Vermessung AVT-ZT-GmbH
Ingenieurkonsulenten für
Vermessungswesen

3D glacier monitoring with historical aerial images - from 1954 to today

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Geoprocessing and Archiving of historical aerial images, Paris, 3-4 June, 2019

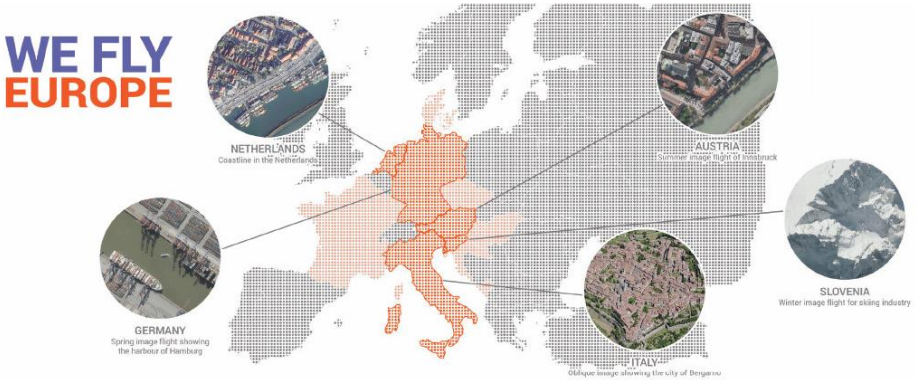
Outline

- Partners & Project aims
- Data analysis
- Approaches for 2D/3D
- Results
- Remarks & Conclusions

Portrait AVT

- Vermessung **AVT**-ZT GmbH
  - Mapping company founded in **1970**
  - HQ in **Imst**, Tyrol / Austria
  - About 100 employees
  - Active in all branches of surveying
- Since 2019: **AVT Airborne Sensing**
  - Former Terra Messflug GmbH and Weser
  - 25 people
  - Various **sensors** and **platforms**
  - Broad range of **projects**
    - Photo flights in **Europe** (2-22 cm GSD)
    - Country-wide orthophotos
    - Historical aerial data processing
    - High-resolution surveying
    - Lidar mapping with detailed classification
    - Terrestrial and indoor mapping

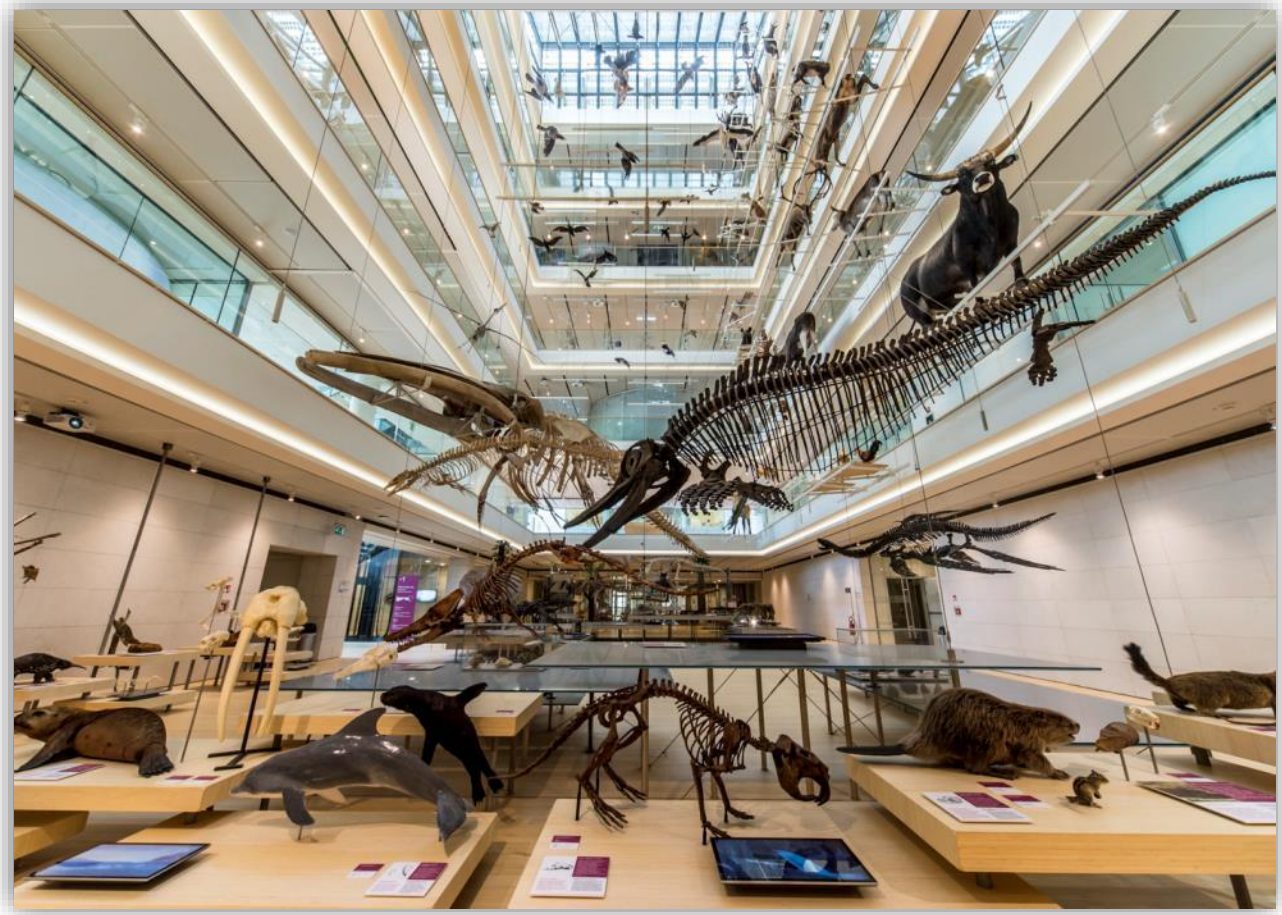
terra messflug + weser airborne sensing → AVT Airborne Sensing GmbH



4x

Portrait MUSE

- **MUSE** is the Science Museum of Trento, Italy, an auxiliary body of the Autonomous Province of Trento.



2,7 M visitors

Research units

Glaciology activities @MUSE

- Glaciers monitoring:

Cadastre of Italian glaciers

COMITATO GLACIOLOGICO ITALIANO

GENERALE CARLO PORRO E INGEGNERE PIETRO LABUS

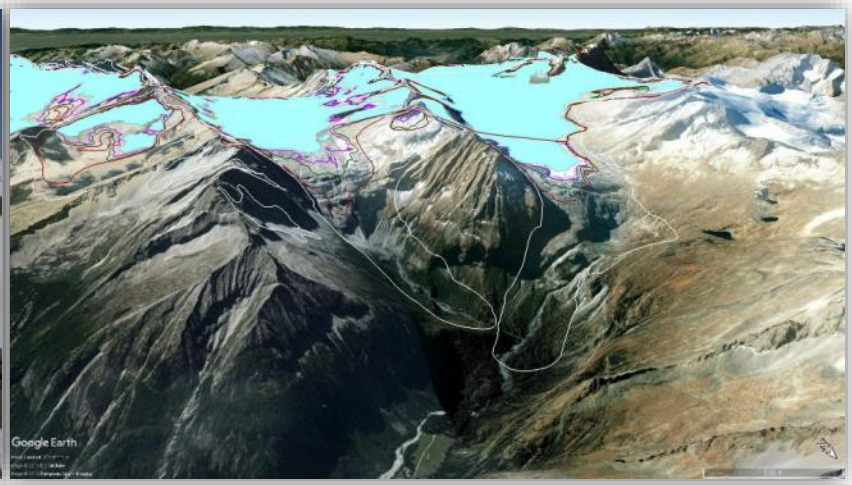
ATLANTE
DEI
GHIACCIAI ITALIANI

PARTE PRIMA

CARTA COROGRAFICA
SCALA 1:500.000

Mass balance
«direct» method

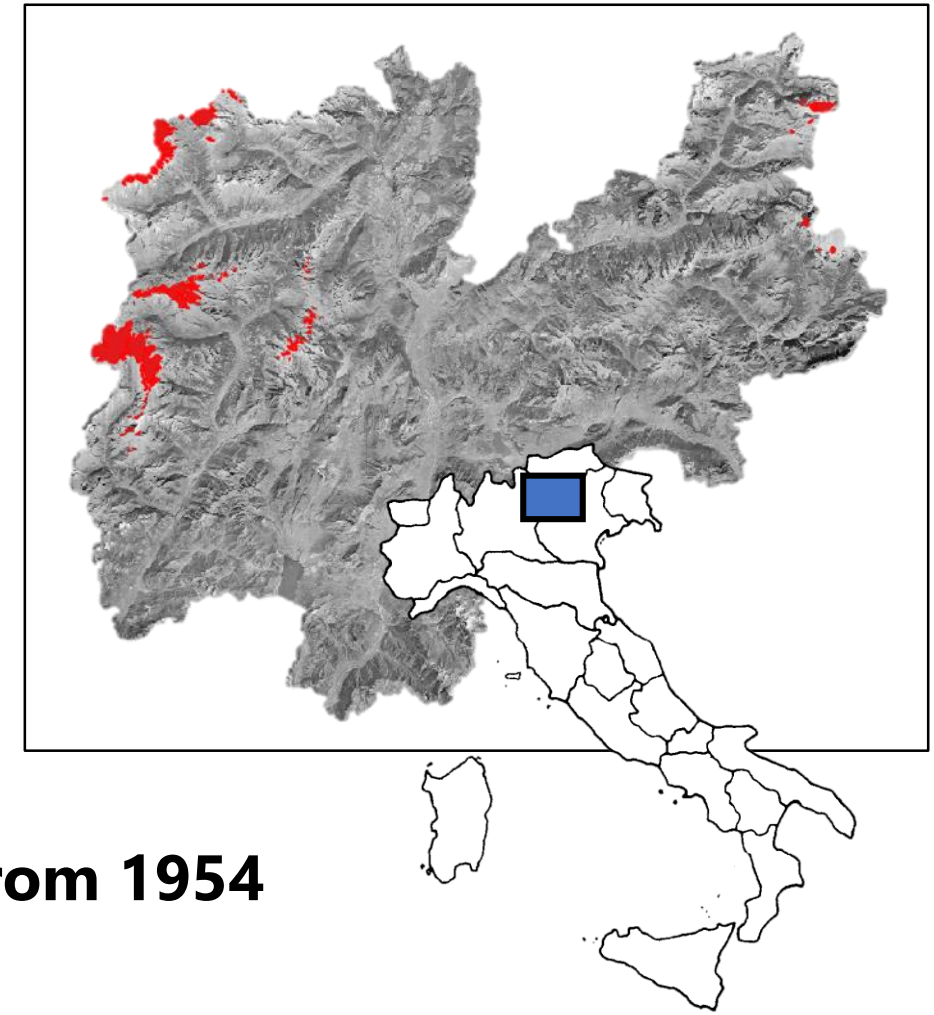
Mass balance
Geodetic method



Glaciers perimeters
From orthophotos and RS

Glaciers cadastre of Trentino

- Current situation in Trentino:
  - 128 glaciers
  - Size 77 km^2
  - Adamello, largest in Italy
- Monitoring of:
  - Perimeters (2D):
    - 1954, 1988, 2003, 2015
  - Volumes (3D): **New**
    - 1954/2015



Inclusion of 2D/3D data from 1954

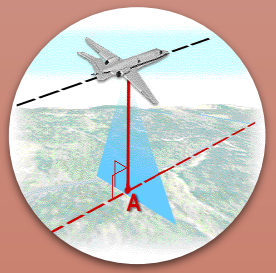
Workflow for 2D/3D geospatial products

Data collection

- Coverage analysis
- Quality analysis

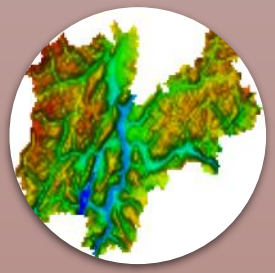
Internal Orientation

- Estimation of PP, focal lengths, distortions



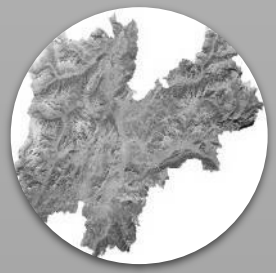
Exterior Orientation

- Estimation of image position and attitude



DSM/DTM generation

- *Stereo measurements*
- *DIM*
- Fusion

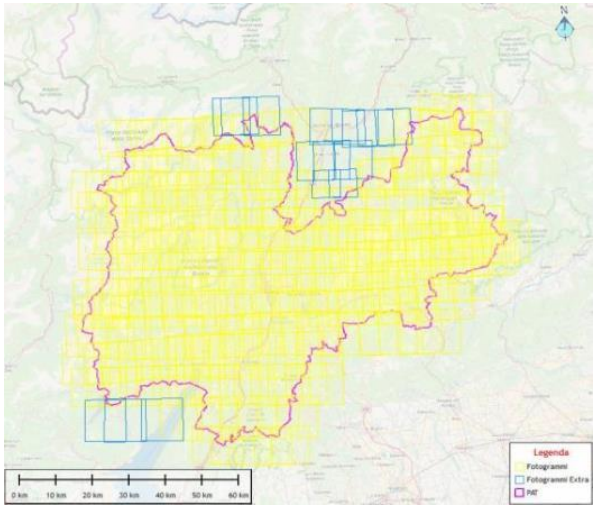


Orthophoto production

- Image orthorectification
- Tiling

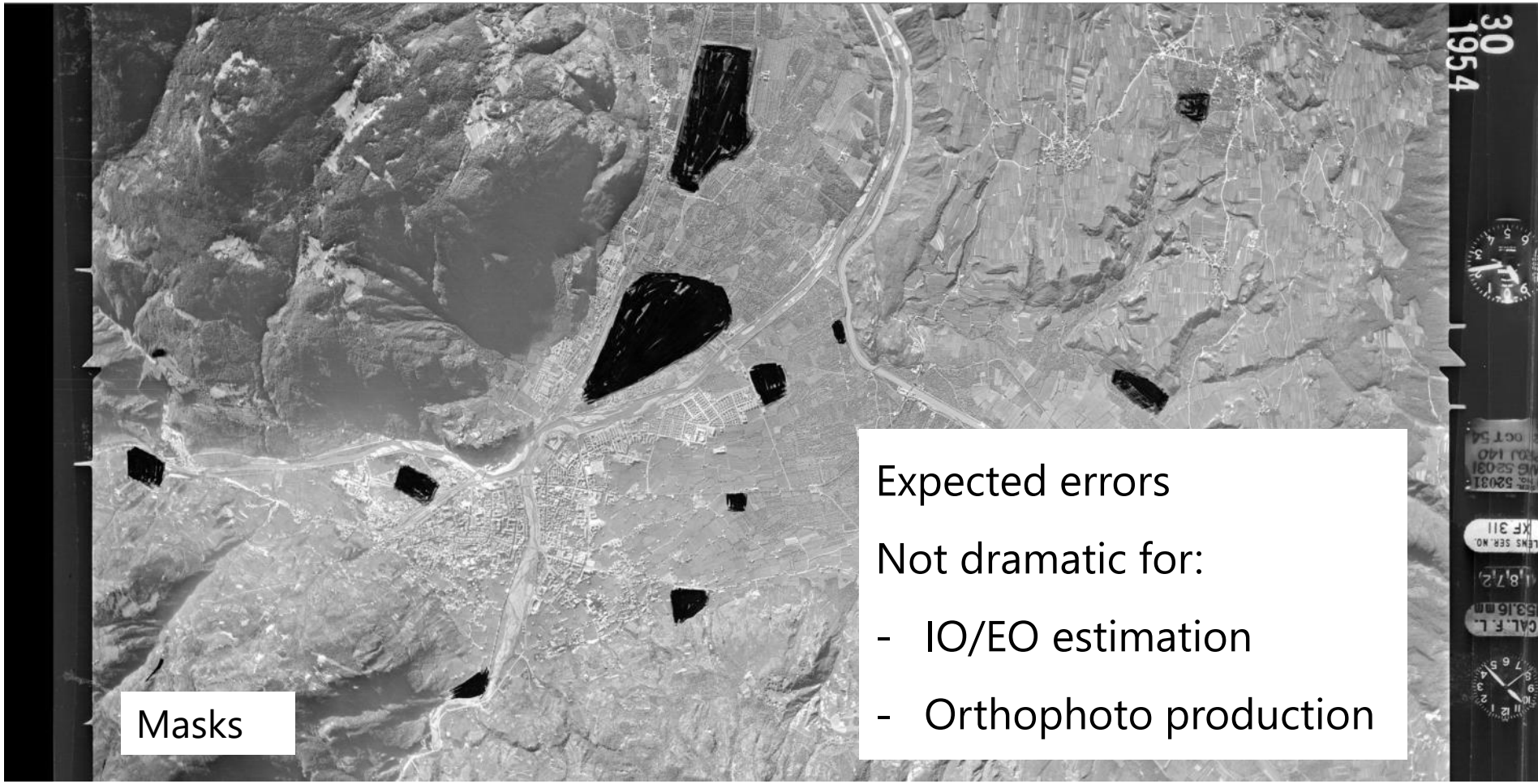
1954 Flight

- Photograms on Province of Trento:
  - About 300 photograms, 23 cm x 23 cm Cameras: XF311 with f=153.16, XF353 with f=153.89, KF7660, with f=153.34
- Acquisition:
  - August / October 1954 by US Aviation
  - mean scale 1:55.000, overlap 60%-30%
  - Coverage: Province of Trento, 150 – 3.500m
- Scanned by IGM at 2.400 dpi
  - GSD 58,8 cm



Photograms quality

Photograms quality



Masks

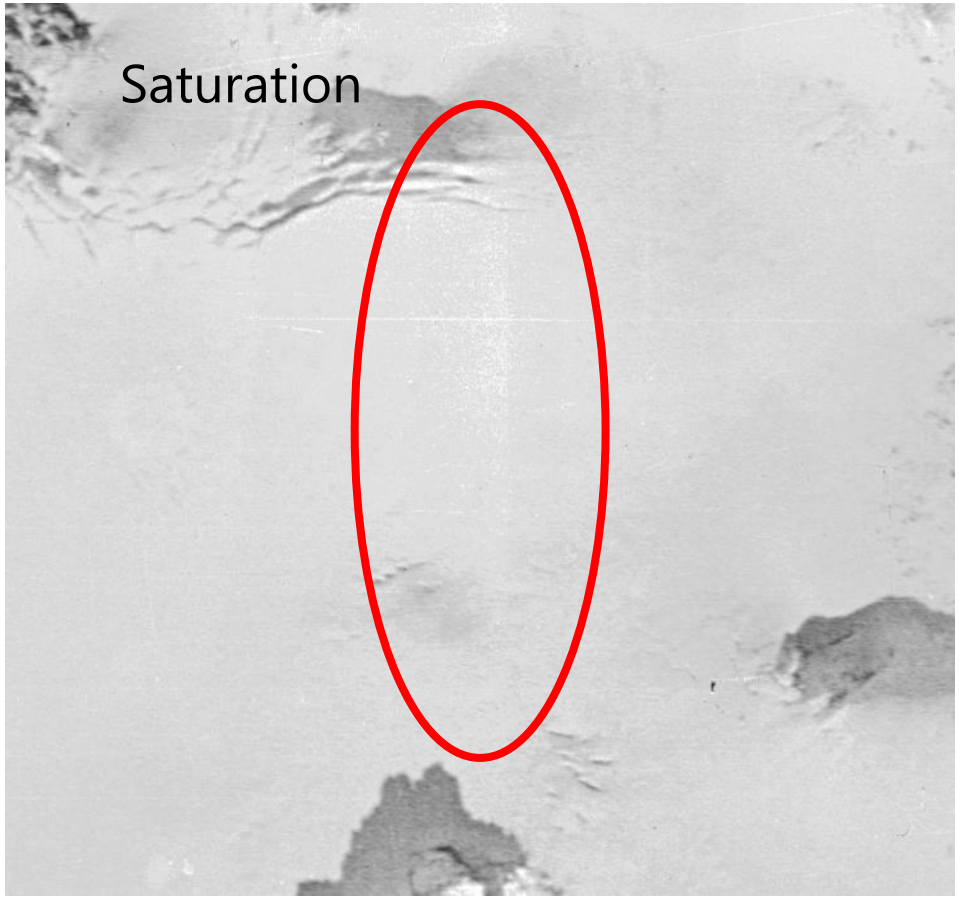
Expected errors

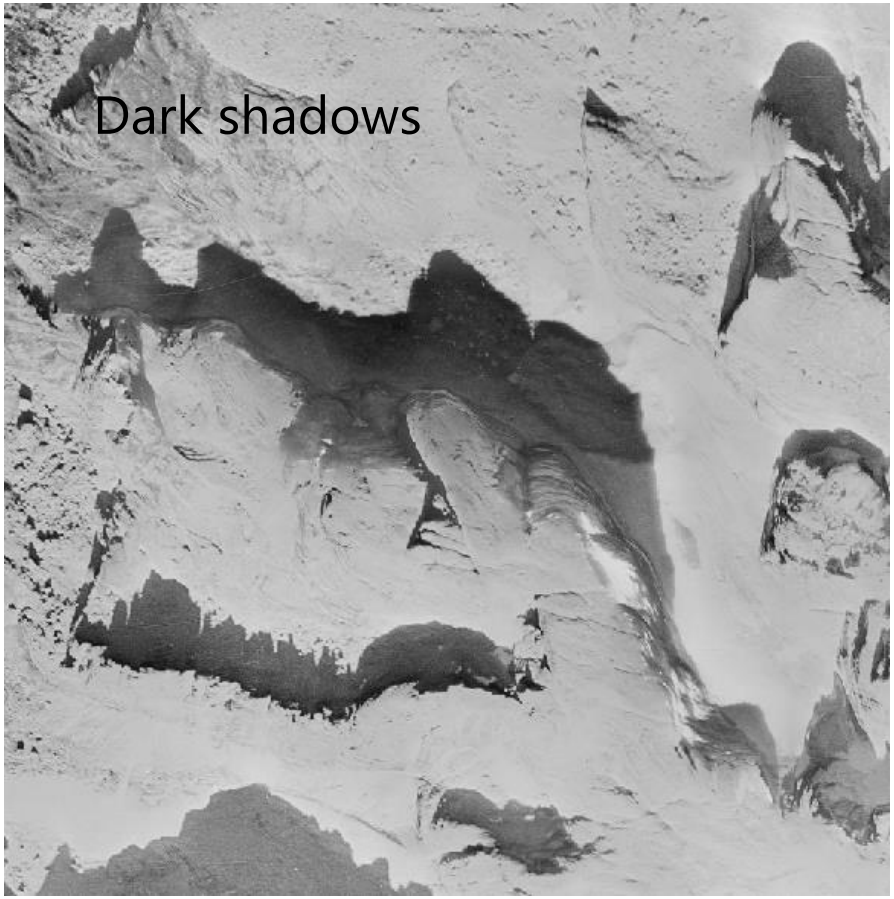
Not dramatic for:

- IO/EO estimation
- Orthophoto production

Photograms quality

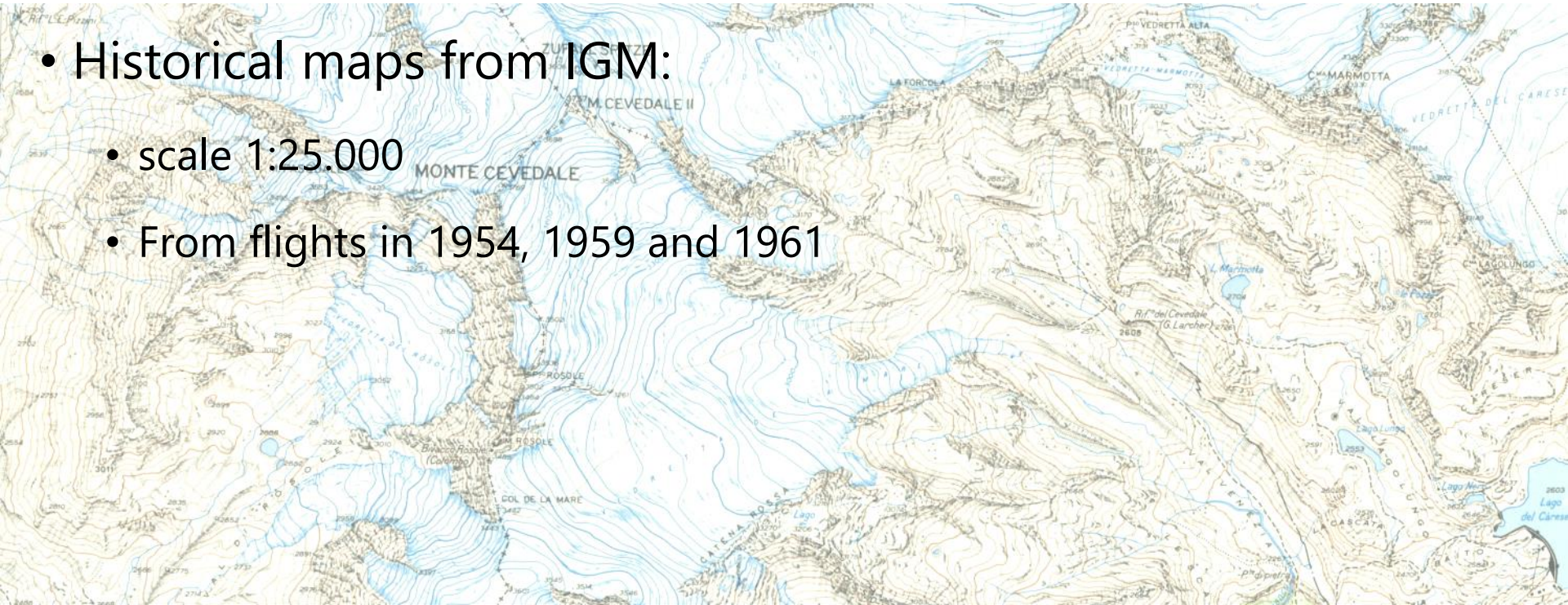
- Additional crucial errors for the glacier project!
  - Low radiometric quality





Other data

- Technical maps, edition 1998
  - DTM 10m x 10m generated from 1998 technical maps
- DTM 5m x 5m from LiDAR, edition 2009
- Technical maps, edition 2013
- Historical maps from IGM:
  - scale 1:25.000
  - From flights in 1954, 1959 and 1961



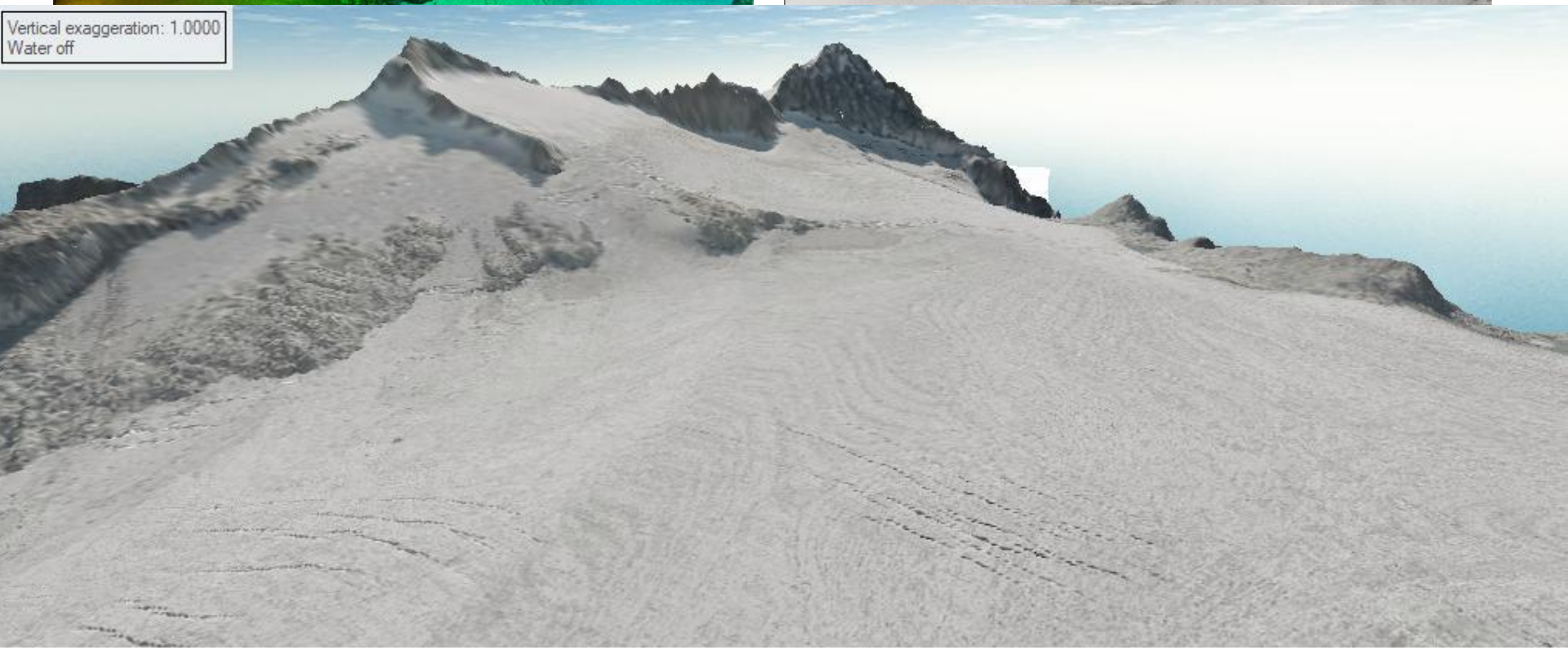
AVT Aerial flight 2015

- Photogrammetric flight on the glaciers, 21/09/2015
  - GSD 8 cm, 80/60, 116 km^2

Area (working title)	Sigma zero	RMSE GCP [m] X Y Z	RMSE CHKs [m] X Y Z	RMSE GNSS [m] X Y Z	RMSE IMU [deg] ω Φ κ
Vezzano	0.7 µ	0.018	n/a	0.039	0.001
	0.15 pix	0.028		0.037	0.001
		0.04		0.049	0.005
Marmolada	0.7 µ	0.033	n/a	0.045	0.001
	0.15 pix	0.045		0.059	0.001
		0.058		0.059	0.005
Alimonte	0.7 µ	0.028	0.023	0.055	0.001
	0.15 pix	0.049	0.081	0.056	0.001
		0.049	0.24	0.06	0.004
Presanello	0.9 µ	0.027	n/a	0.049	0.001
	0.2 pix	0.024		0.044	0.001
		0.02		0.045	0.008
San Matteo	0.7 µ	0.024	0.076	0.047	0.001
	0.15 pix	0.029	0.128	0.044	0.001
		0.025	0.265	0.035	0.005

Aerial flight 2015

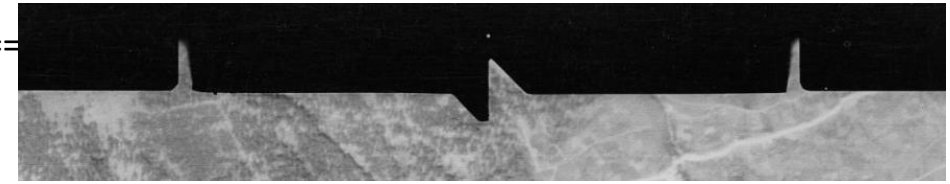
- 3D glacier modelling by DIM, grid 10 cm for DSM and TrueOP



Adamello glacier, 2015

Internal orientation

- Manual measurement of fiducial marks



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Interior Orientation
Done by : FB
Date : 06:02:12 21/11/2018
Image : 10_3255
File : R:\Projekte\31854_HDOP_Trentino\30_Bilder\10_3255.tif
Type : Manual

Fiducial Mark	Image coordinates from camera file x [mm]	y [mm]	Residuals vx [mm]	vy [mm]	Measured pixel coord. column [pix]	row [pix]
1	-119.0000	0.0000	-0.1903	-0.0060	22568.0000	11326.0000
3	117.0000	0.0000	-0.1949	-0.0061	250.0000	11300.0000
4	0.0000	-116.0000	0.1926	0.0061	11290.0000	318.0000
2	0.0000	116.0000	0.1926	0.0061	11266.0000	22310.0000

Transformation 6 Parameter (2 rot. , 2 scale)
Origin [mm] 119.5791 -119.2099
Scale 0.0106 0.0105
Rotation of Axes [grad] -199.9261 0.0696

Sigma0 [mm] 0.2725
r.m.s. [mm] 0.1363

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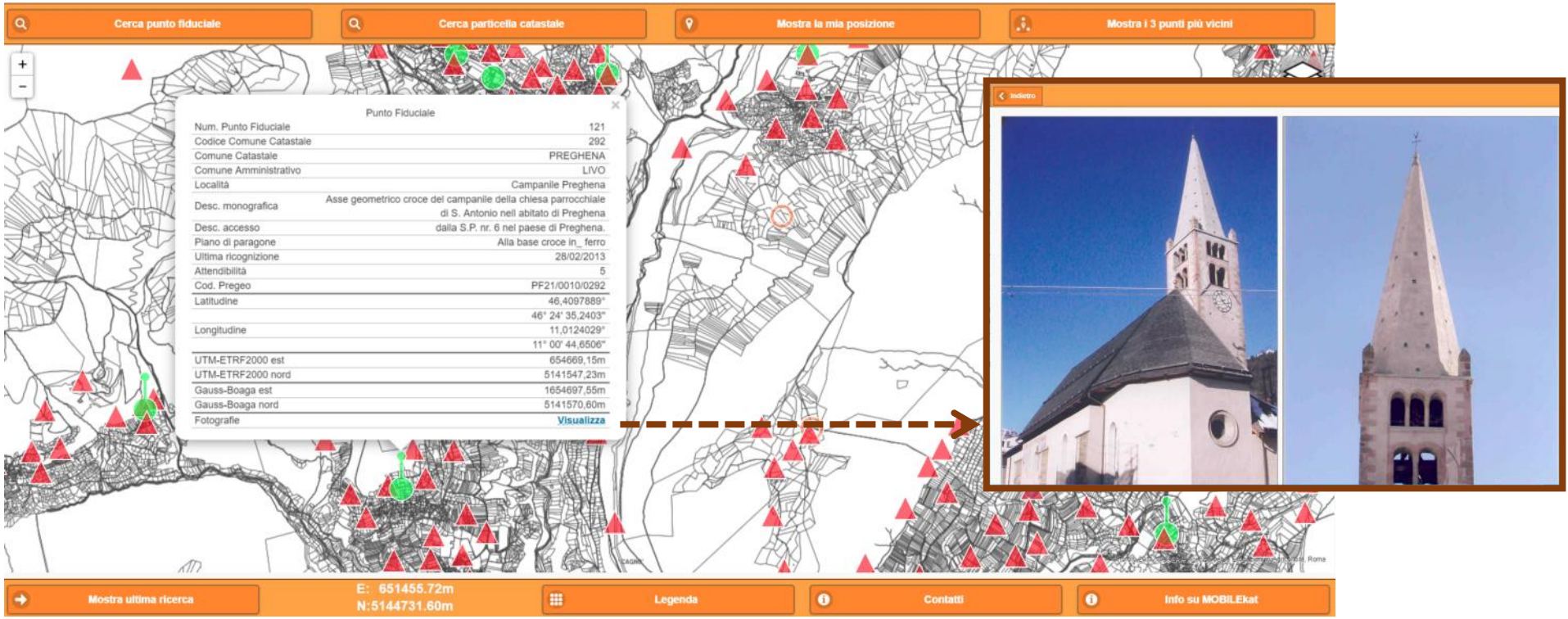
Aerial Triangulation

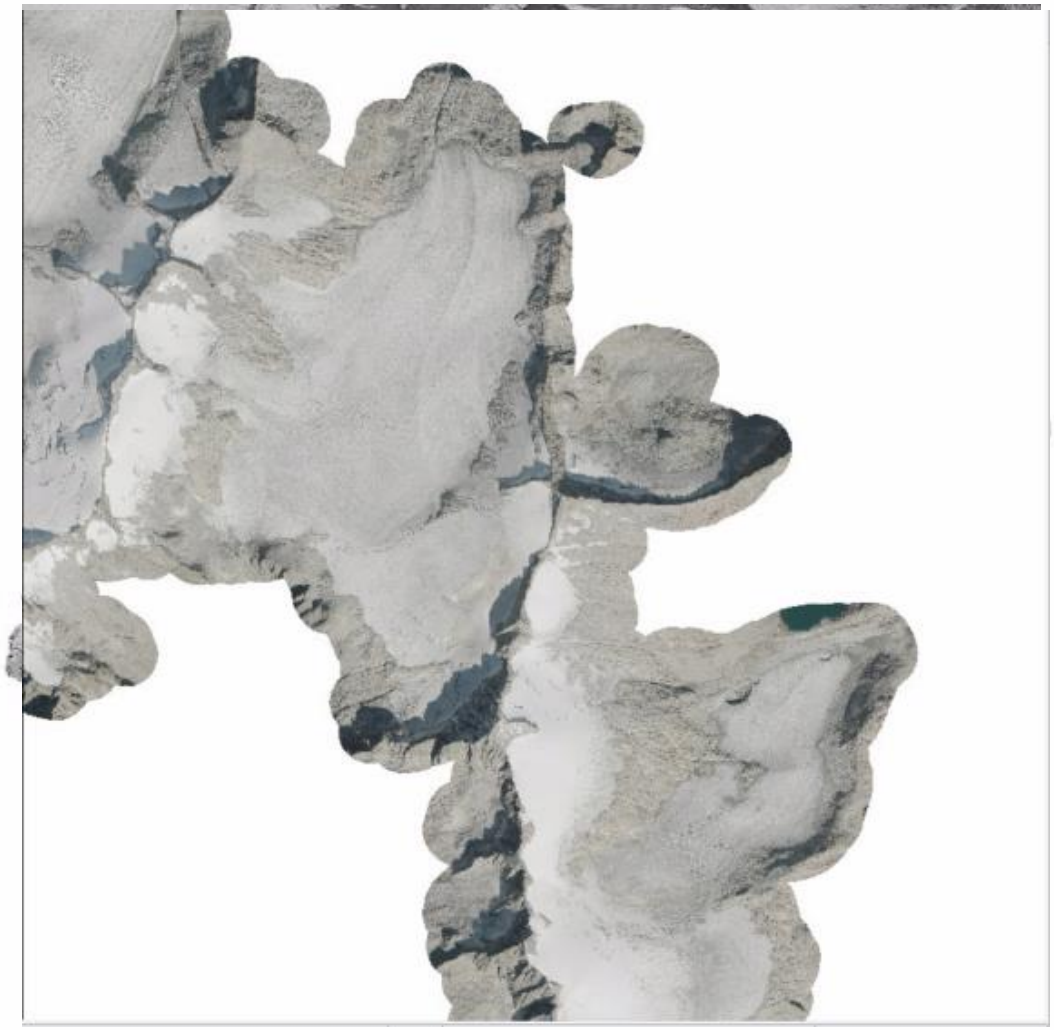
- Ground points collection from:
  - Previous projects (few)
  - Public database of fiducial points from Province (mainly churches)



- AT with 13 GCPs, RMSE: 1,49m (X), 1,18 m (Y), 1,40m (Z)

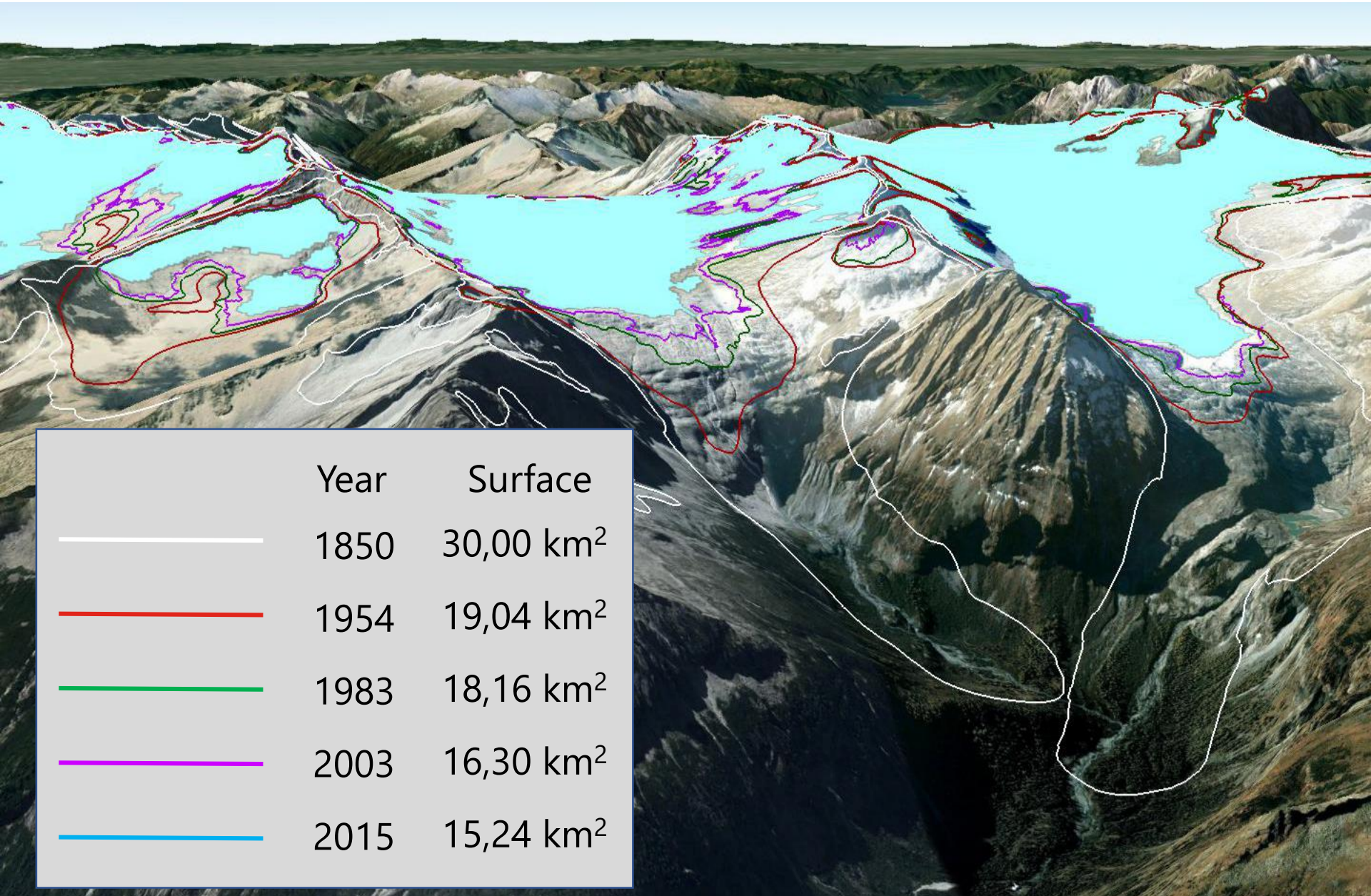
Orthophoto production

- All Province of Trento, ~6.230 km^2, GSD 1m



Zoom 1954

2D perimeter temporal analysis – Adamello glacier



Year	Surface
1850	30,00 km^2
1954	19,04 km^2
1983	18,16 km^2
2003	16,30 km^2
2015	15,24 km^2

Historical 3D glacier modelling

Test on Caseres

Classical stereo photogrammetry

- Stereo measurements of mass points and breaklines + Interpolation
- Manual, expertise required

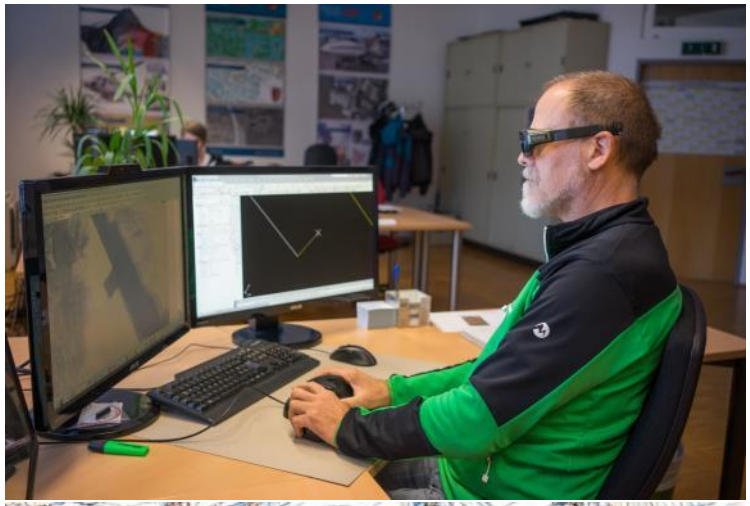
Historical maps digitalization

- 2D digitalization in GIS environment + Interpolation
- Manual, precision depends on maps, training required

Test on Busazza

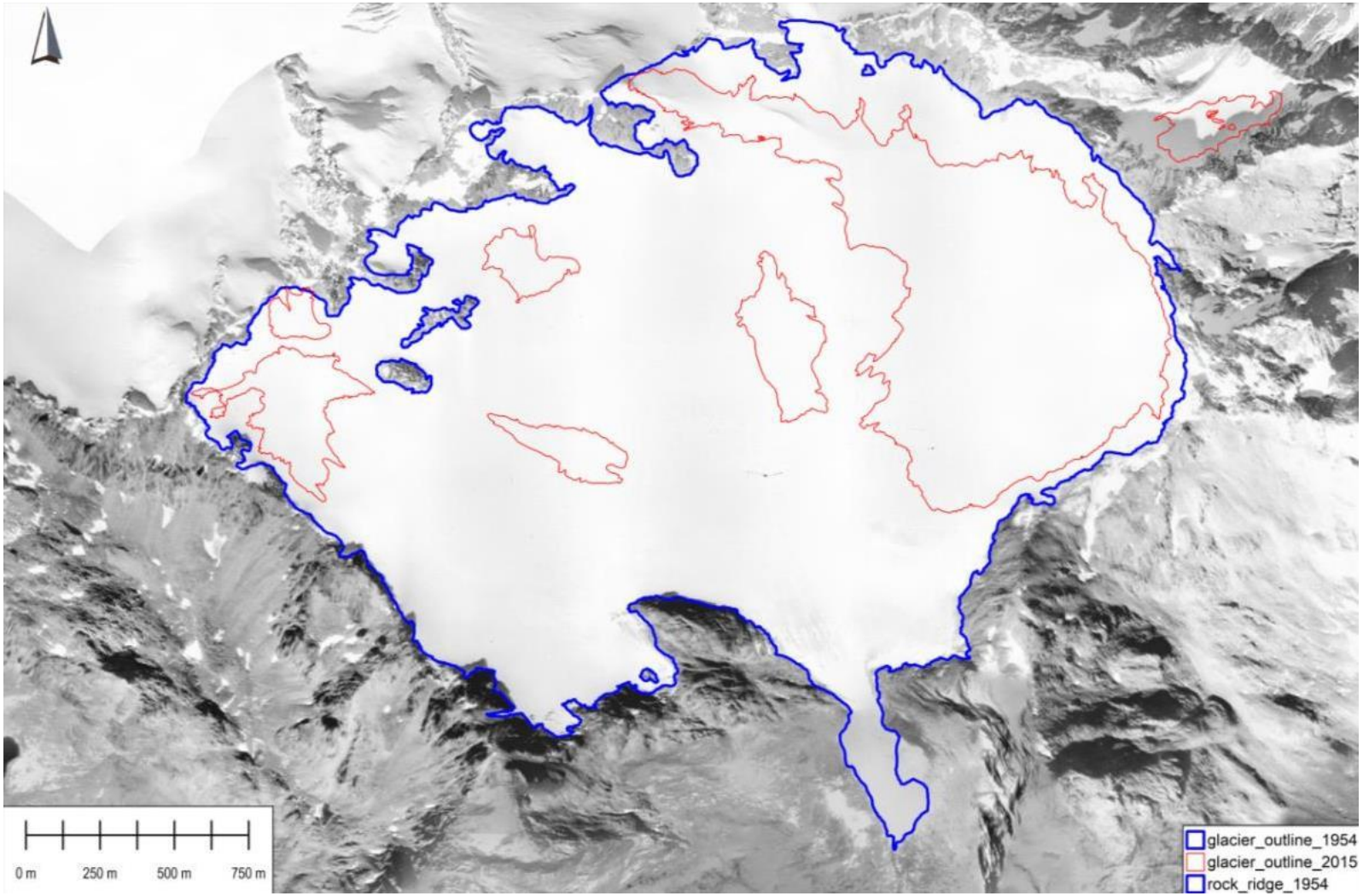
Image Matching

- Good AT and overlap required
- Automatic



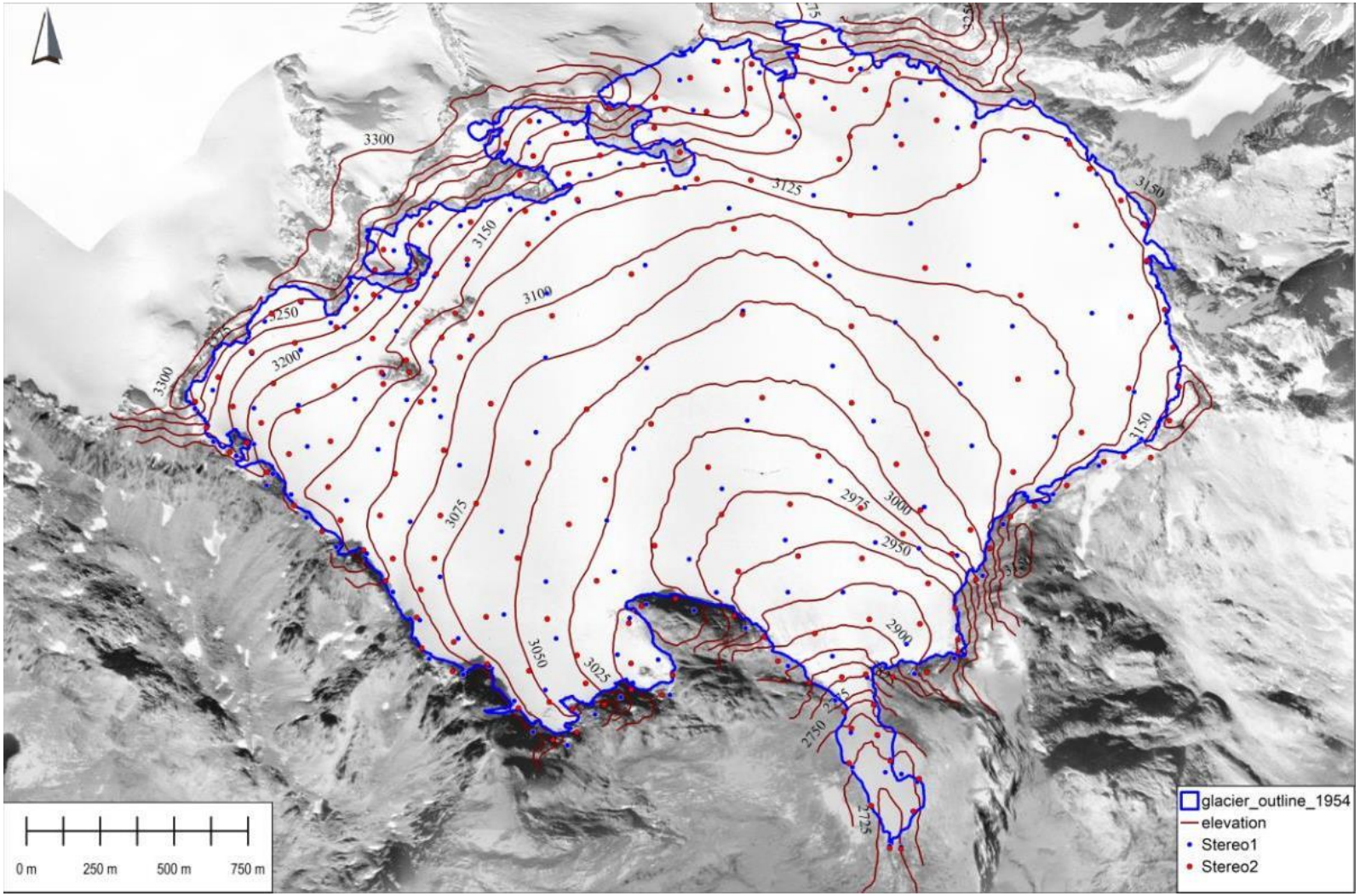
3D & Image quality: test on Careser

Glaciers outlines in 1954 (~ 5 km^2) and 2015 (1,63 km^2)



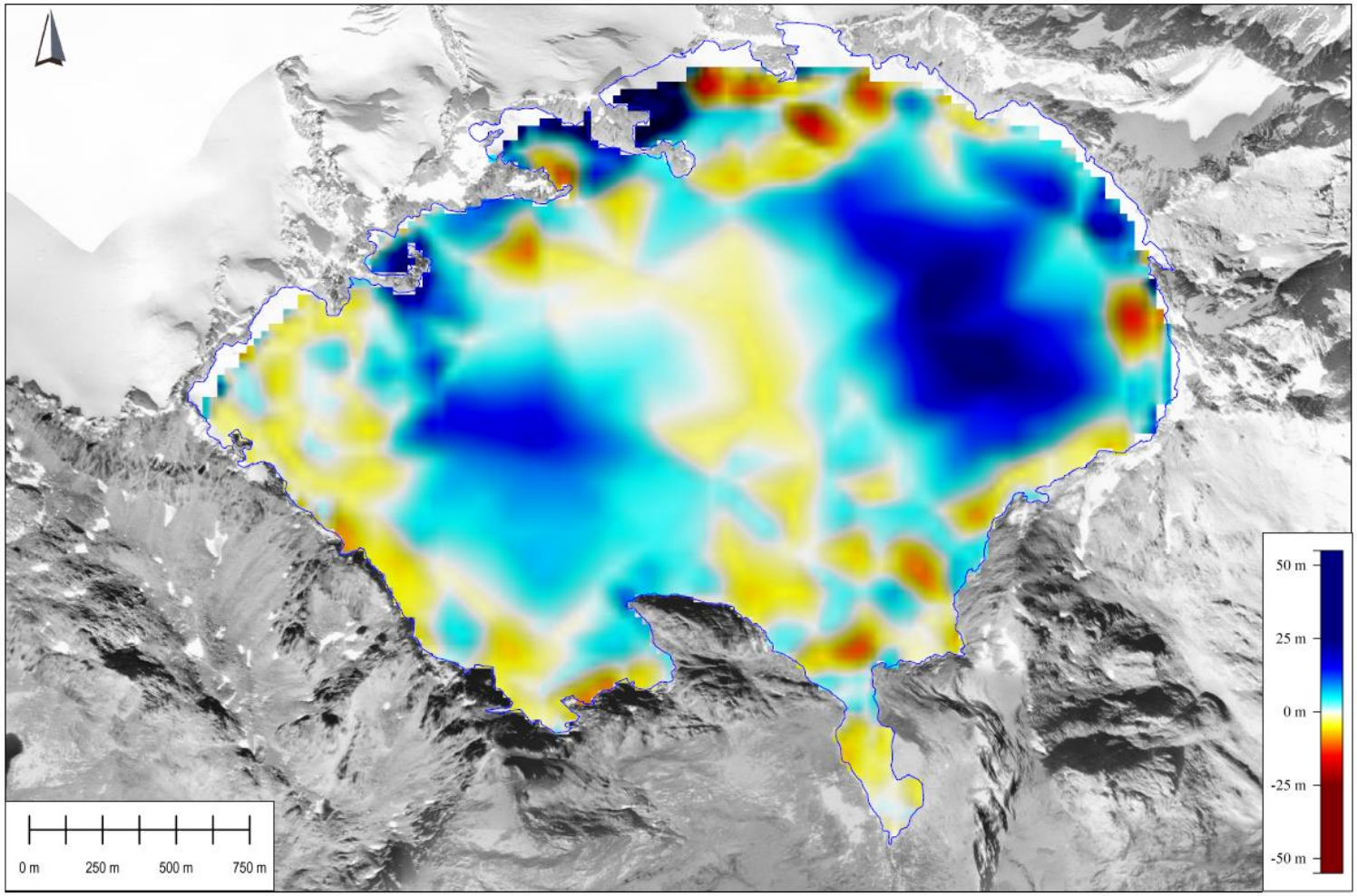
3D & Image quality: test on Caseres

Digitized contour lines, 2 sets of stereo measurements with same operator



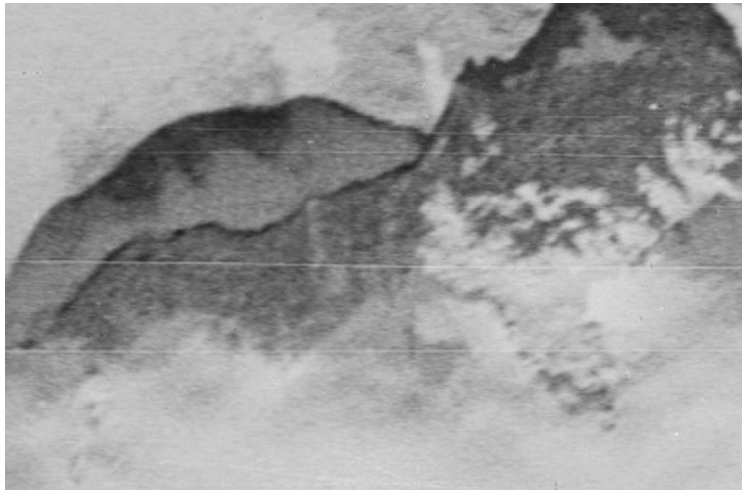
3D & Image quality: test on Caseres

- Generation of 3 independent DEMs
- Significant differences in manual stereo models!
  - overexposed areas, higher elevations with low structure and very homogeneous surface



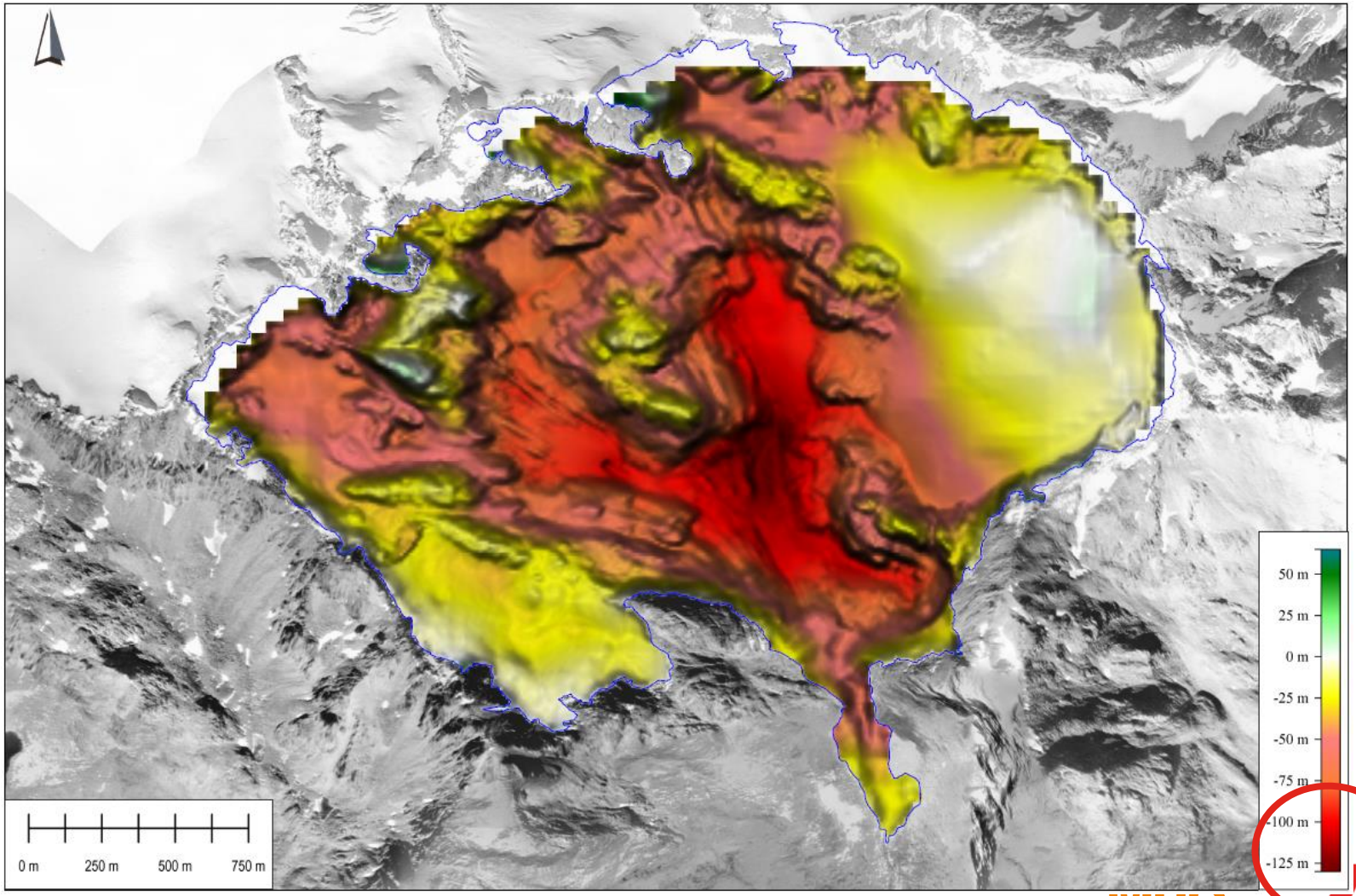
3D & Image quality: test on Busazza glacier

- Test on Dense Image Matching
  - 3 images
  - AT accuracy around 1 m
  - Two commercial softwares
- Unsatisfactory results:
  - Noise
  - Not reliable estimated coordinates
- Possible reasons:
  - Insufficient overlap
  - Low radiometric quality
- Successful approach in 2015 flight



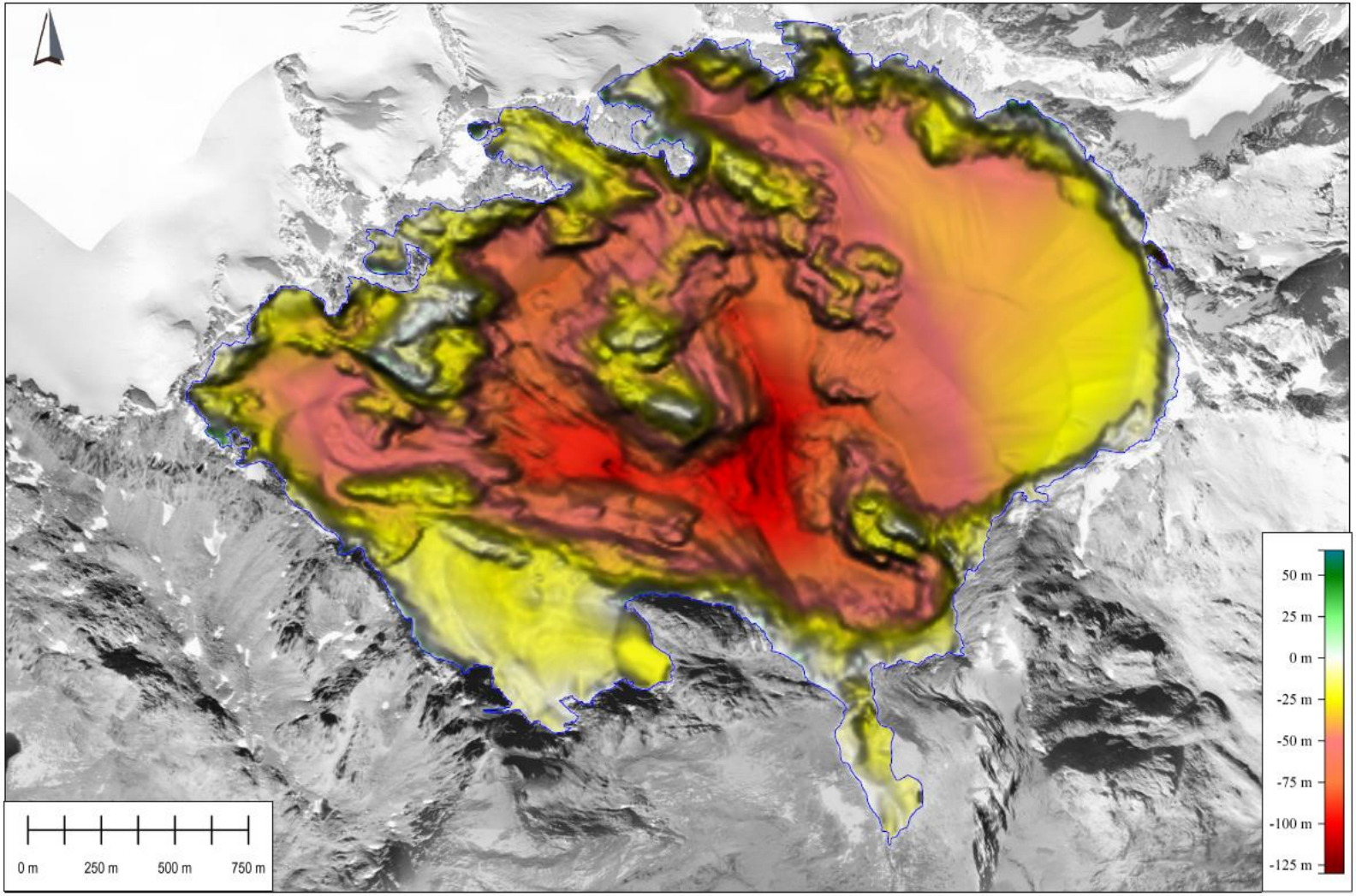
3D Temporal comparisons

- Comparisons between 1954 (stereo) and 2015



3D Temporal comparisons

- Comparisons between 1954 (contour lines) and 2015



3D information extraction

Unique approach not possible with low resolution aerial images

Manual measurements

- Image quality acceptable in small distinct regions
- Historical maps not available

Dense image Matching

- Image quality acceptable in large regions

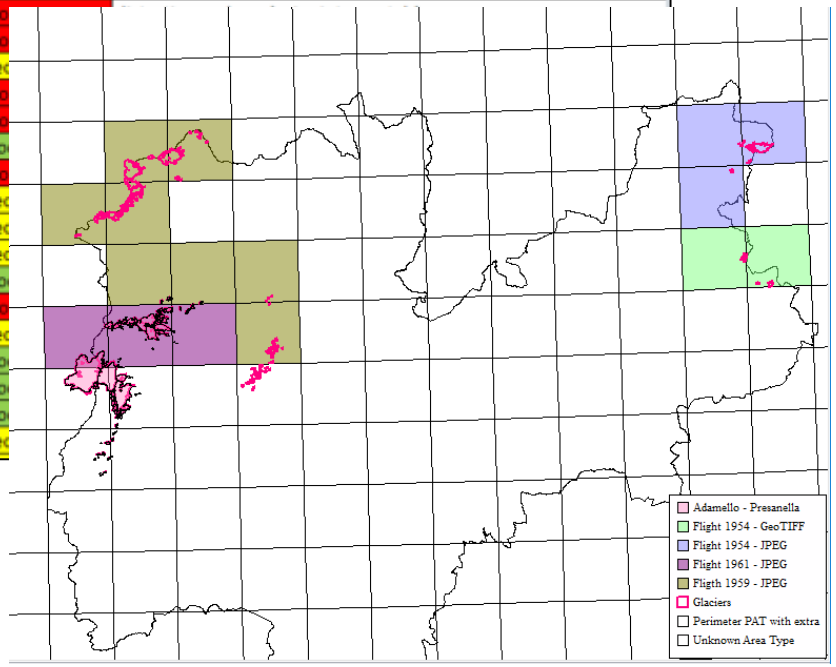
Contour line digitalization

- Image quality not acceptable

Strategy

- Glaciers classification according to data availability and quality
- Method definition for each area

	A	B	C	D	E	F
1	OBJECTID	NOME	CODICE	cod_PEG	Classification *)	Comments **)
2	1	Ghiacciaio di Vernel inf 1	943.1	TNMAR02a1	medium	double imaging, low contrast between rock and ice
3	2	Ghiacciaio di Vernel inf 2	943.2	TNMAR02a2	good	remnant glacier parts
4	3	Ghiacciaio Inferiore di Vernale	945.1	TNMAR05a	medium	low contrast between glacier foreland, distortion at southern bord
5	4	Ghiacciaio della Busa dei Camosci (settore Nord) 1	946.1a	TNPAL04a	poo	
6	5	Ghiacciaio della Busa dei Camosci (settore Nord) 2	946.1b	TNPAL04b	poo	
7	6	Ghiacciaio di Val Pestacapre	665.4	TNBRE40	med	
8	7	Ghiacciaio delle Preson	665.7	TNBRE45	poo	
9	8	Ghiacciaio Nord Occidentale di Cima Sassara	665.8	TNBRE46	poo	
10	9	Ghiacciaio di Ricolonda	674.2	TNPRE39	goo	
11	10	Ghiacciaio della Val Gelada di Tuenno	665.3	TNBRE39	poo	
12	11	Ghiacciaio del Passo Cagalatin	668.0	TNPRE29	med	
13	12	Ghiacciaio Settentrionale Inferiore di Cima Scarpacò	673.1	TNPRE34	med	
14	13	Ghiacciaio del Passo di Stavel 1	677.0a	TNPRE41b2	med	
15	14	Ghiacciaio Orientale della Busazza inf. 1	681.0a	TNPRE42a2	goo	
16	15	Ghiacciaio del Passo d'Amola	644.1	TNPRE21a2	poo	
17	16	Ghiacciaio nord-occidentale del Monte Cercen	680.0	TNPRE42c	med	
18	17	Ghiacciaio di presena orientale 1	683.0a	TNPRE43b2	goo	
19	18	Ghiacciaio nardis ovest 2	640.0b	TNPRE16a4	goo	
20	19	Ghiacciaio nardis ovest 1	640.0a	TNPRE16b	goo	
21	20	Ghiacciaio Nord Orientale della Cima Quattro Cantoni	642.0	TNPRE21c2	med	



Remarks & Conclusions

- Photogrammetry as a useful tool for glaciologists for historical (and current) glacier monitoring:
  - Larger extent, reduced field work, continuous (vs punctual) information
- Glacier delimitation:
  - 3D stereo measurements improve the information from 2D orthophoto digitalization in several critical situations
  - Topographic maps do not always agree with the source aerial images, in case of Careser below 2.800 m
- 3D (height, volume) analysis:
  - Very high value information from historical images!
  - No other comparable source

Remarks & Conclusions

- Historical aerial images
  - Standard processing feasible (i.e. AT, OP, stereo plotting)
  - Main shortcoming: low radiometry on glaciers
  - DIM might be successful on other datasets
- Heterogeneous approach for 3D data extraction, according to data quality and availability
- Future steps:
  - completion of the modelling on the other glaciers
  - DIM tests on other historical flights

Thank you for your attention!