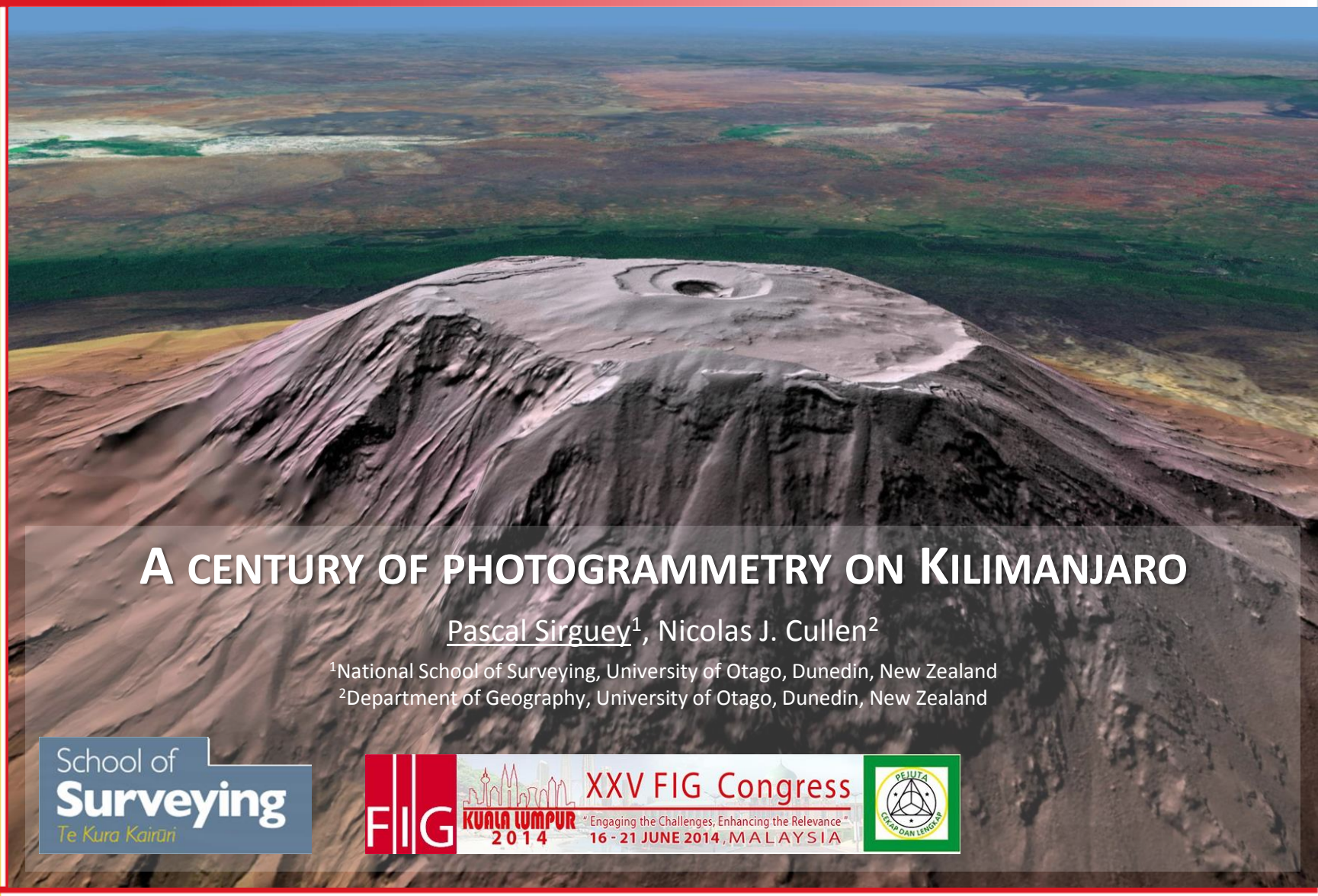

A CENTURY OF PHOTOGRAMMETRY ON KILIMANJARO

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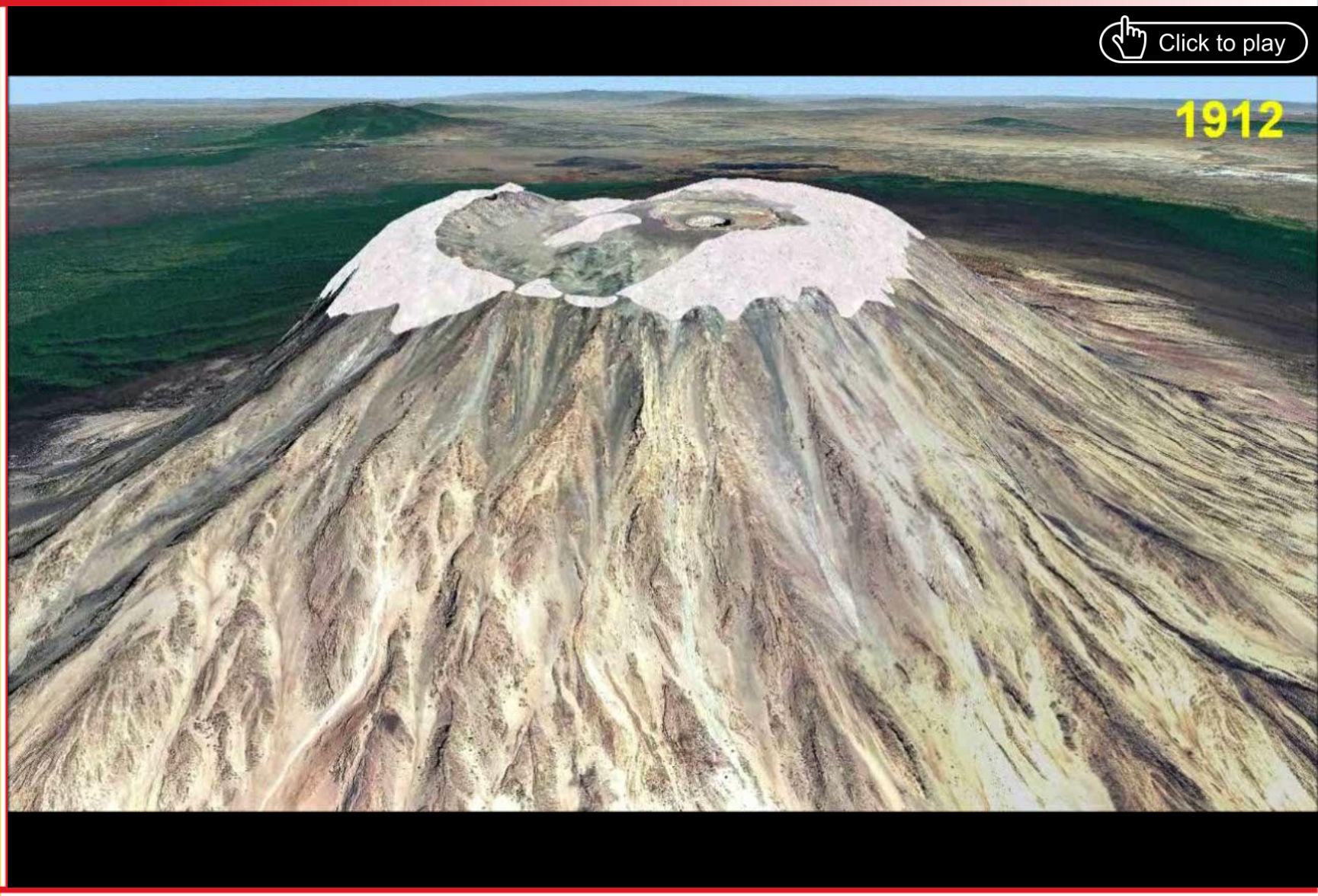
School of Surveying
Te Kura Kairūri

FIG XXV FIG Congress
KUALA LUMPUR 2014 "Engaging the Challenges, Enhancing the Relevance"
16 - 21 JUNE 2014, MALAYSIA

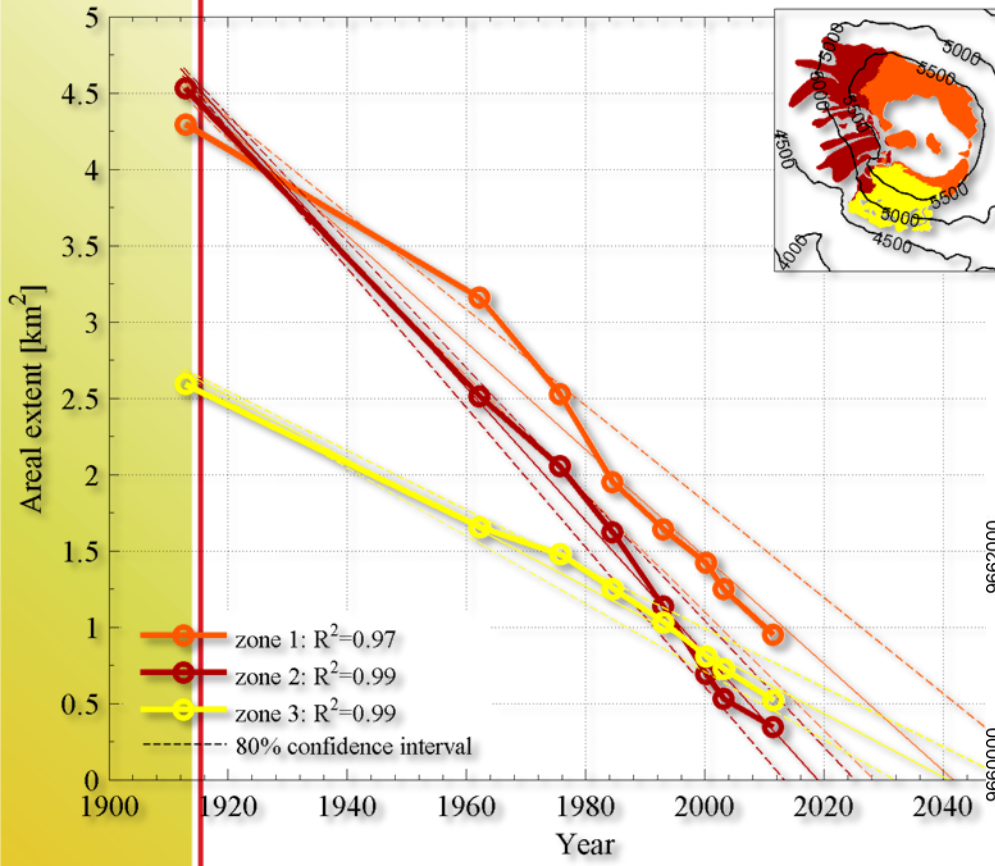
A century of ice retreat, the mapping reloaded

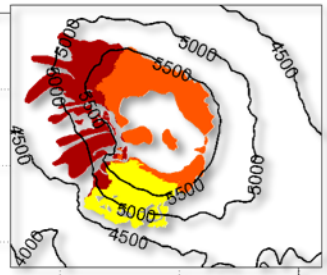


Cullen *et al.* (2013)

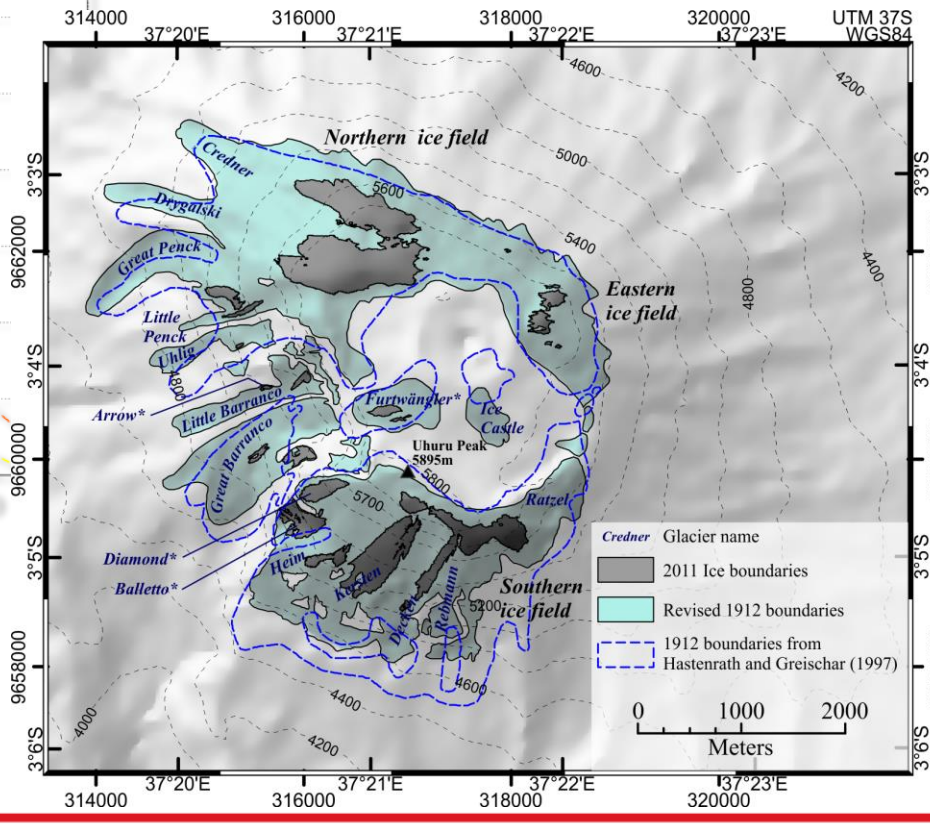
A century of ice retreat, the mapping reloaded

Areal extent retreat sequence



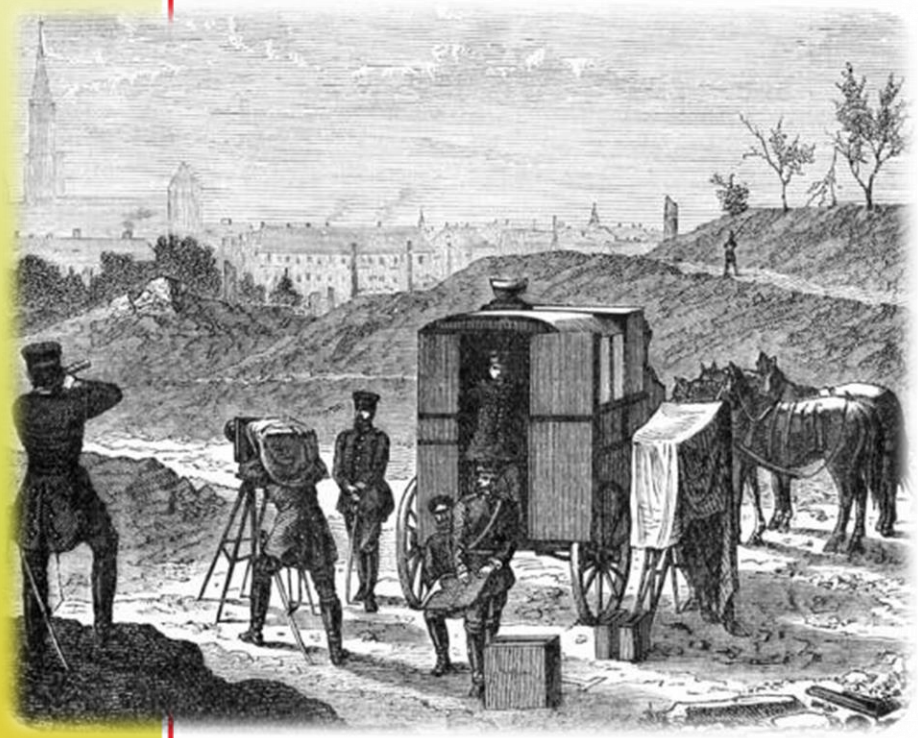


Cullen *et al.* (2012), A century of ice retreat on Kilimanjaro: the mapping reloaded, *The Cryosphere*, **7**(2), 419-431, doi: 10.5194/tc-7-419-2013.

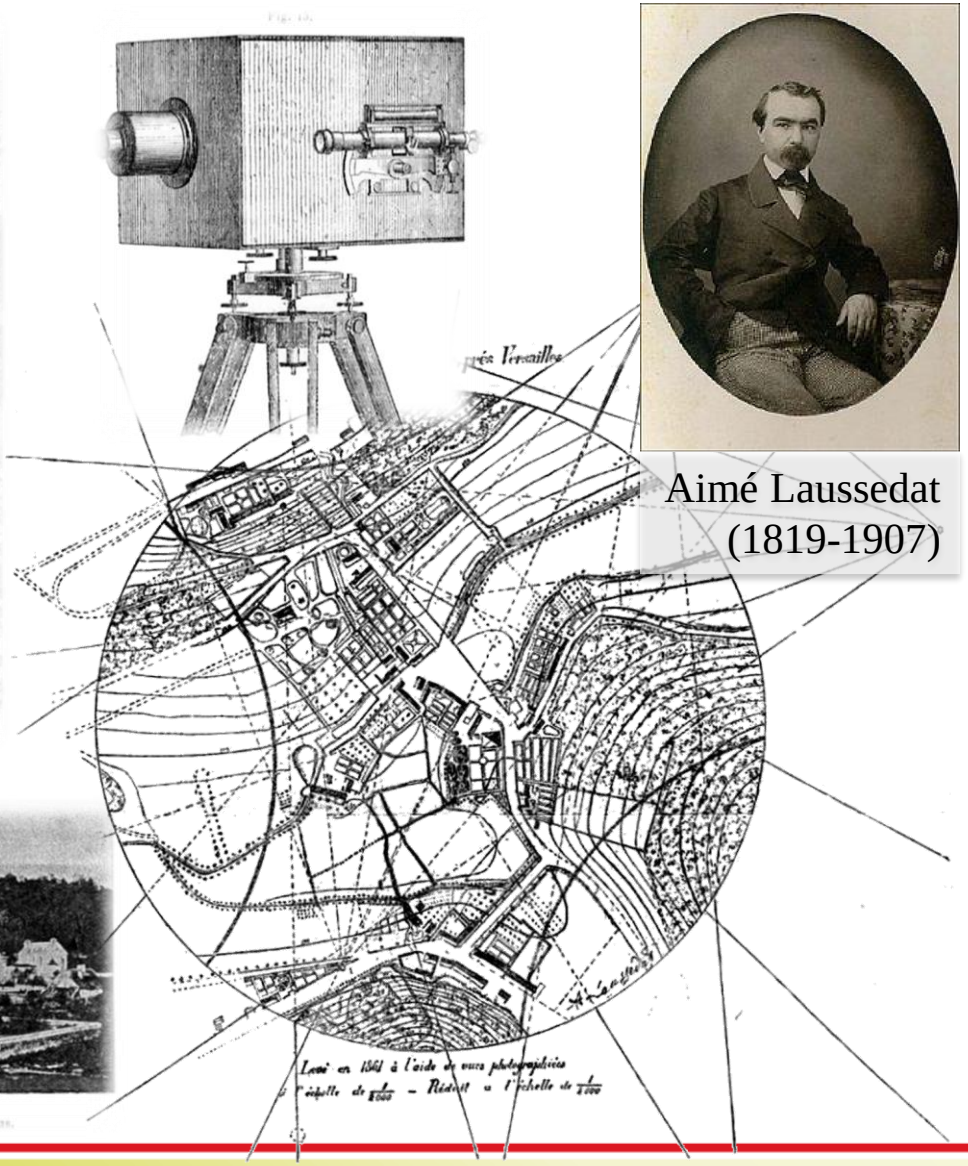


Celebrating the past…

Métrophotographie



Aimé Laussedat
(1819-1907)



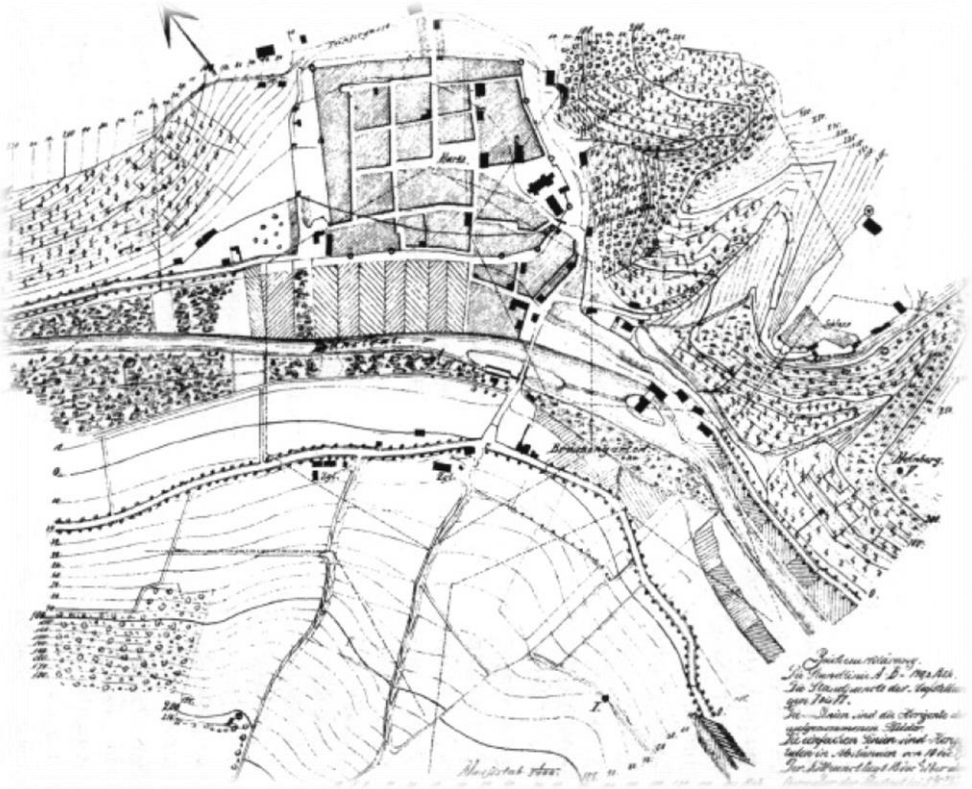
Plan d'un village levé en 1861 à l'aide de la Photographie.

First comprehensive topographic survey obtained by "*Métrophotographie*", township of Buc, near Versailles, France, 1861 (Laussedat, 1899).

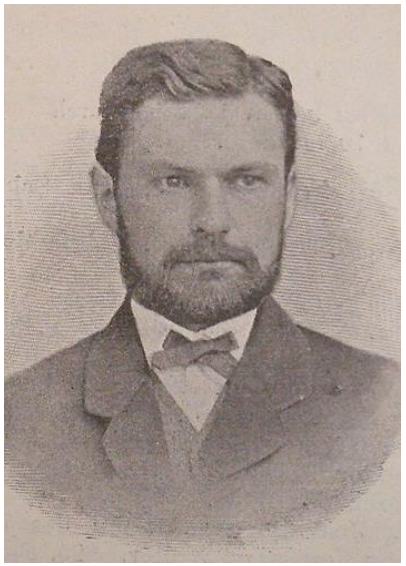
Celebrating the past…

Photometrographie

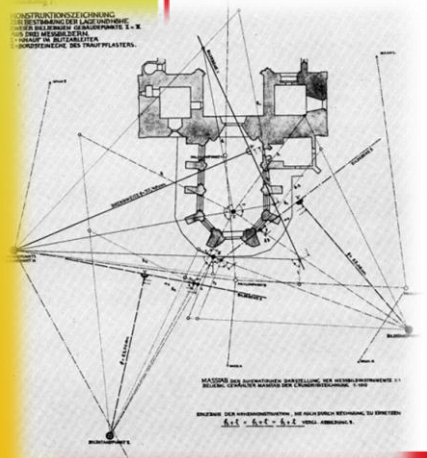
Albrecht Meydenbauer
(1834-1921)



Map of Freyburg/Unstrut from 1867 constructed by means of terrestrial **Photometrographie** (Grimm, 2007)



Otto Kersten
(1839-1900)

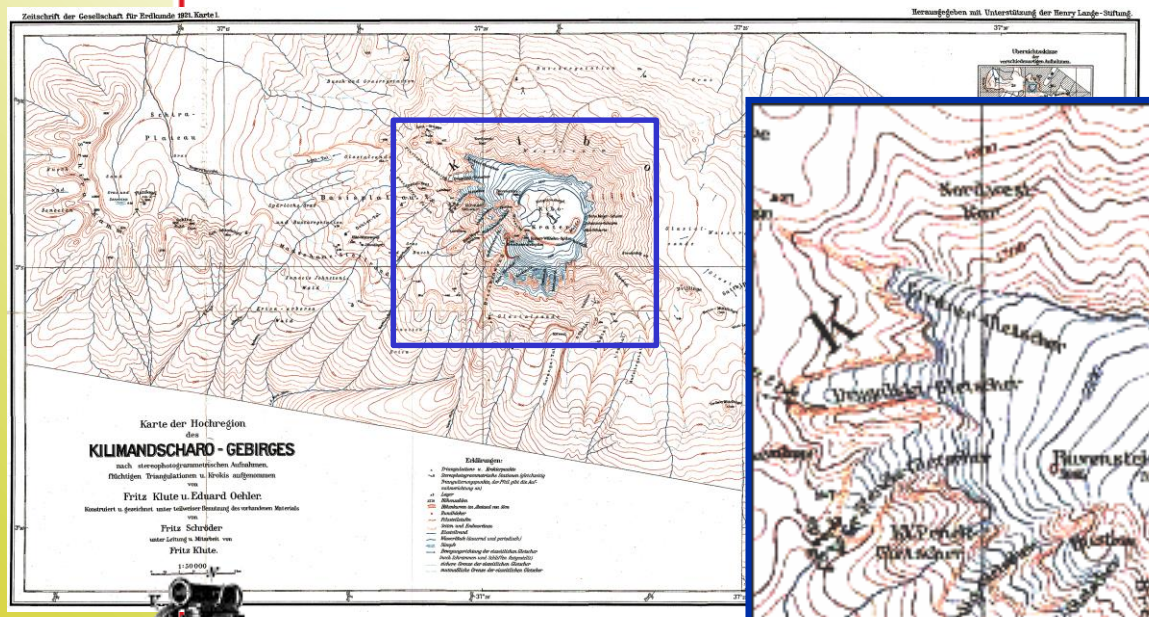


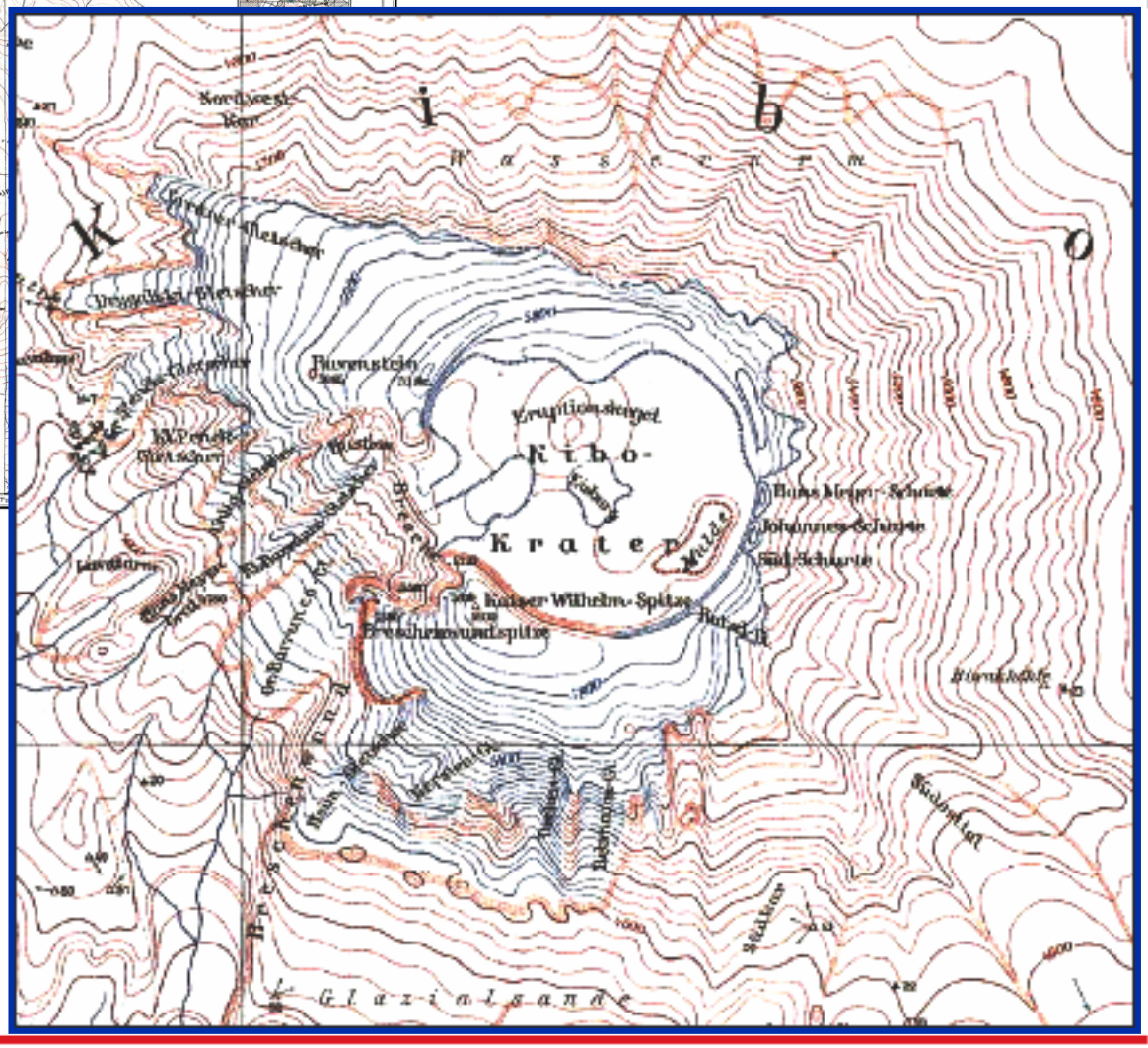
Cathedral of Wetzlar

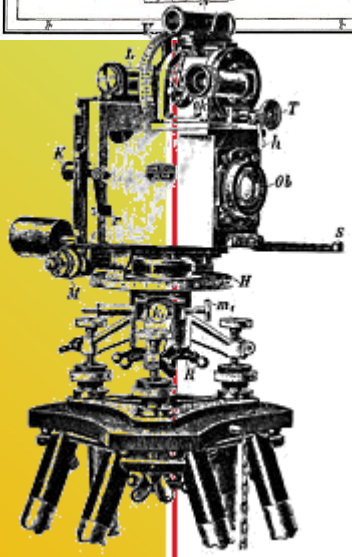
Coin the name Photogrammetry in 1867

Kilimanjaro, 100 years of photogrammetry

Ground photogrammetry 1912





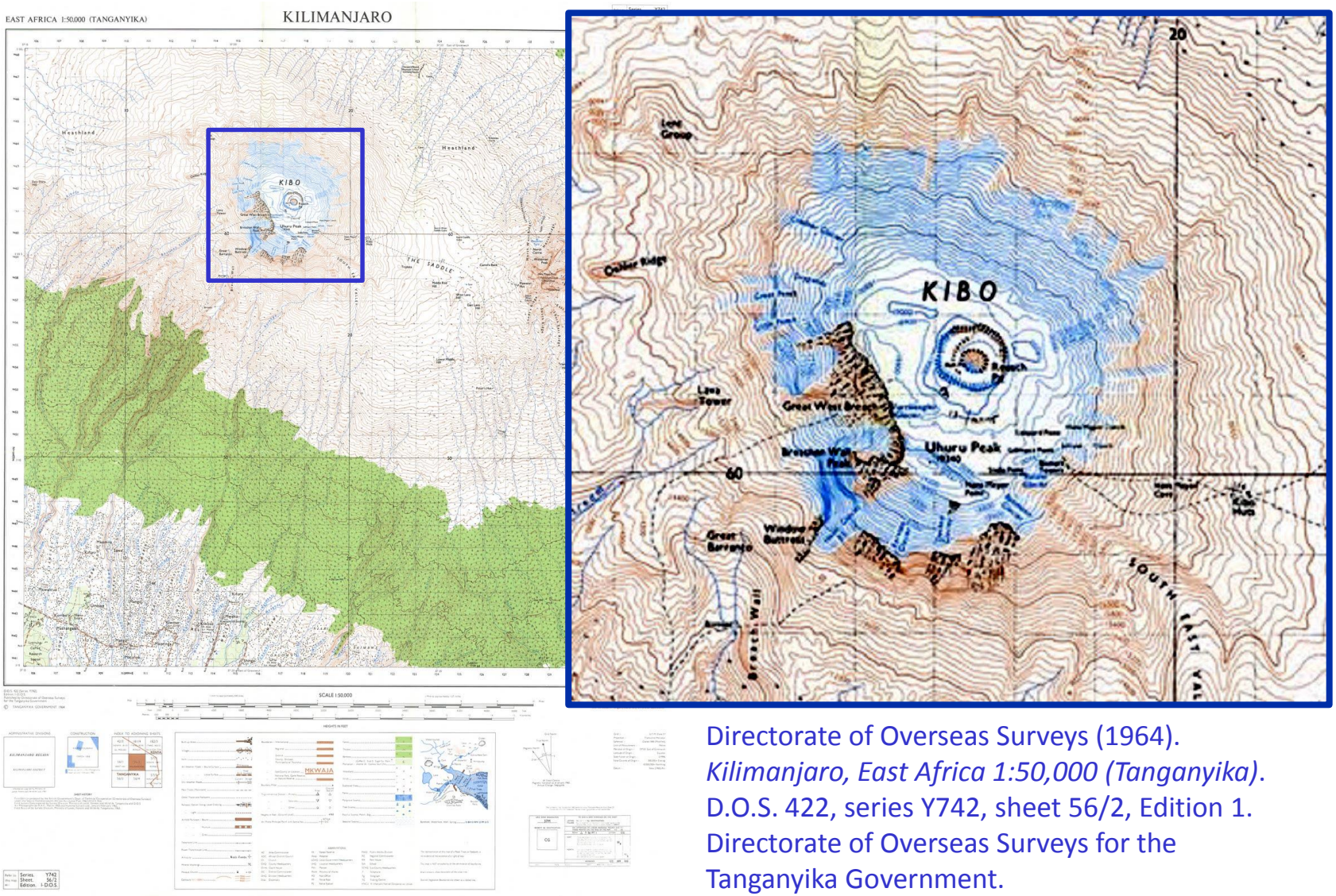


Klute, F. (1920). *Ergebnisse der Forschungen am Kilimandscharo*, 1912. Berlin: D. Reimer (E. Vohsen).

Carl Zeiss photo-theodolite 1908

Kilimanjaro, 100 years of photogrammetry

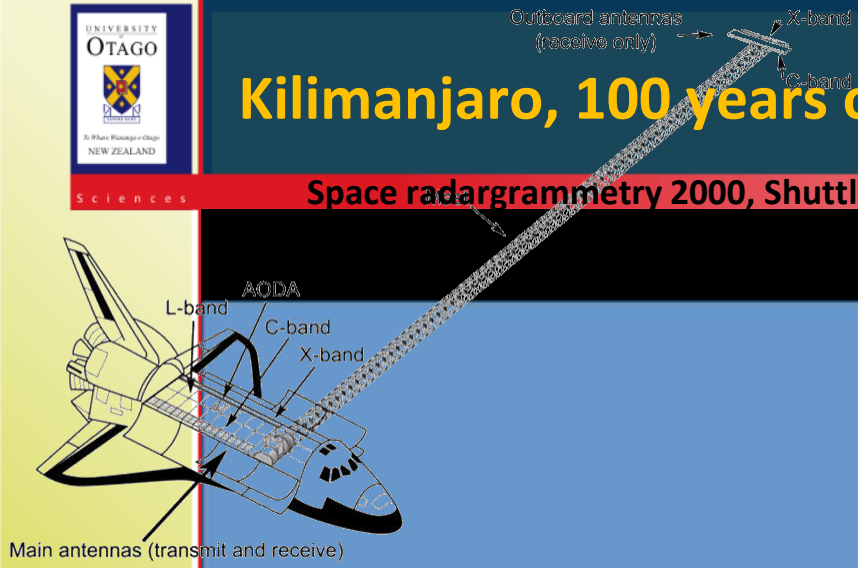
Aerial photogrammetry 1962



Directorate of Overseas Surveys (1964). *Kilimanjaro, East Africa 1:50,000 (Tanganyika)*. D.O.S. 422, series Y742, sheet 56/2, Edition 1. Directorate of Overseas Surveys for the Tanganyika Government.

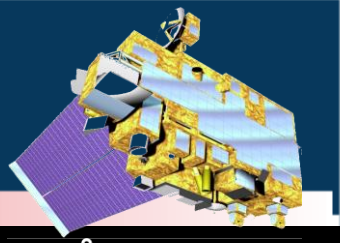
Kilimanjaro, 100 years of photogrammetry

Space radargrammetry 2000, Shuttle Radar Topography Mission (SRTM), 90m



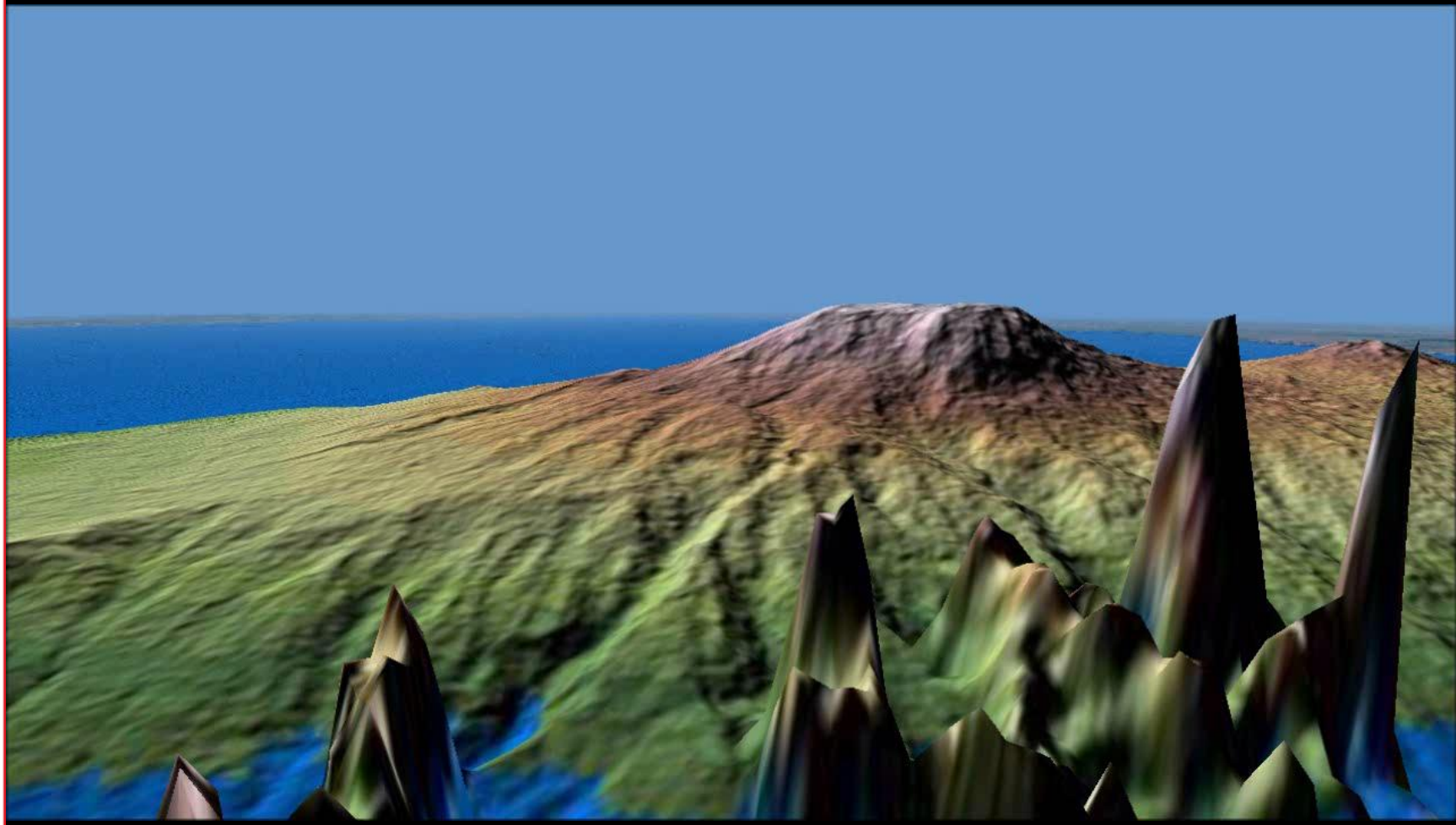
Click to play

Kilimanjaro, 100 years of photogrammetry

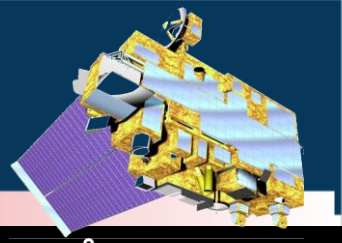


ASTER GDEM V2, 30m

Click to play

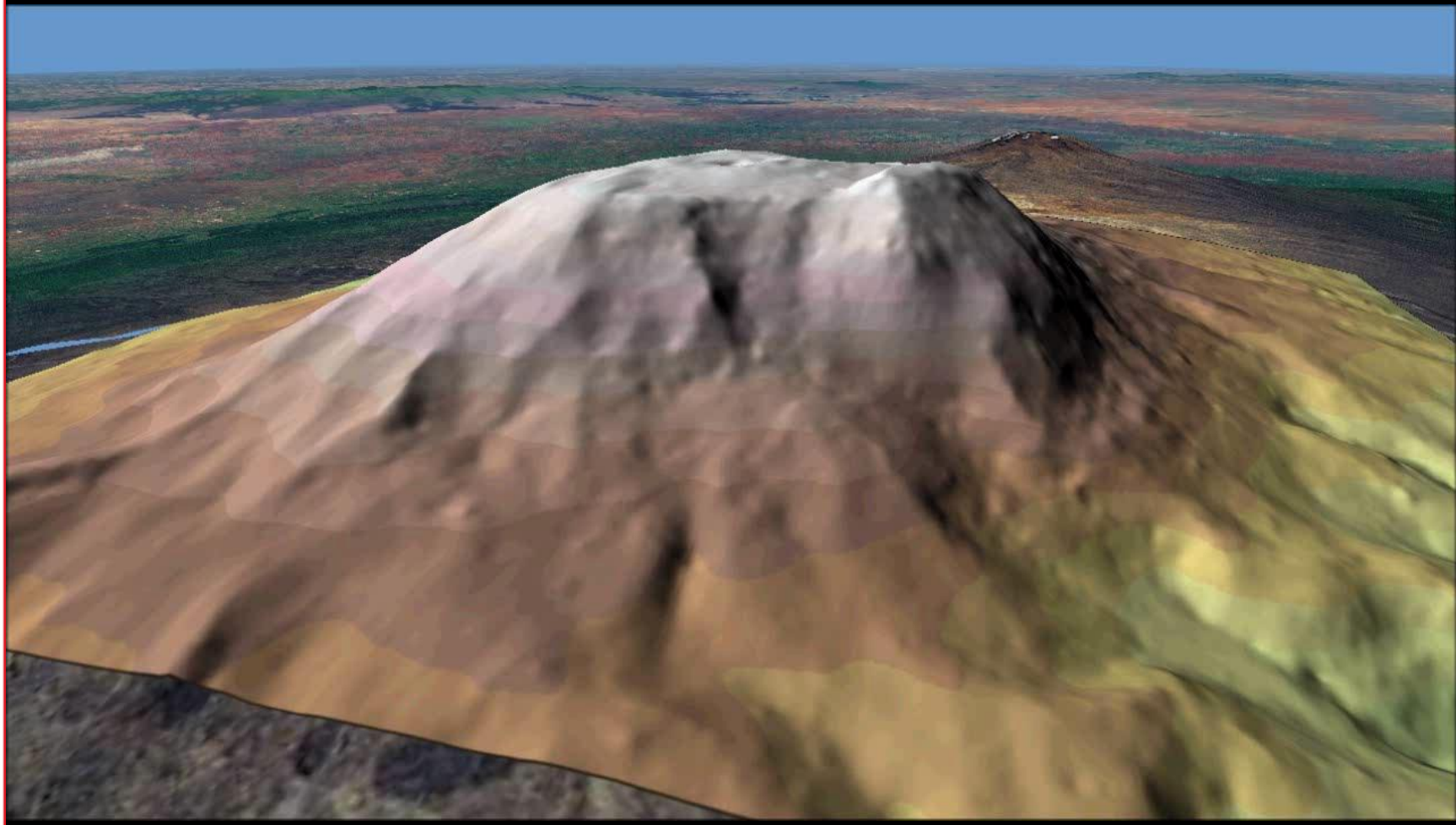


Kilimanjaro, 100 years of photogrammetry



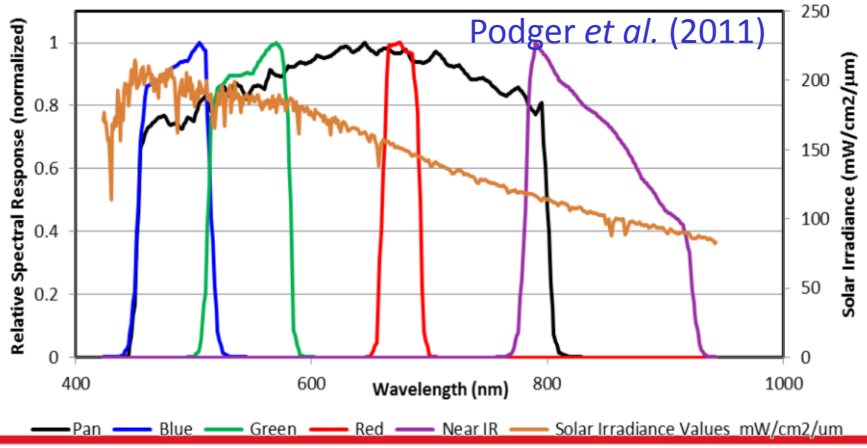
ASTER 19 August 2004, 15m

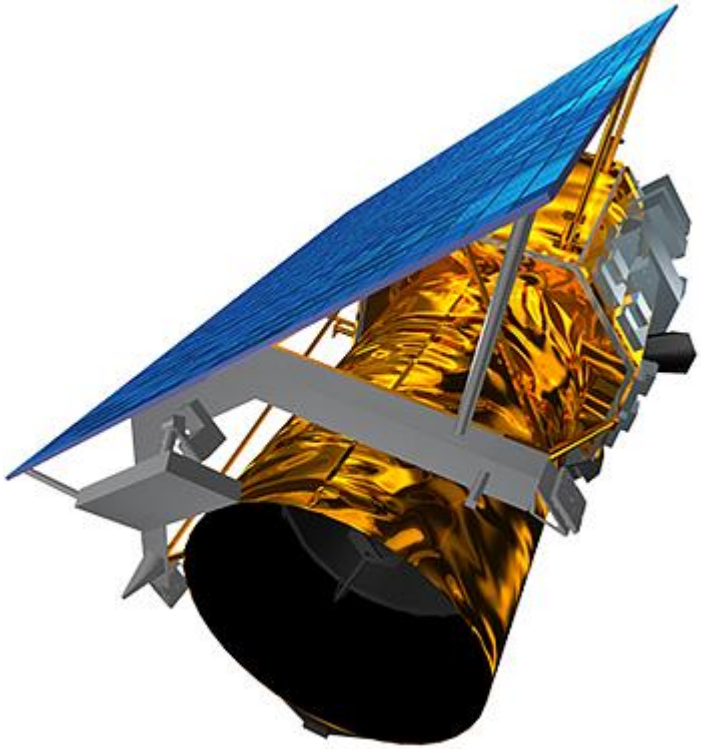
Click to play



GeoEye-1 imagery

Launch Date	September 6, 2008
Orbit	682km, 98.1° inclination 10:30am local time equatorial crossing
Spatial Res.	PAN: 0.41 m XS: 1.65 m
Spectral Res.	PAN: 450 - 800 nm Blue: 450 - 510 nm Green: 510 - 580 nm Red: 655 - 690 nm NIR: 780 - 920 nm
Temporal Res.	Up to 2.1 days
Radiometric Res.	11 bits



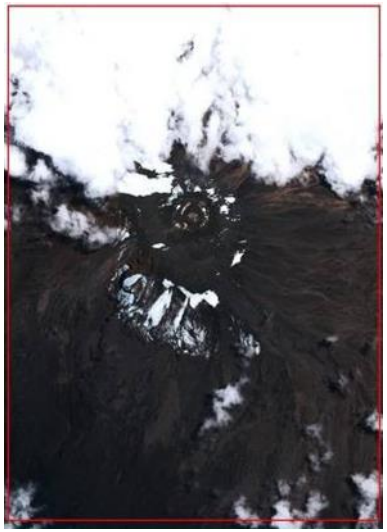


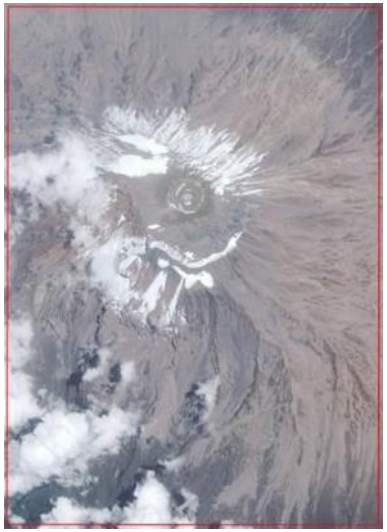
GeoEye-1 Satellite Sensor - Image Credit: GeoEye

.50-Meter	Positional Accuracy		
	CE90	LE90	NMAS
GeoStereo	4 m	6 m	1:5,000
Precision	2 m	3 m	1:2,500

Multi-ray photogrammetry of GeoEye-1 imagery

GeoEye Imagery



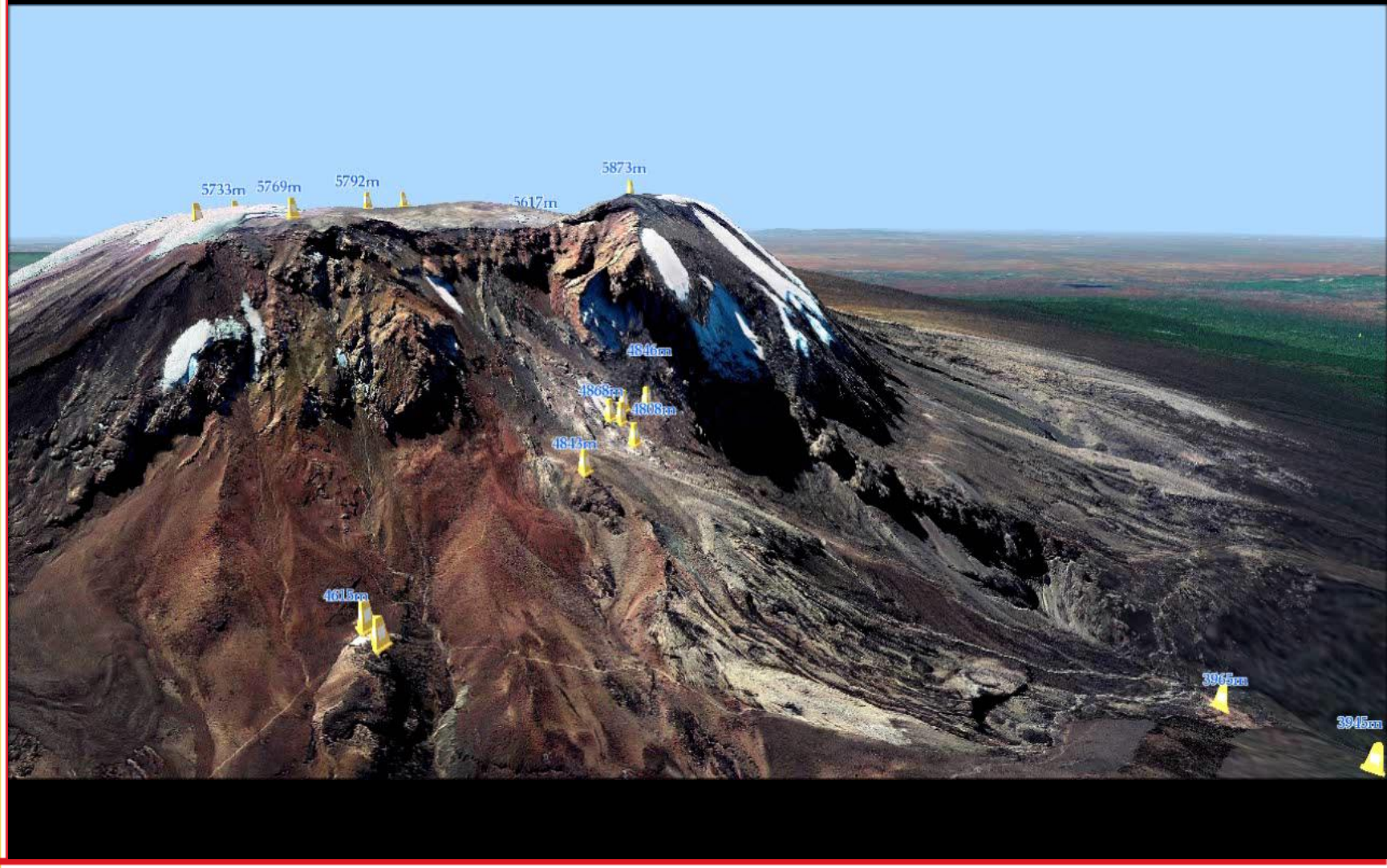


Date of stereo pair (GMT)	Pixel size [m]	Cloud [%]	View Azim.	View Elev.
20 Sep 2012, 7:58	0.50	25	226.6	74.3
07:57	0.50	30	354.5	61.6
9 Oct 2012, 07:49	0.50	65	33.8	61.3
07:50	0.50	52	147.1	74.1
20 Oct 2012, 07:50	0.50	59	33.8	64.4
07:51	0.50	54	155.8	73.3
23 Oct 2012, 07:59	0.50	68	345.7	61.6
08:00	0.50	57	258.2	75.5
24 Jan 2013, 07:48	0.50	22	68.7	71.8
07:49	0.50	23	156.7	64.4

Sirguey & Cullen (2013, 2014)

Multi-ray photogrammetry of GeoEye-1 imagery

Ground Control Points (20-26 September 2012)



Sirguey & Cullen (2013, 2014)

Multi-ray photogrammetry of GeoEye-1 imagery

Triangulation and accuracy assessment

- 20 GCPs (Leica GS20 DGPS) (20-26/09/2012)
  - Reference: MAL2 IGS, Malindi, Kenya (270km)
- ~300 Tie Points
  - Tie all dates together in a single image block
- Independent assessment via Leave-one-out cross validation

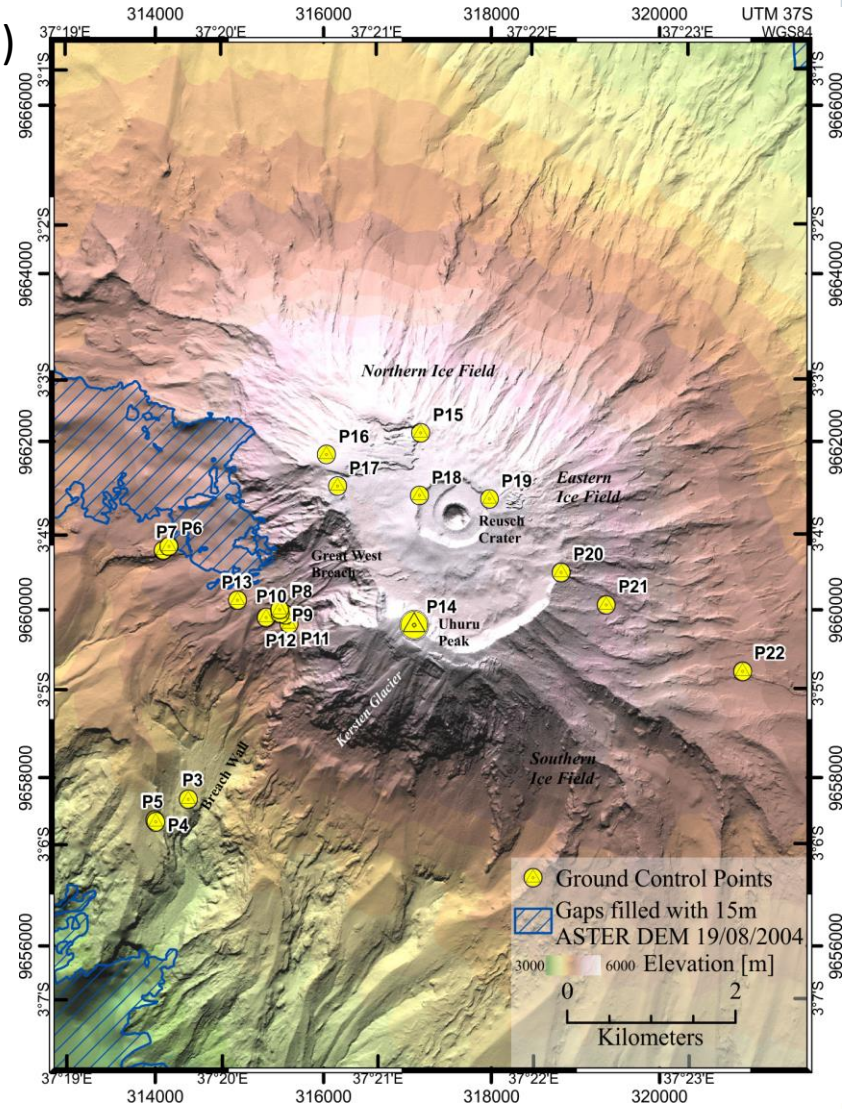
Table 1. Results of the image triangulation.

Image blocks	Pixel size [m]	Image RMSE [px]	Residuals of the control points [m]		
			RMS_x	RMS_y	RMS_z
GeoEye-1	0.5	0.27	0.42	0.61	1.09
Leave-one-out cross validation:			**0.45**	**0.67**	**1.19**

Table 1. Accuracy of the final DEM product.

RMSE	CE90	LE90	NMAS
0.86 m	**1.31 m**	**2.12 m**	**1:1,600**

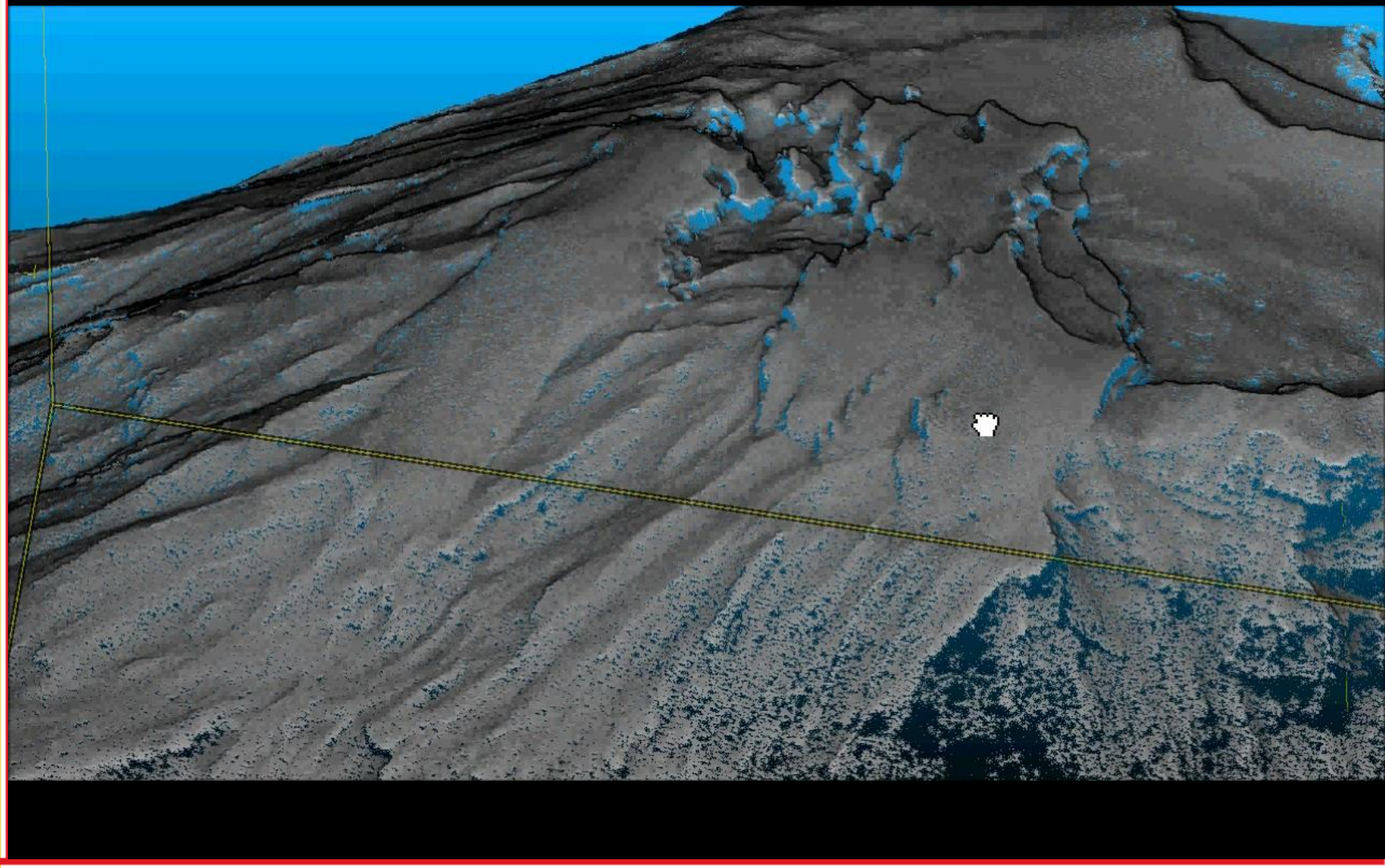
.50-Meter	Positional Accuracy		
	CE90	LE90	NMAS
GeoStereo	4 m	6 m	1:5,000
Precision	2 m	3 m	1:2,500



Sirguey & Cullen (2013, 2014)

Multi-ray photogrammetry of GeoEye-1 imagery

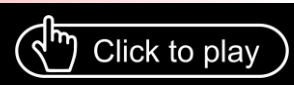
Point Cloud



Sirguey & Cullen (2013, 2014)

Mapping Kilimanjaro, photogrammetry strikes back…

KILISoSDEM2012



Sirguey & Cullen (2013, 2014)

Mapping Kilimanjaro, photogrammetry strikes back…

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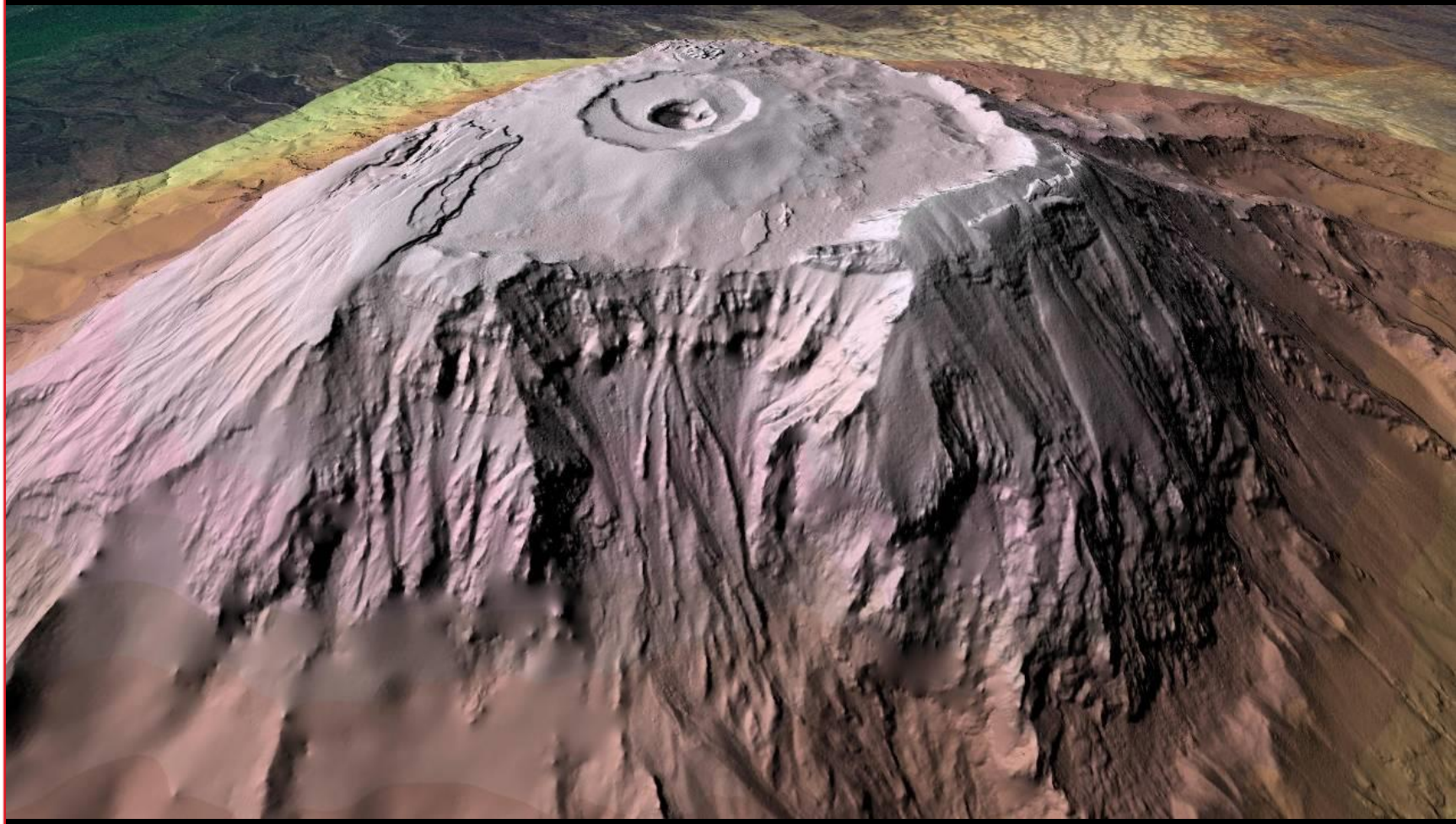

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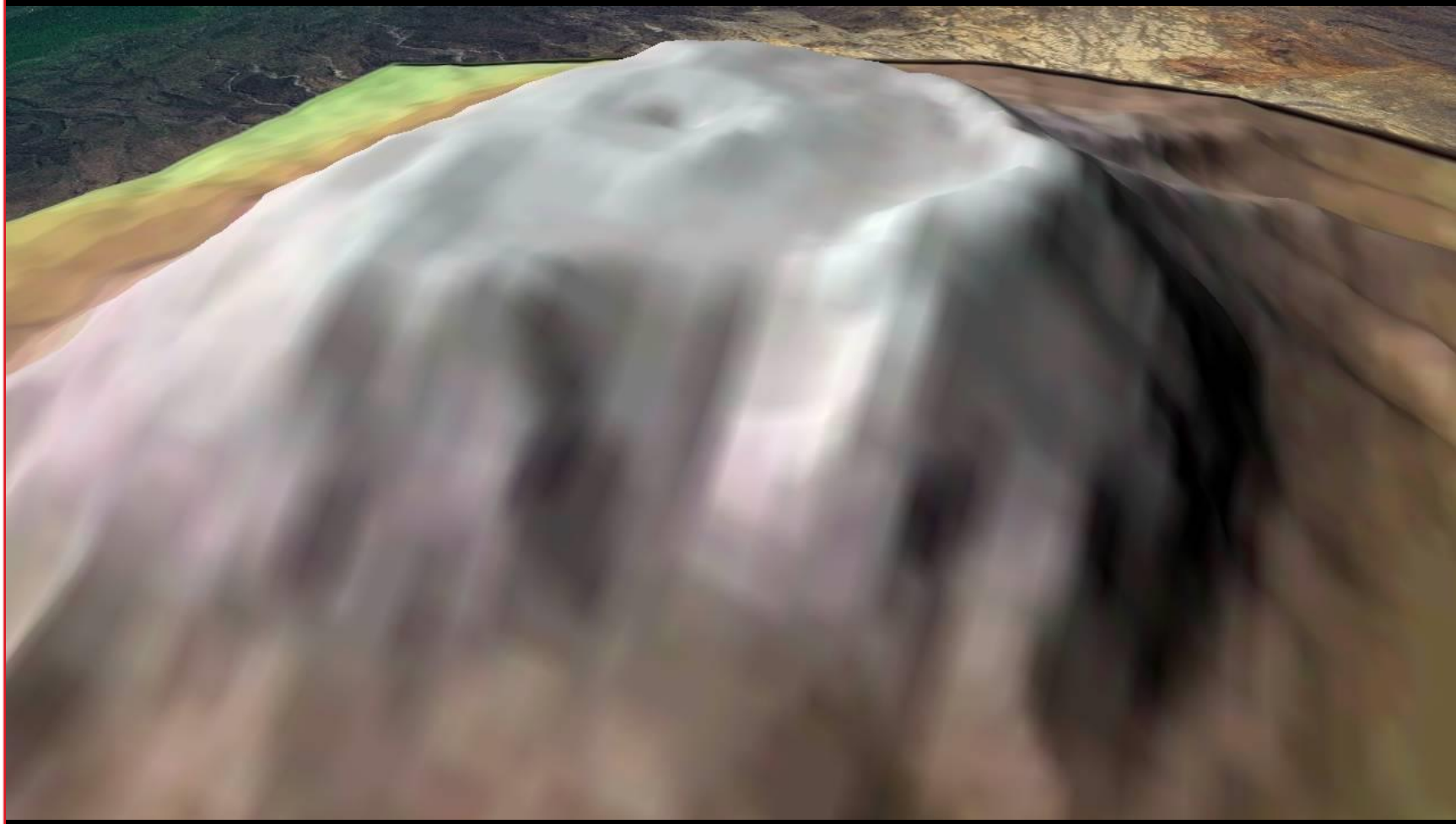
Space radargrammetry 2000, Shuttle Radar Topography Mission



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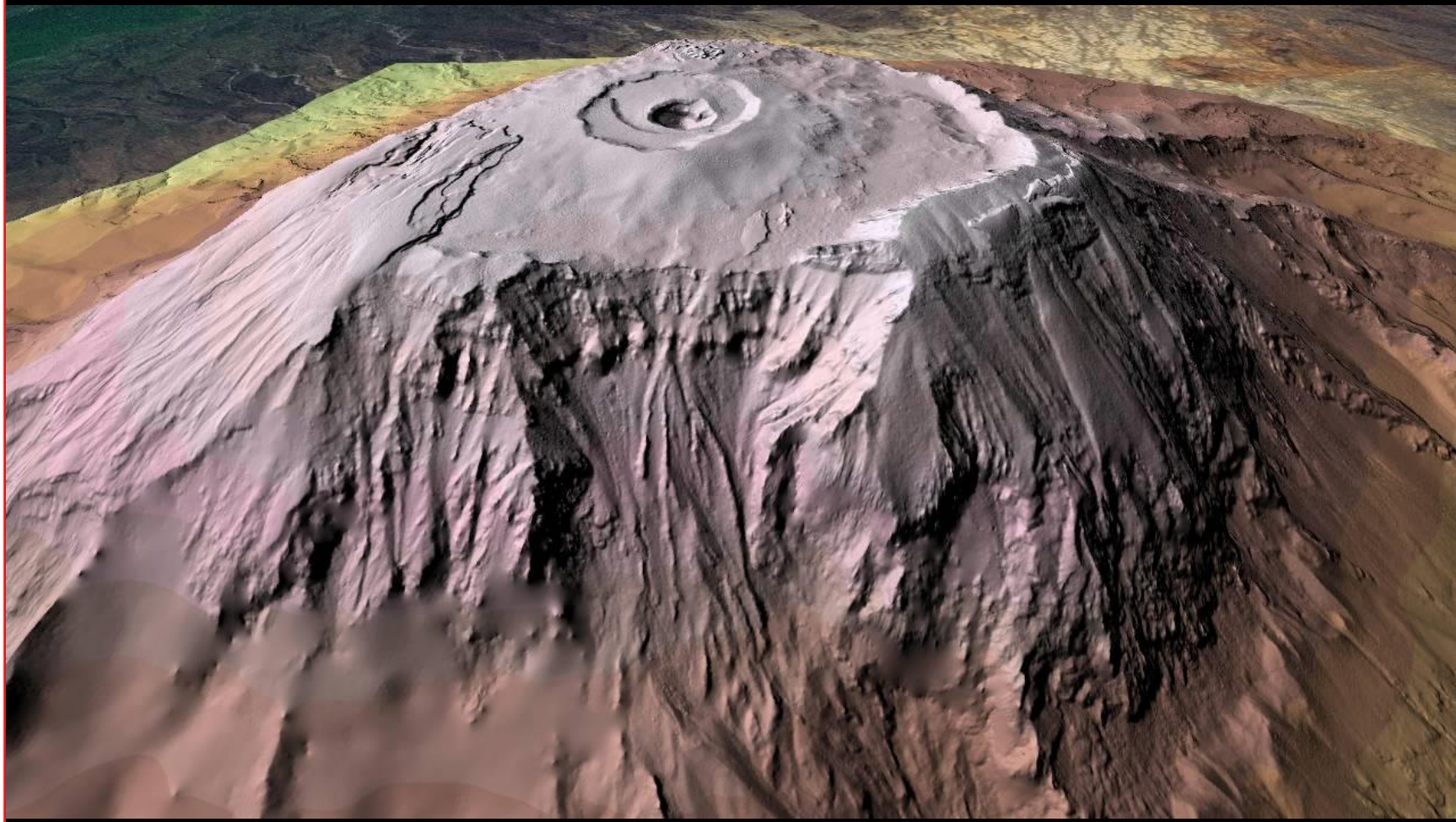
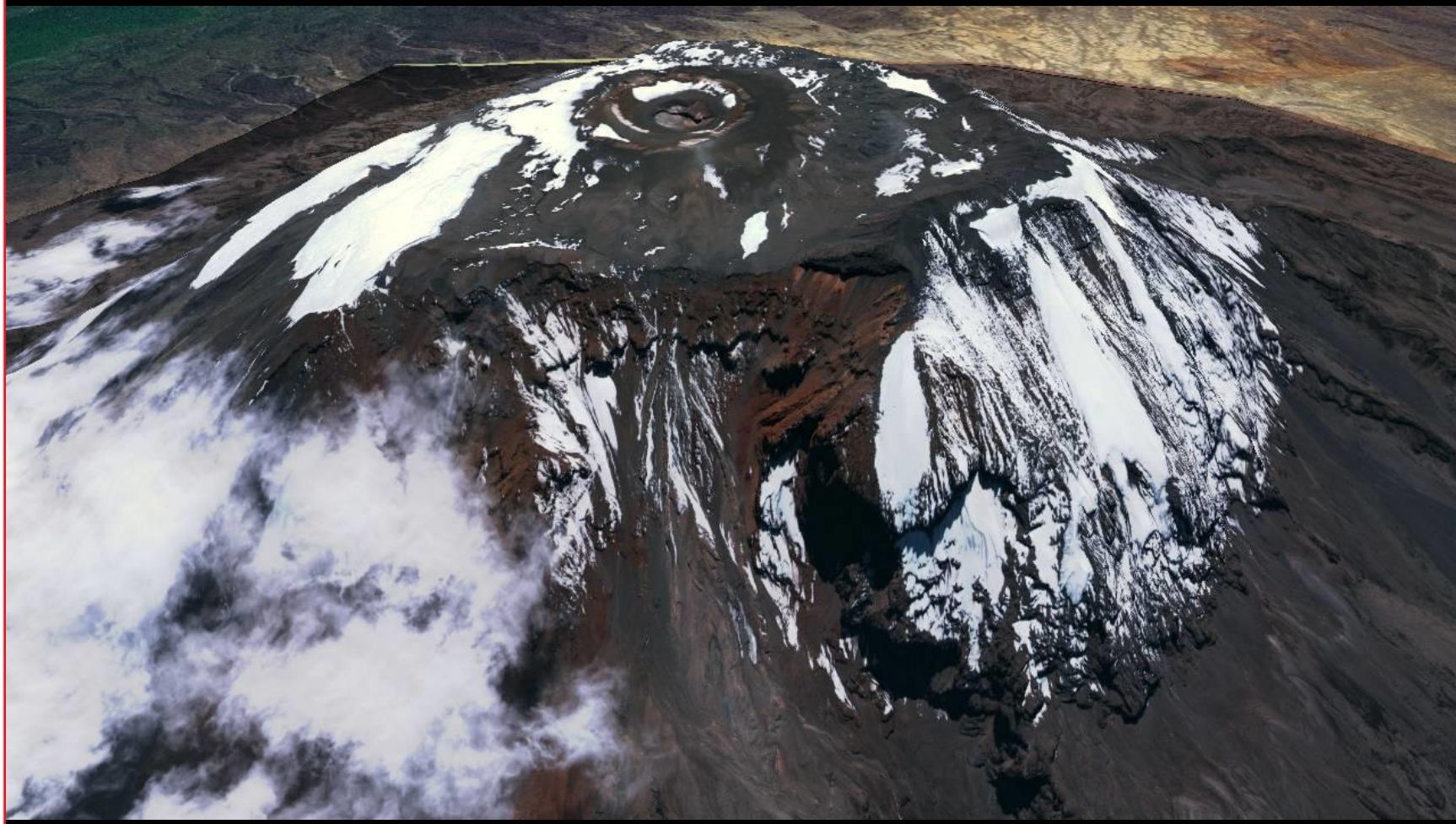
KILISoSDEM2012



Sirguey *et al.* (2014)

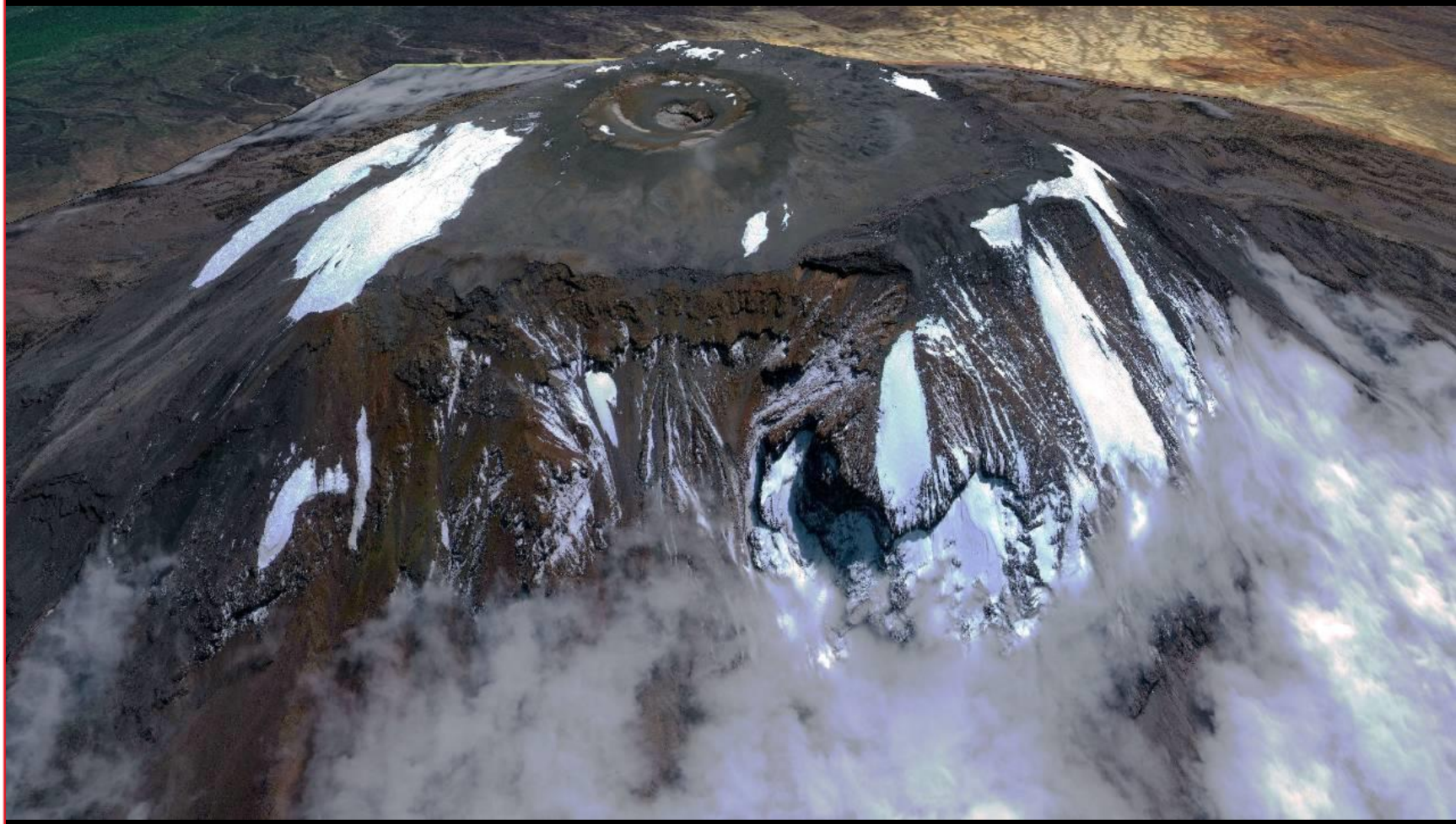
Mapping Kilimanjaro, photogrammetry strikes back…

Pan sharpened orthoimage: 20 September 2012



Mapping Kilimanjaro, photogrammetry strikes back…

Pan sharpened orthoimage : 23 October 2012



Take home points

- *Kilimanjaro and the photogrammetric science*
  - Intimate relationship with the story of photogrammetry
  - One of the test beds of photogrammetry

- *KILISoSDEM2012*
  - Multiray processing of Very High Resolution Stereo Imagery permits the generation of dense point cloud in rough terrain with metric accuracy.
  - KILISoSDEM2012 exceeds GeoEye Precision product by about 30%.
  - *A new DEM that provides new opportunities to study the topography of Kibo.*

THANKS, QUESTIONS?

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- Acknowledgments

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Te Kura Kairūri

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