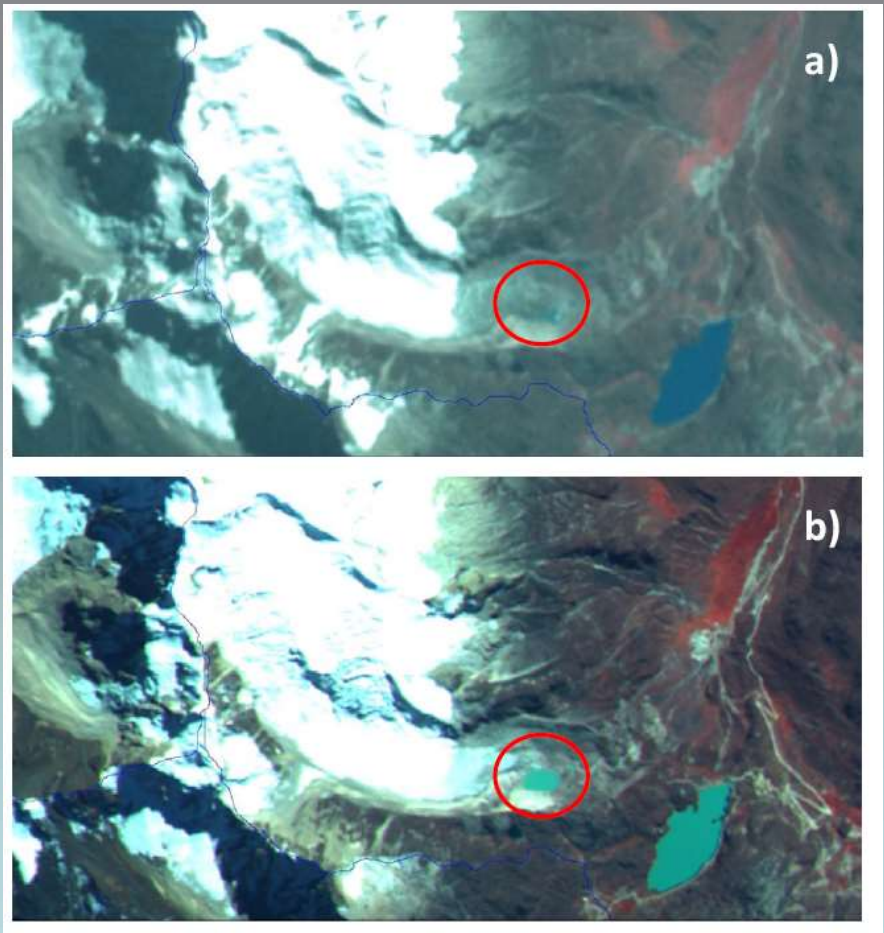
DIGITALIZACIÓN 3D

-Digitalización 3D de contornos glaciares.
- Digitalización 3D de lagunas glaciares.
- Digitalización 3D de Bofedales
- Delimitación de cuencas.

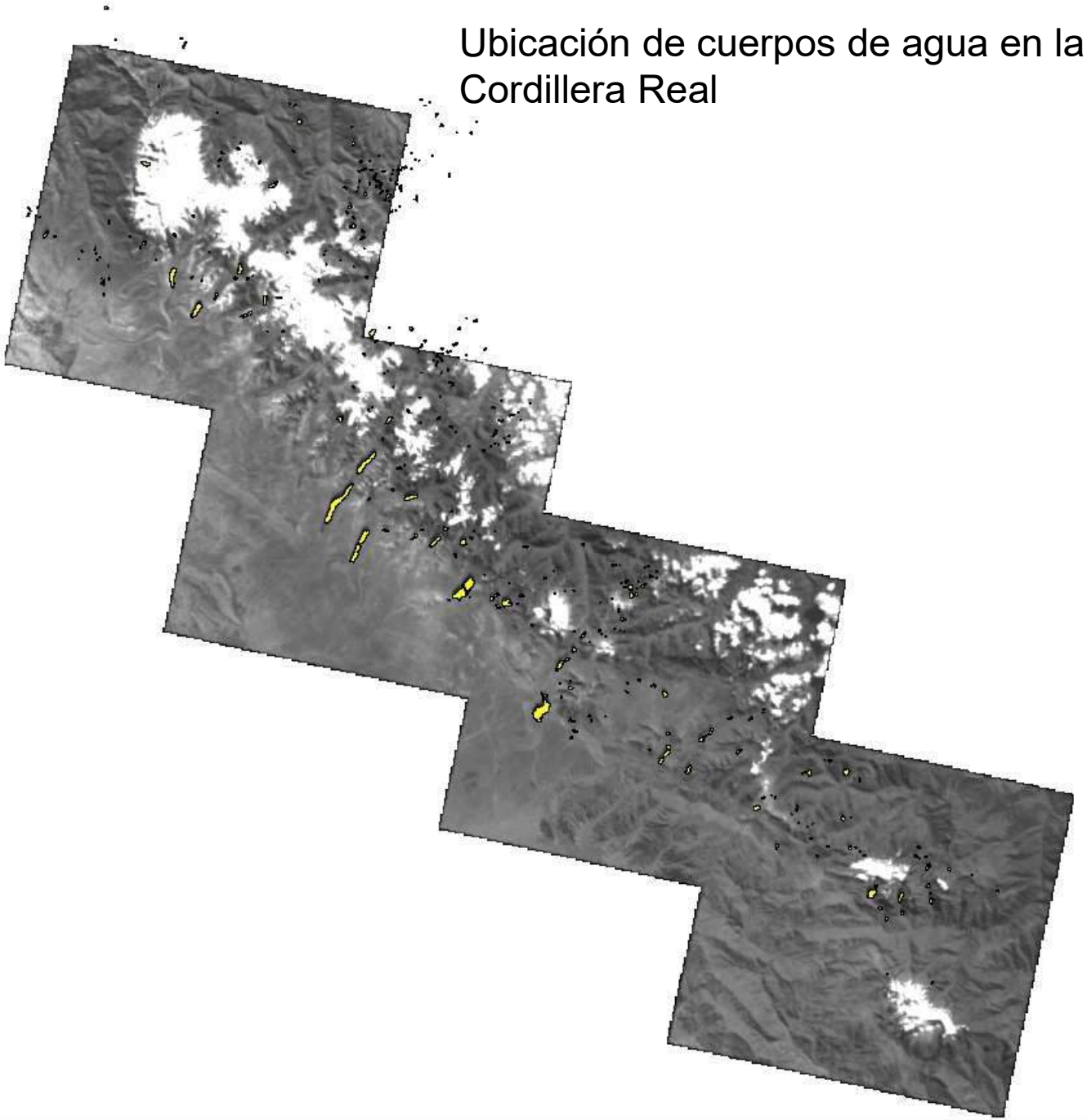


ALOS – PRISM
Illampu - 2009

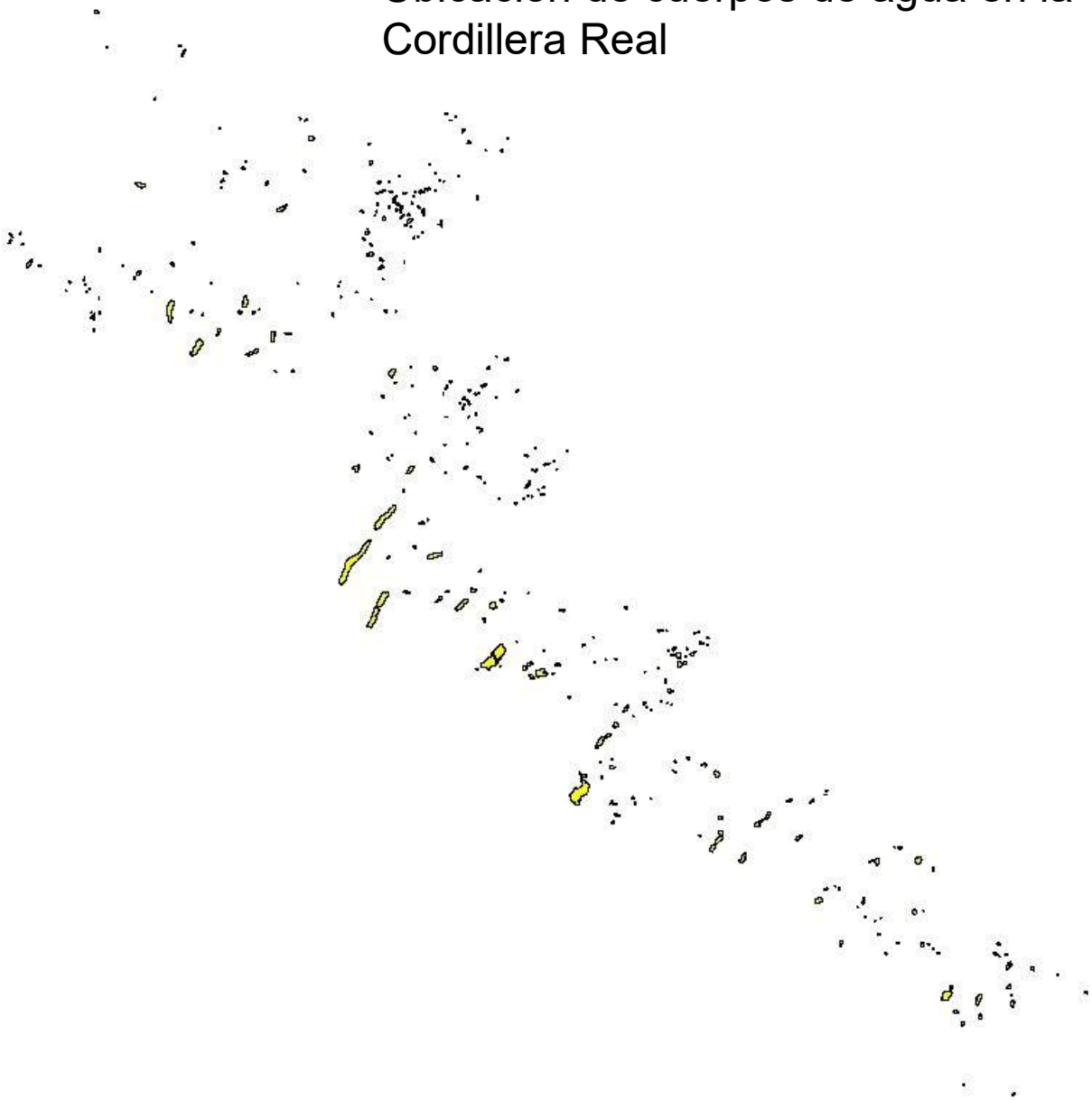

a)
b)
c)

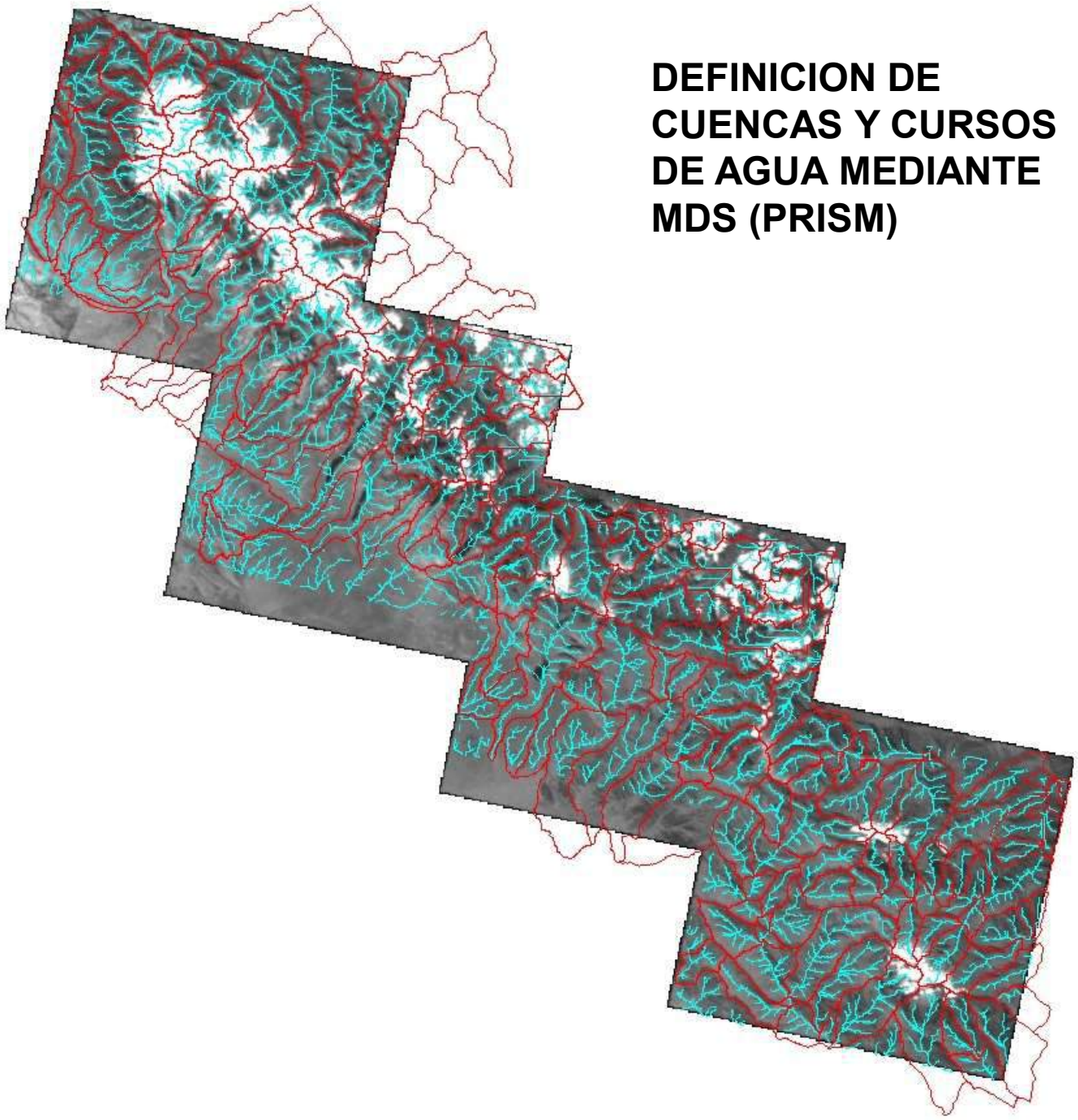

a)
b)

Ubicación de cuerpos de agua en la Cordillera Real

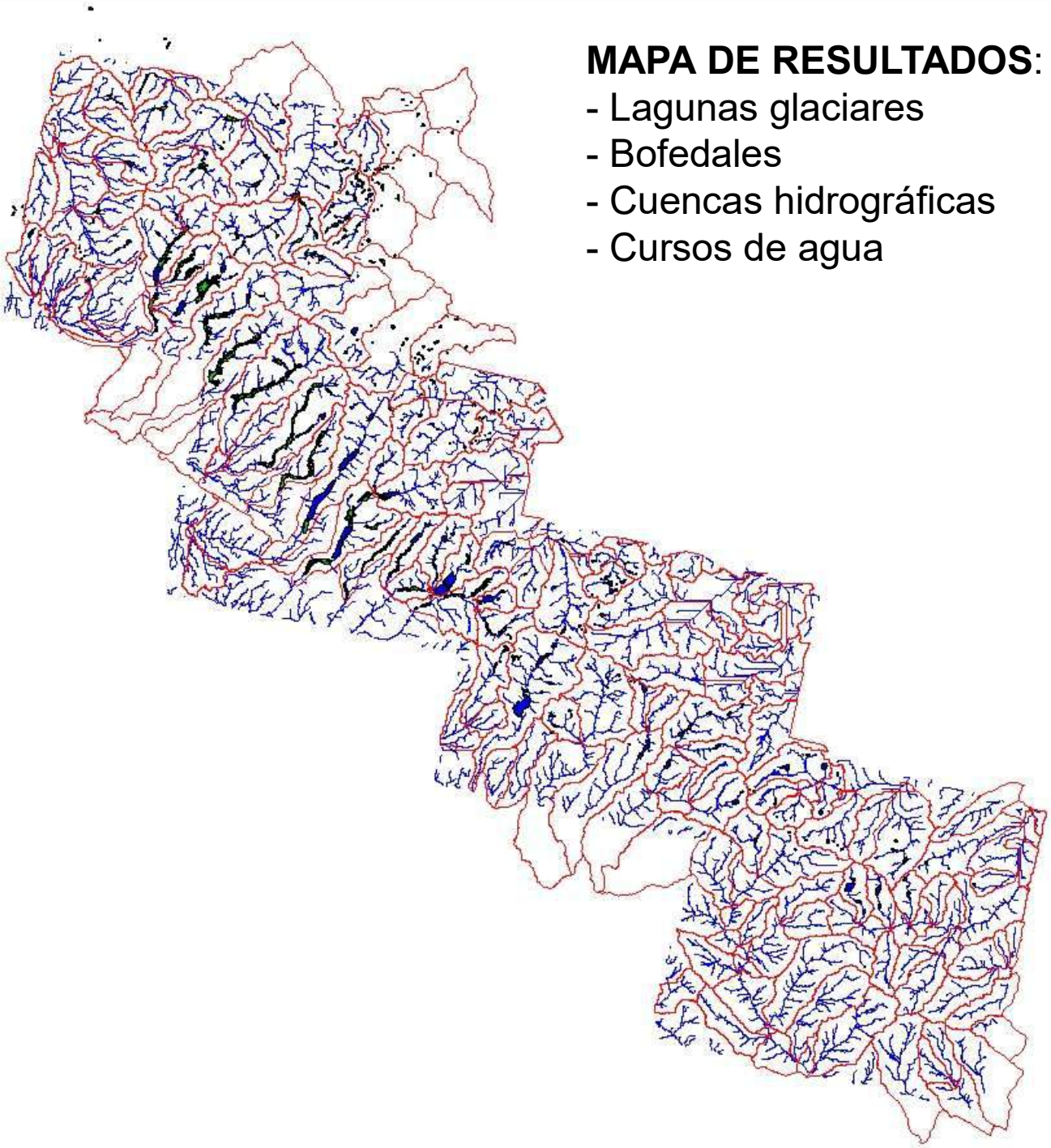


Ubicación de cuerpos de agua en la Cordillera Real





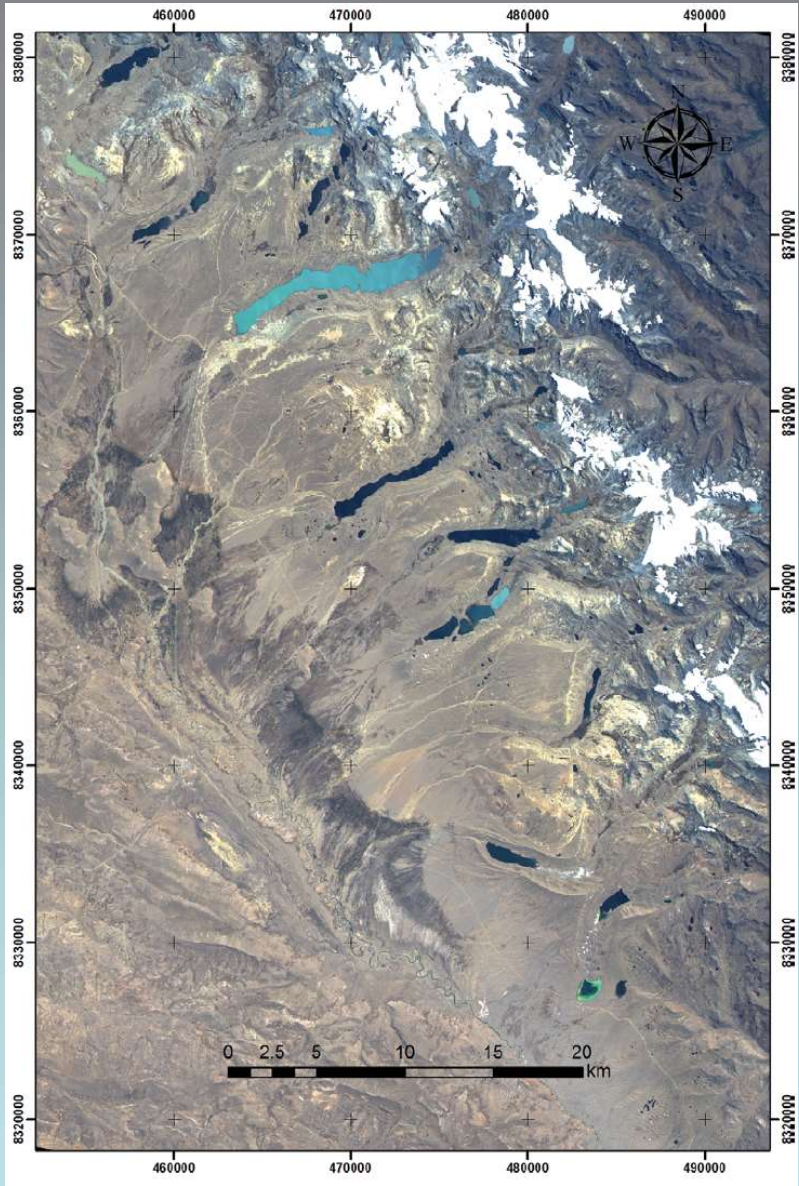
DEFINICION DE CUENCAS Y CURSOS DE AGUA MEDIANTE MDS (PRISM)

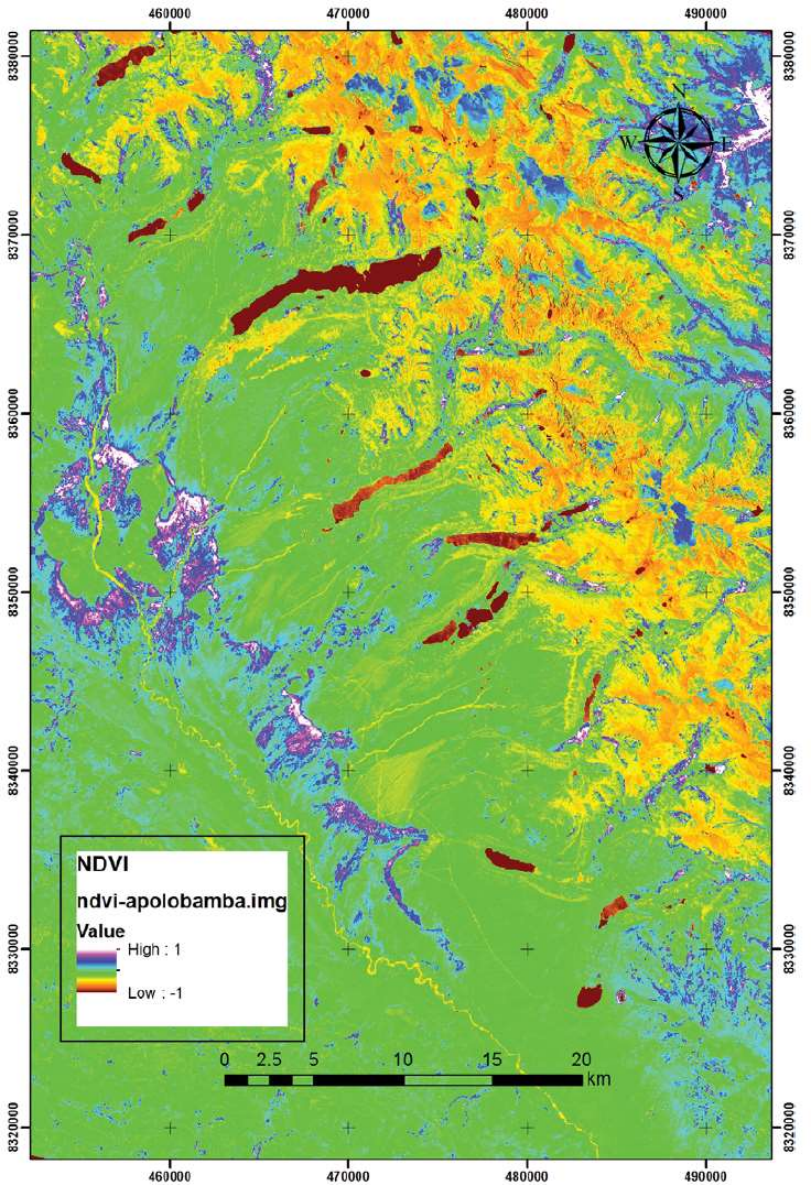


MAPA DE RESULTADOS:

- Lagunas glaciares
- Bofedales
- Cuencas hidrográficas
- Cursos de agua

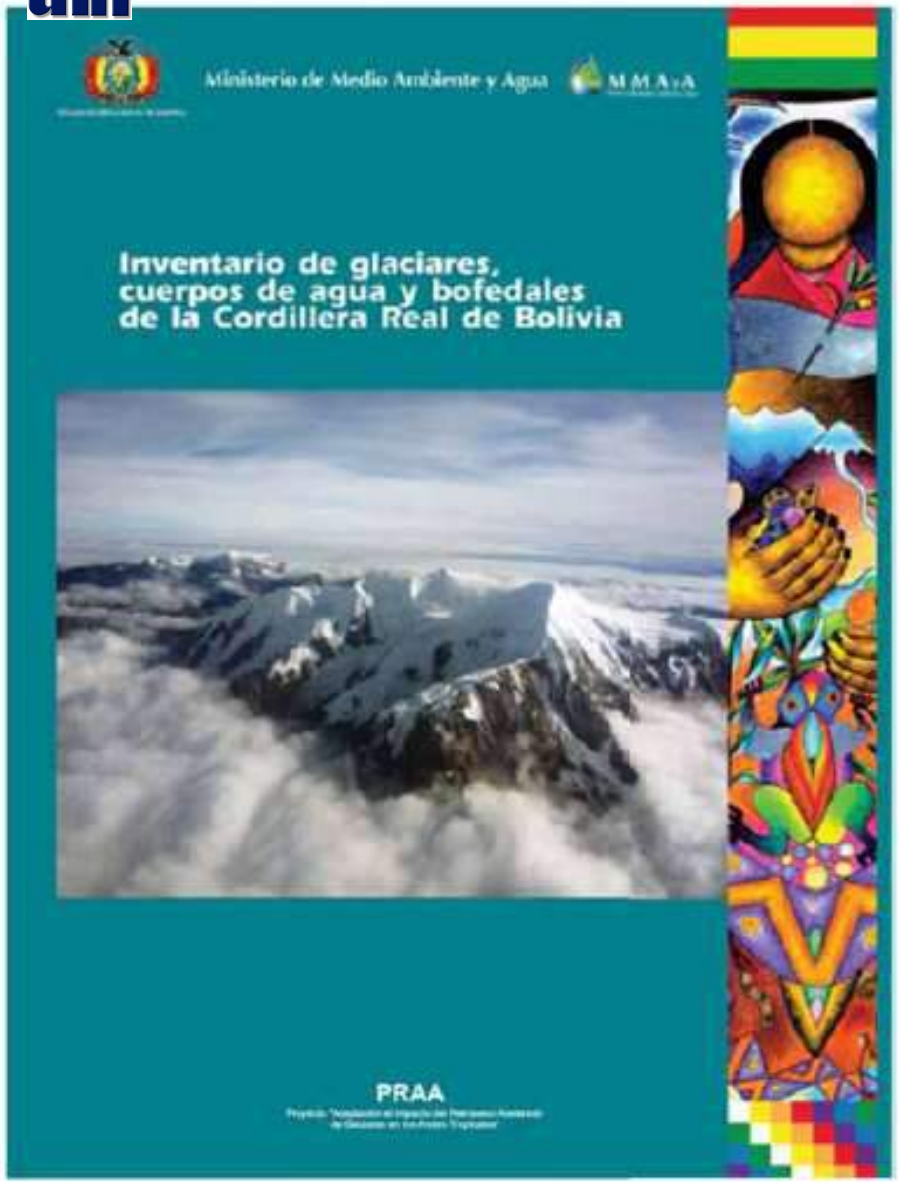
Identificación de Cuerpos de Agua y Bofedales
Mediante el sensor multiespectral AVNIR-2 (ALOS)



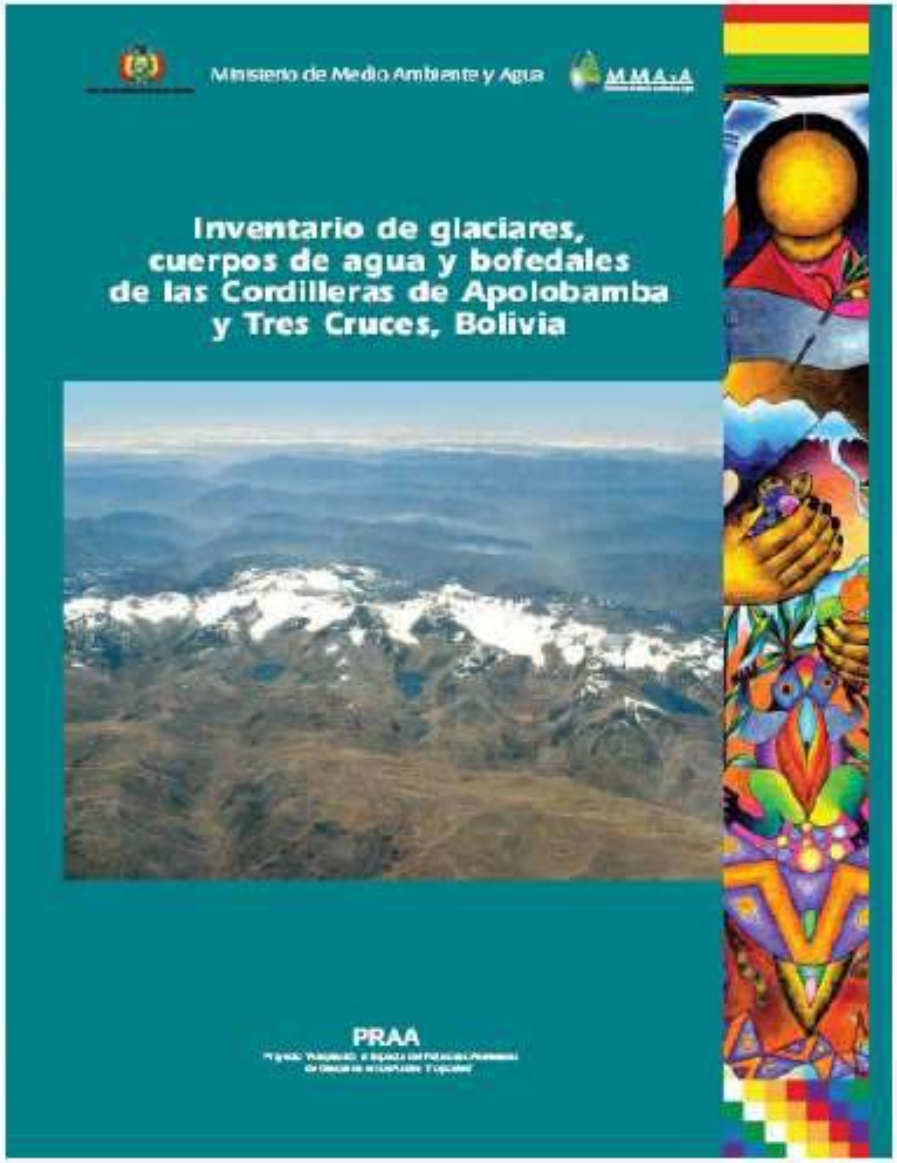


Apolobamba

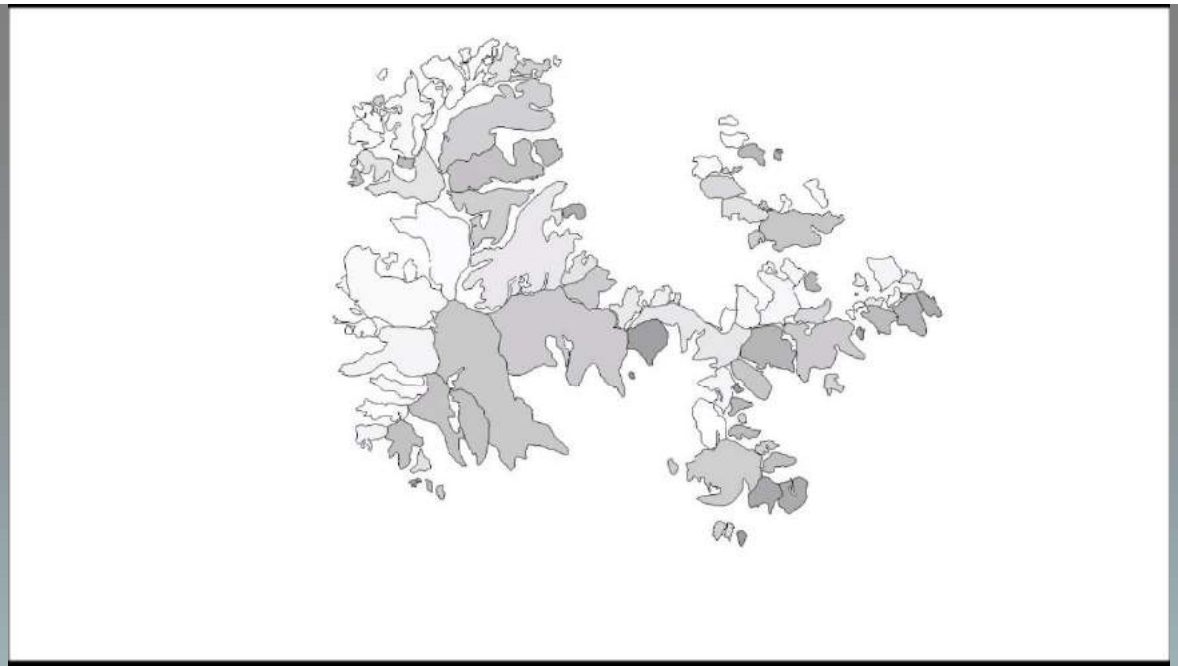
El Inventario Nacional de Glaciares



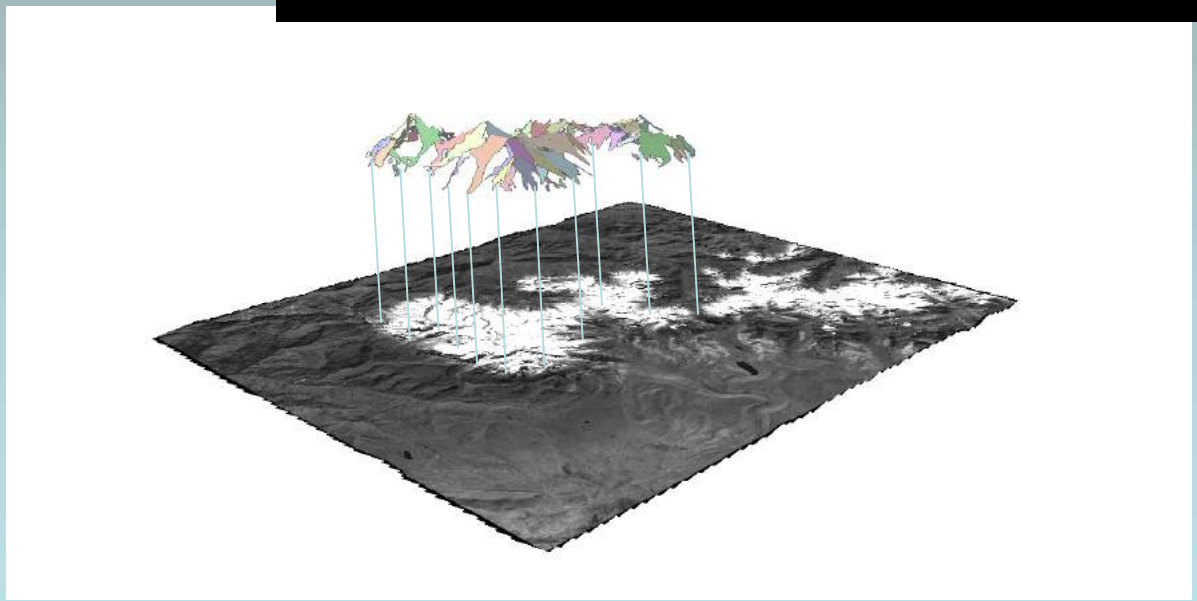
2013



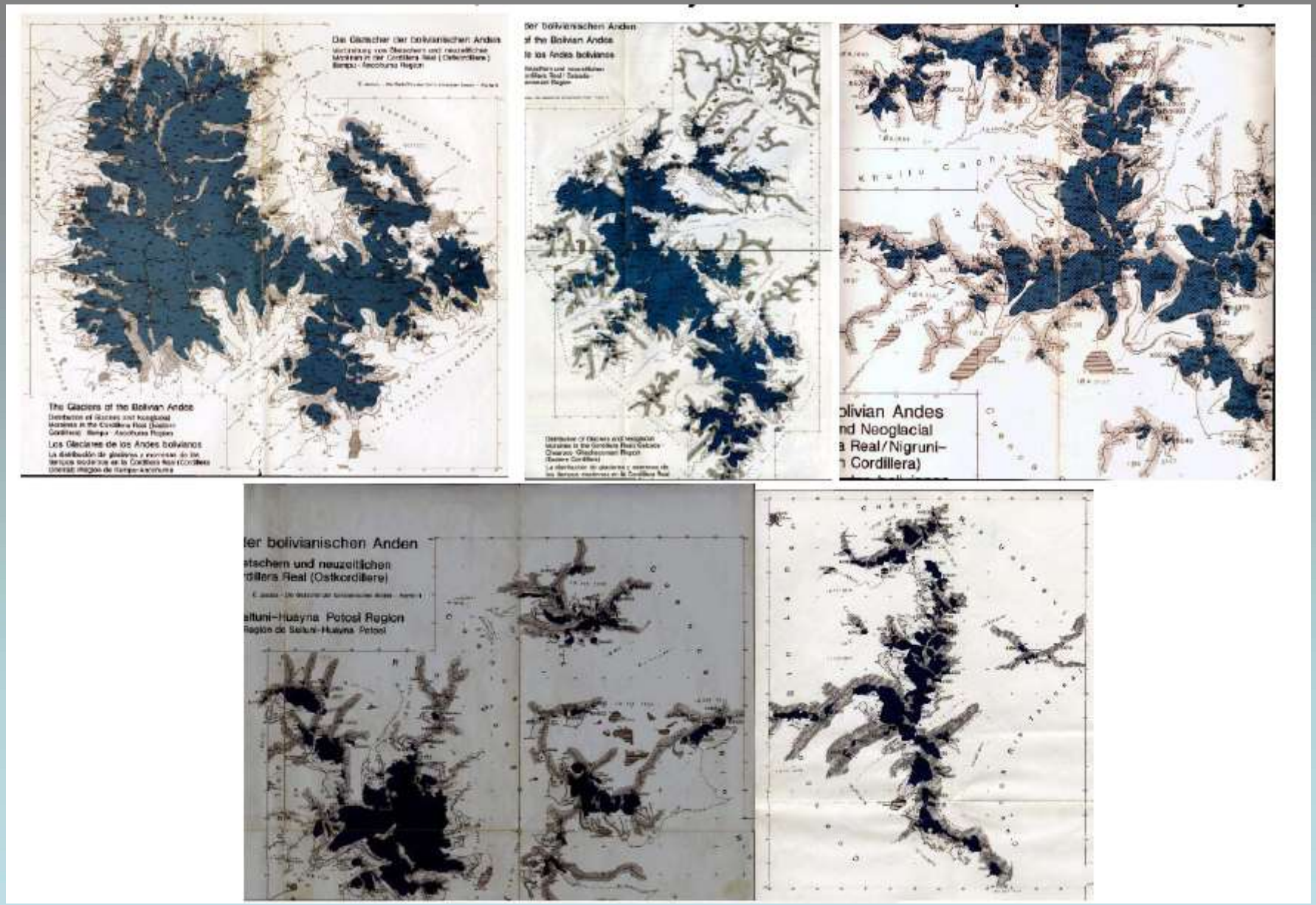
2014



Nevado Illampu

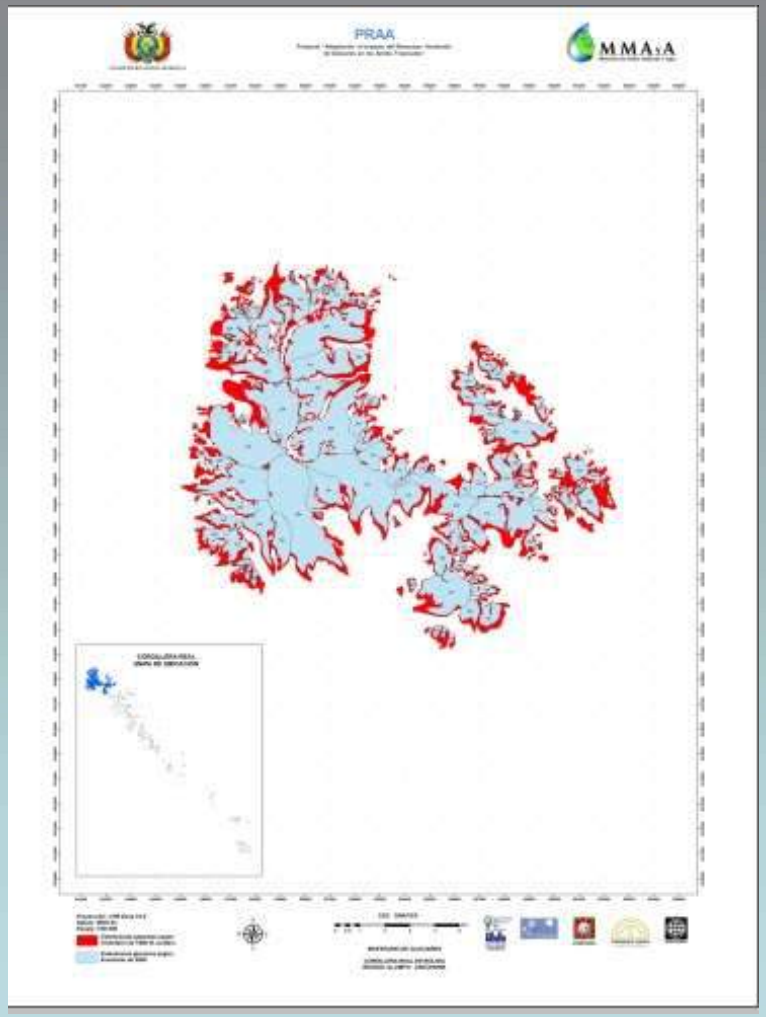


PRIMER INVENTARIO COMPLETO DE LOS GLACIARES BOLIVIANOS

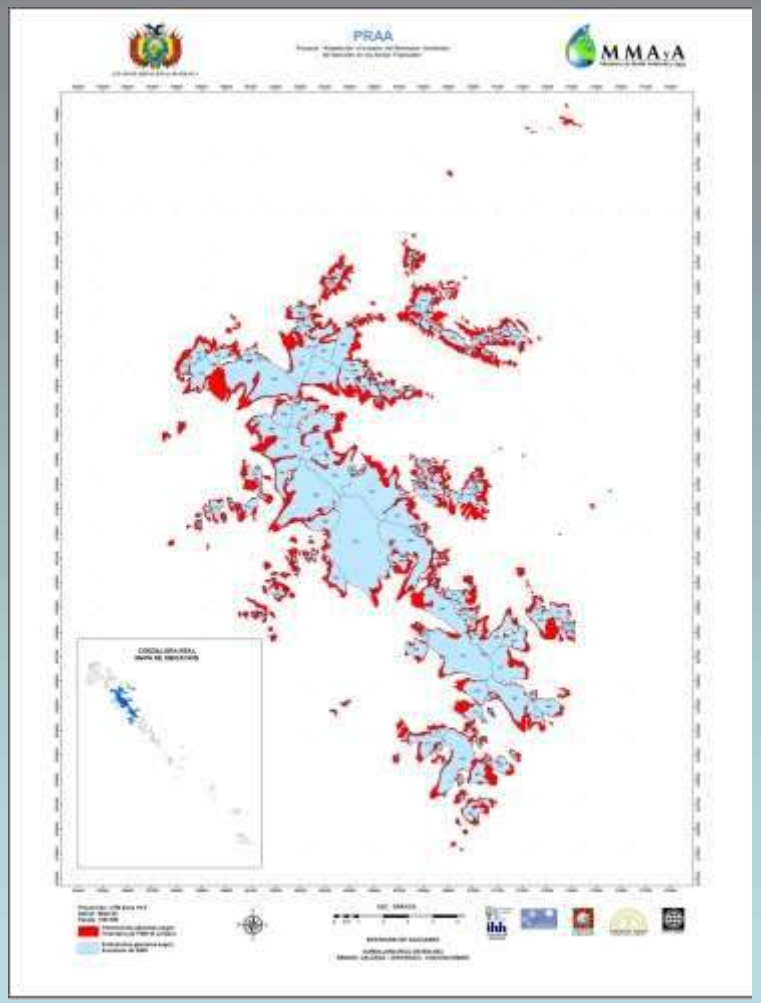


Fuente: Jordan, 1991

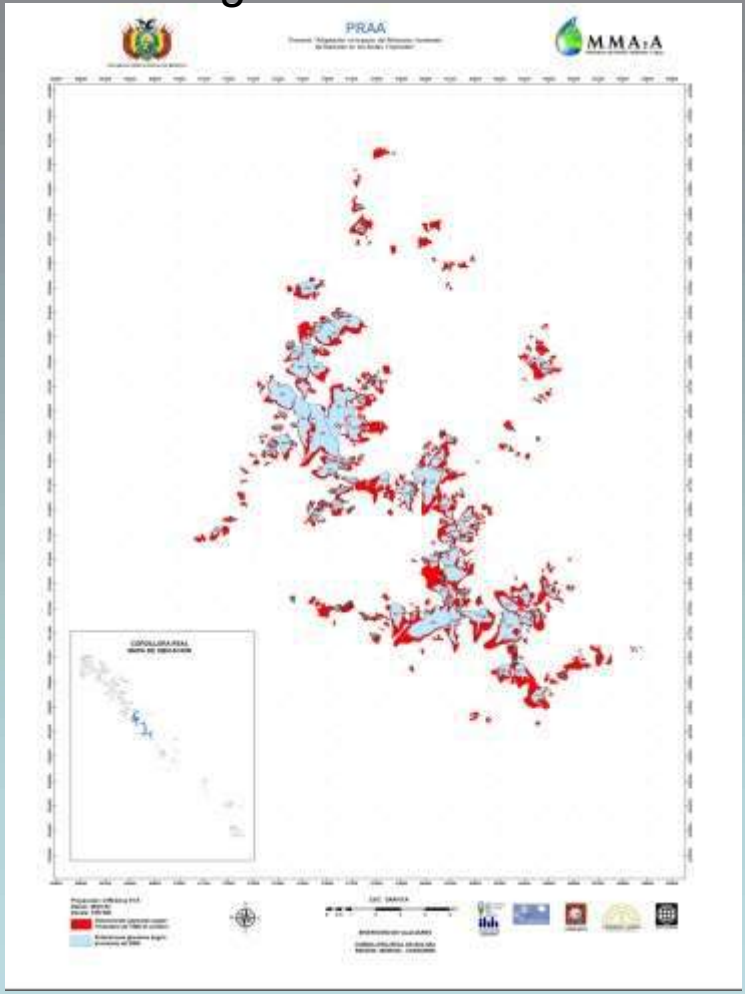
Illampu - Ancohuma



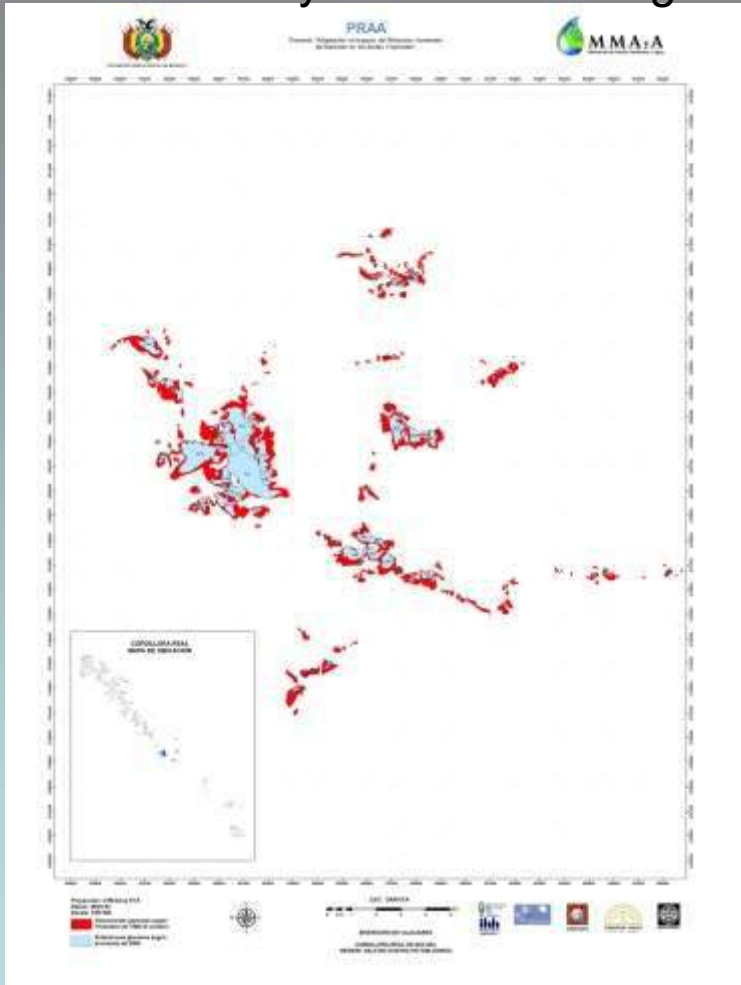
Calzada – Chearoco - Chachacomani



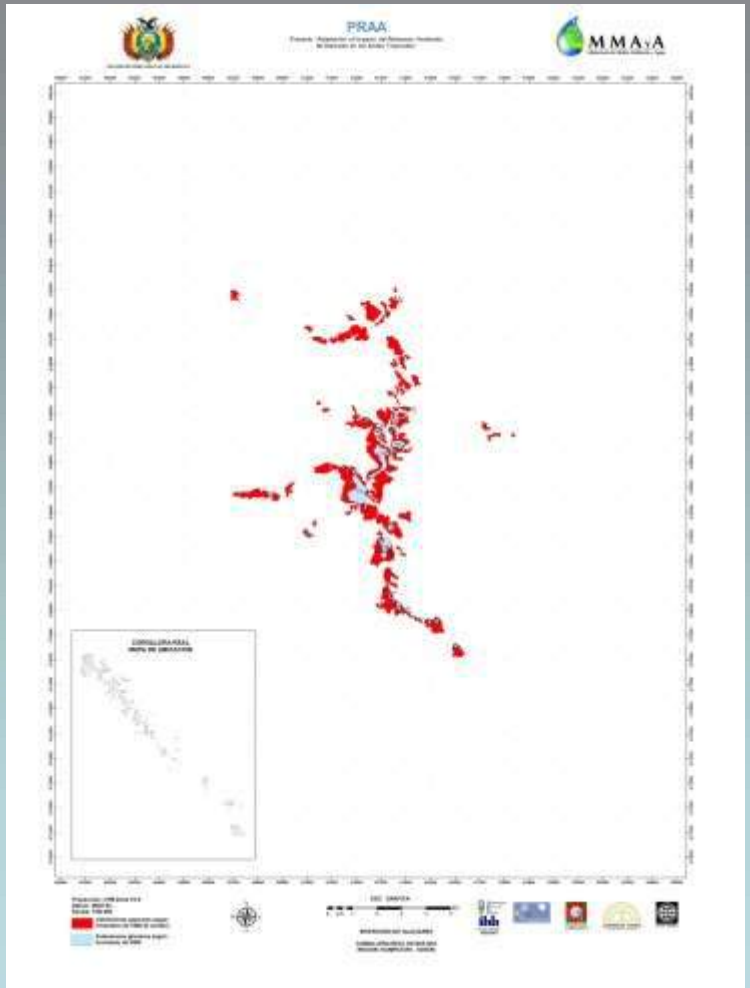
Nigruni - Condoriri



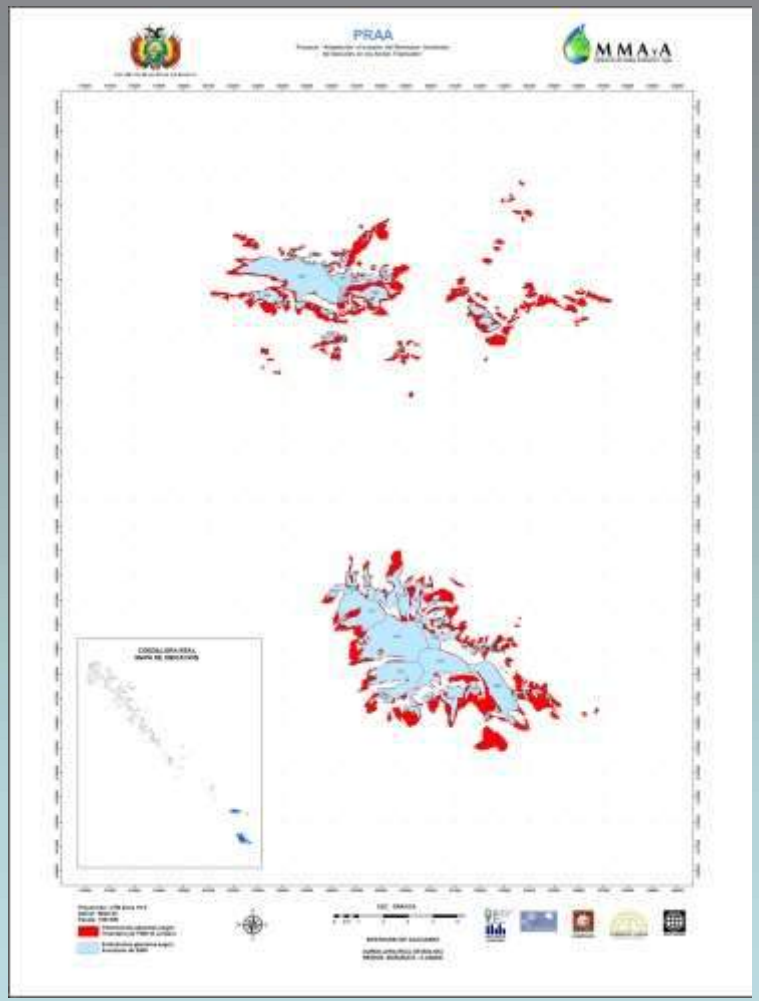
Saltuni – Huayna Potosí - Zongo

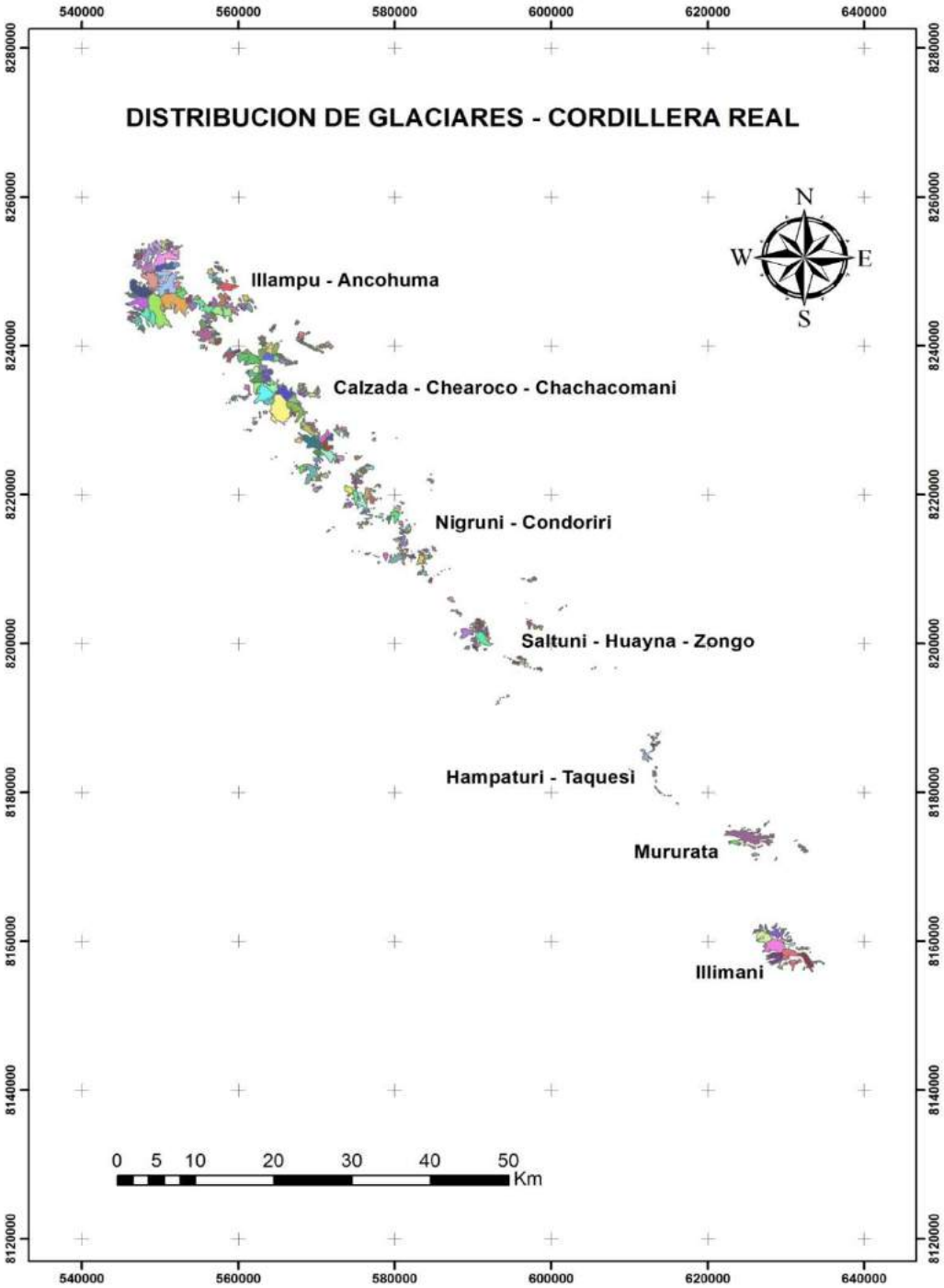


Hampaturi - Takesi



Mururata - Illimani





PRAA

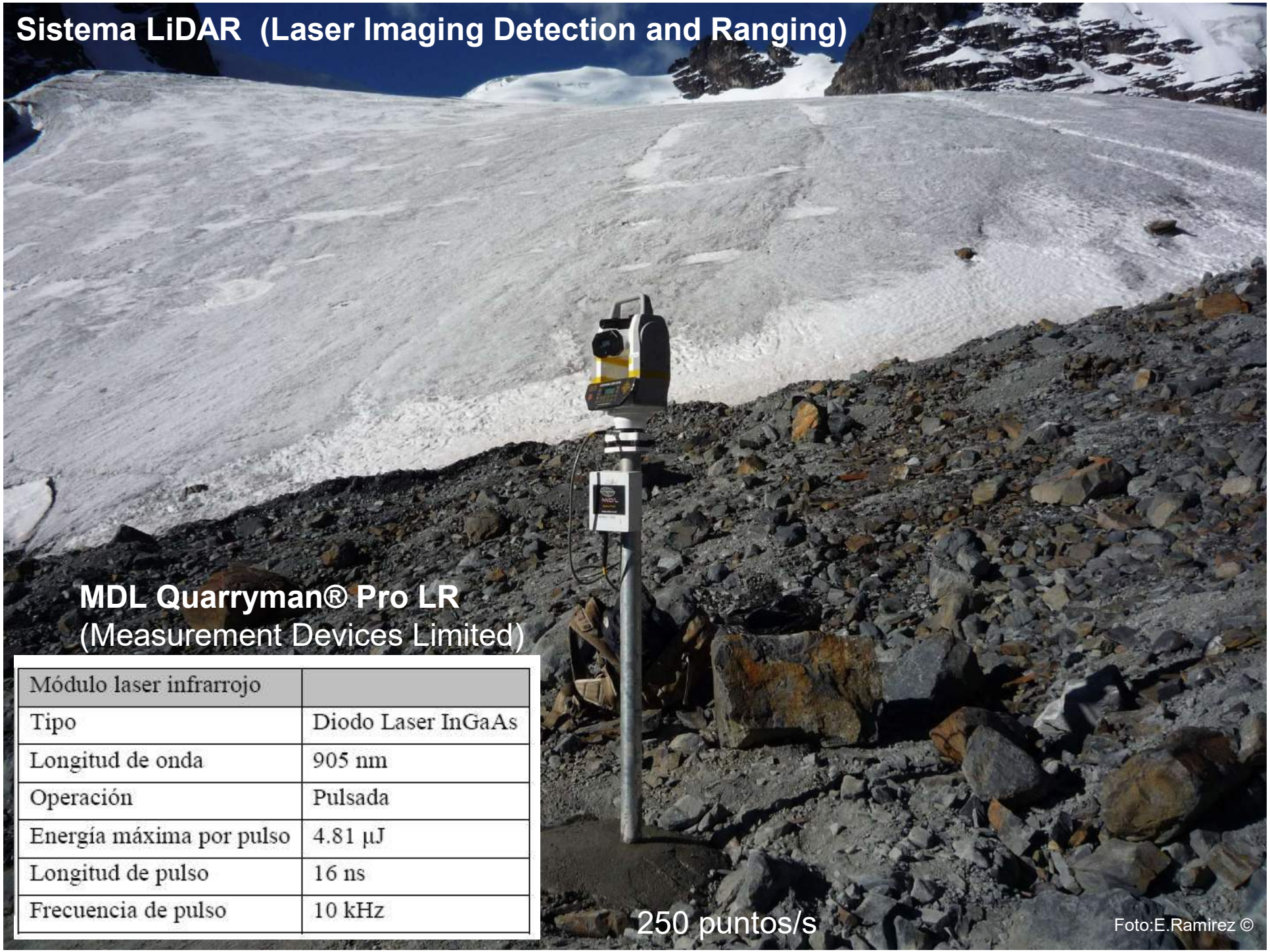
CONCLUSIONES

Clase de Tamaño km²	Número de glaciares		Área	
		%	km²	%
< 0.05	317	46.3	5.8	2.9
0.05 - 0.1	98	14.3	6.6	3.3
0.1 - 0.5	170	24.9	40.8	20.4
0.5 - 1	50	7.3	34.2	17.2
1 - 5	47	6.9	98.8	49.6
> 5	2	0.3	13.1	6.6
Total	**684**	**100**	**199.3**	**100**

Clase por tamaño km²	Número de Glaciares (1980)	Área 1980 km²	Área 2009 km²	Pérdidas de área km²	Pérdidas de área %	Pérdidas de área Acumulado %
< 0.02	157	1.92	0.02	-1.90	-98.9	1.6
0.02 - 0.05	219	7.30	0.58	-6.72	-92.0	7.2
0.05 - 0.1	154	11.07	1.96	-9.11	-82.3	14.9
0.1 - 0.5	247	56.02	21.20	-34.82	-62.2	44.1
0.5 - 1	96	67.72	37.50	-30.22	-44.6	69.5
1 - 5	71	146.71	113.51	-33.19	-22.6	97.4
> 5	4	27.71	24.56	-3.15	-11.4	100
Total	948	318.46	**199.33**	-119.13	**-37.4**	

El área de pérdida entre los años 1980 y 2009 es del **37.4 %, lo que representa 119 km².**

Sistema LiDAR (Laser Imaging Detection and Ranging)

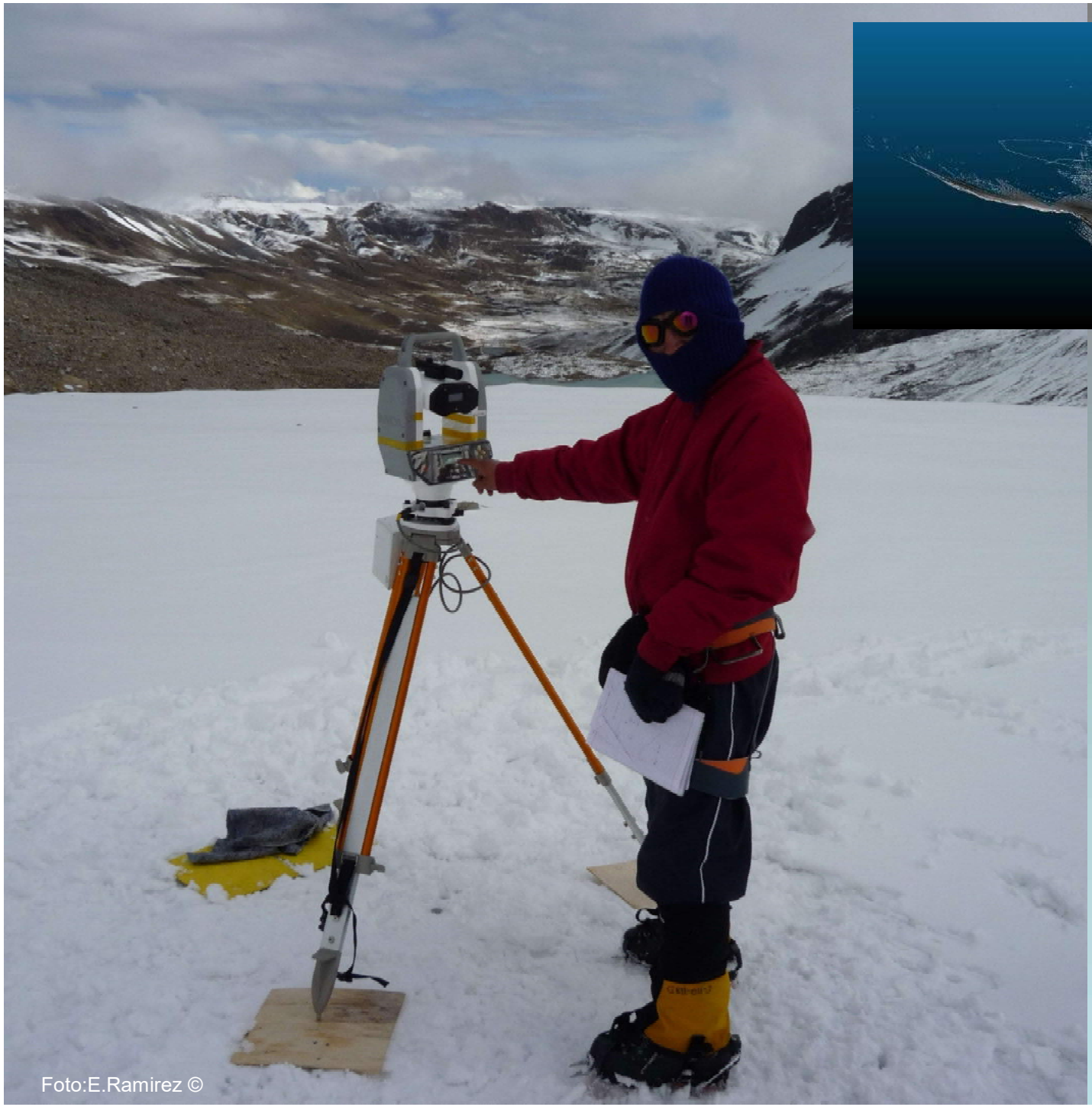


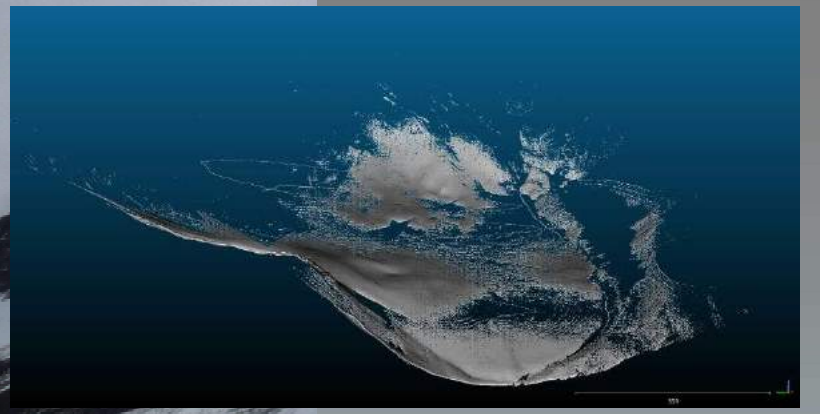
MDL Quarryman® Pro LR
(Measurement Devices Limited)

Módulo laser infrarrojo	
Tipo	Diodo Laser InGaAs
Longitud de onda	905 nm
Operación	Pulsada
Energía máxima por pulso	4.81 µJ
Longitud de pulso	16 ns
Frecuencia de pulso	10 kHz

250 puntos/s

Foto:E.Ramirez ©



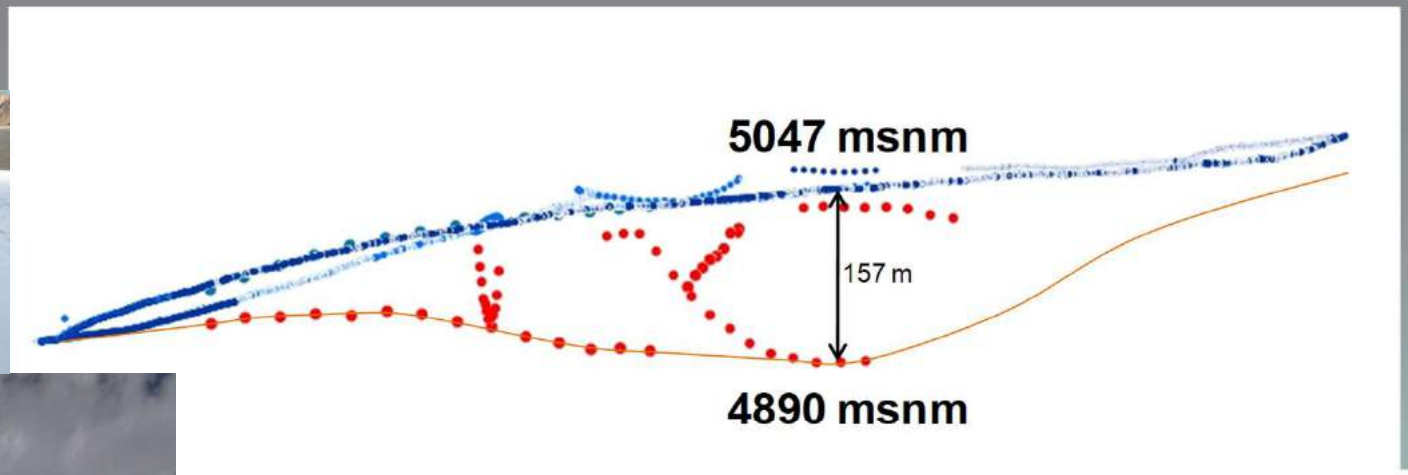


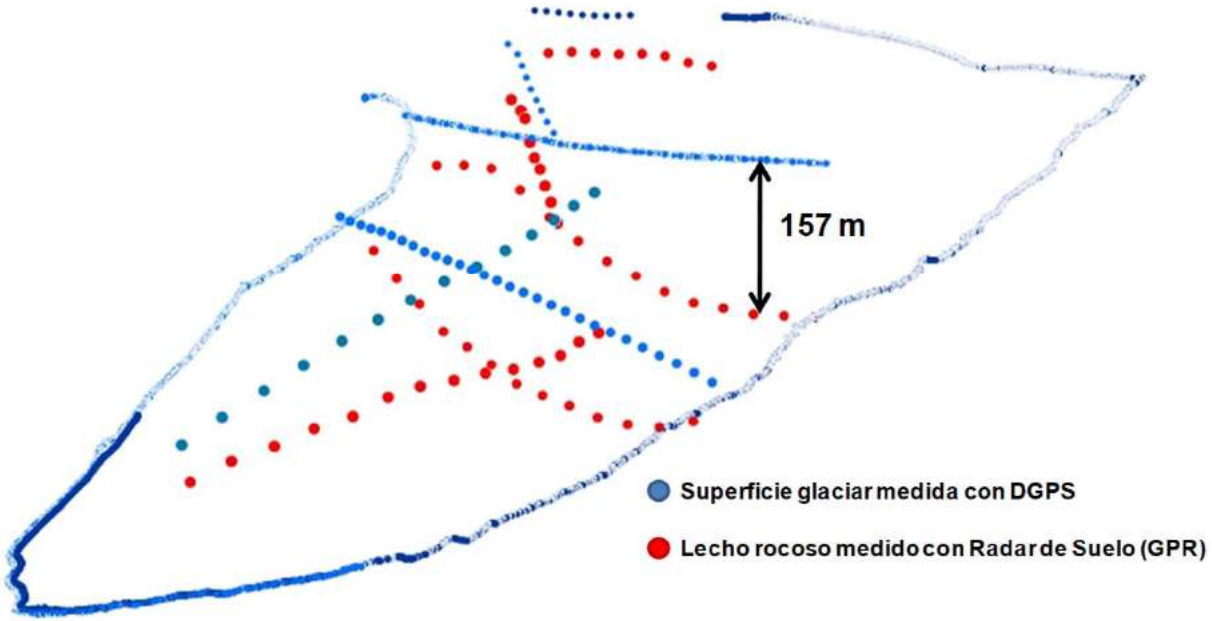
$$R = c \times \frac{t - t_p}{2}$$

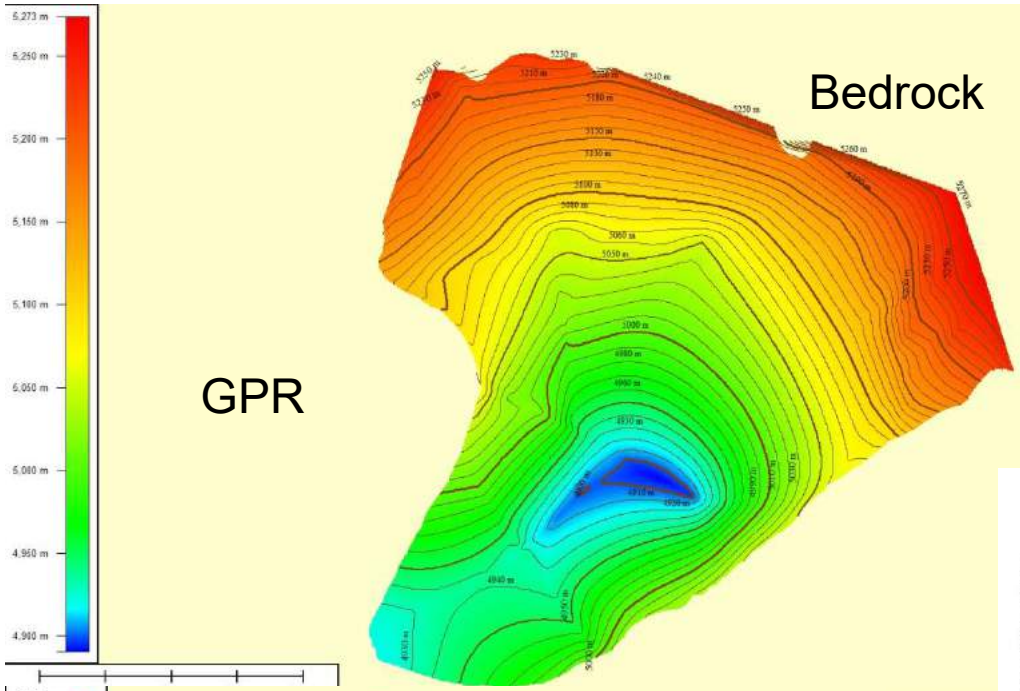
Aplicación de Vehículos No Tripulados

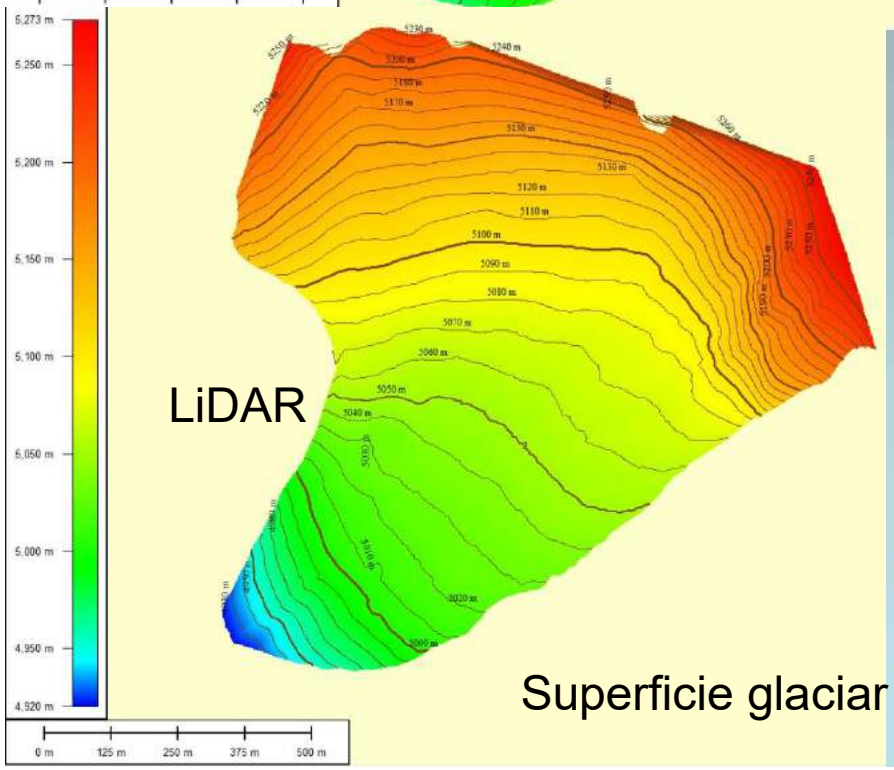
Sobrevuelo con UAV y adquisición de fotos aéreas

MEDICIONES DE ESPESOR DE HIELO (GPR) 10 MHz

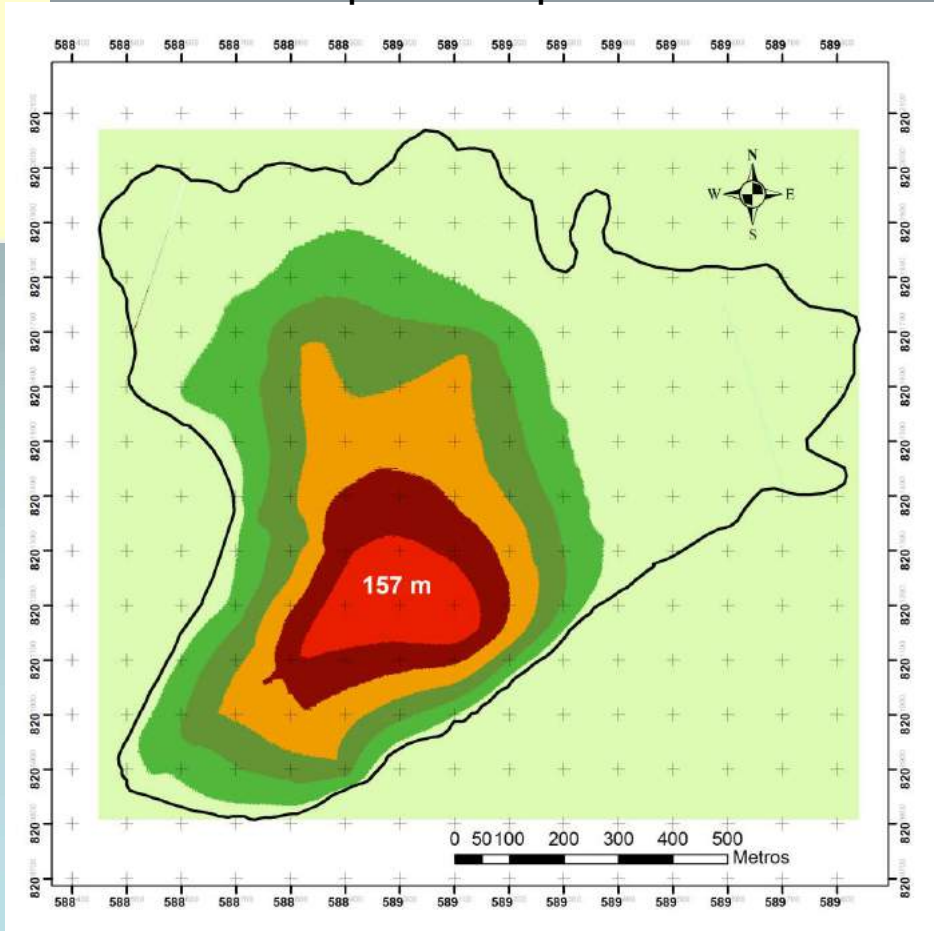








Mapa de Espesores



CONCLUSIONES

•Las potencialidades de los sensores estereoscópicos aplicar técnicas de restitución fotogramétrica para la digitalización de **contornos tridimensionales** (3D) de los glaciares de la Cordillera de Real.

• Esta técnica se constituye una alternativa eficiente para la elaboración de inventarios especialmente para cordilleras con **glaciares pequeños (< 1 km^2).**

• Se han identificado en total **684** cuerpos de hielo sobre la Cordillera Real.

• La Cordillera Real tiene una superficie de **199 km^2**.

• Comparando con el primer inventario nacional (1980) la Cordillera Real perdió el **37.4 %** de su superficie original, lo que representa **119 km^2**.

CONCLUSIONES

Las ventajas del método propuesto se resumen en:

- Menor cantidad de imágenes
- Menor cantidad de puntos de apoyo en tierra
- Misma temporalidad de las escenas
- Menor tiempo de proceso
- **Bajo costo**

Muchas gracias por su atención
Foto: E.Ramírez