Geoinformatic Data Acquisition, Validation and Geologic Application

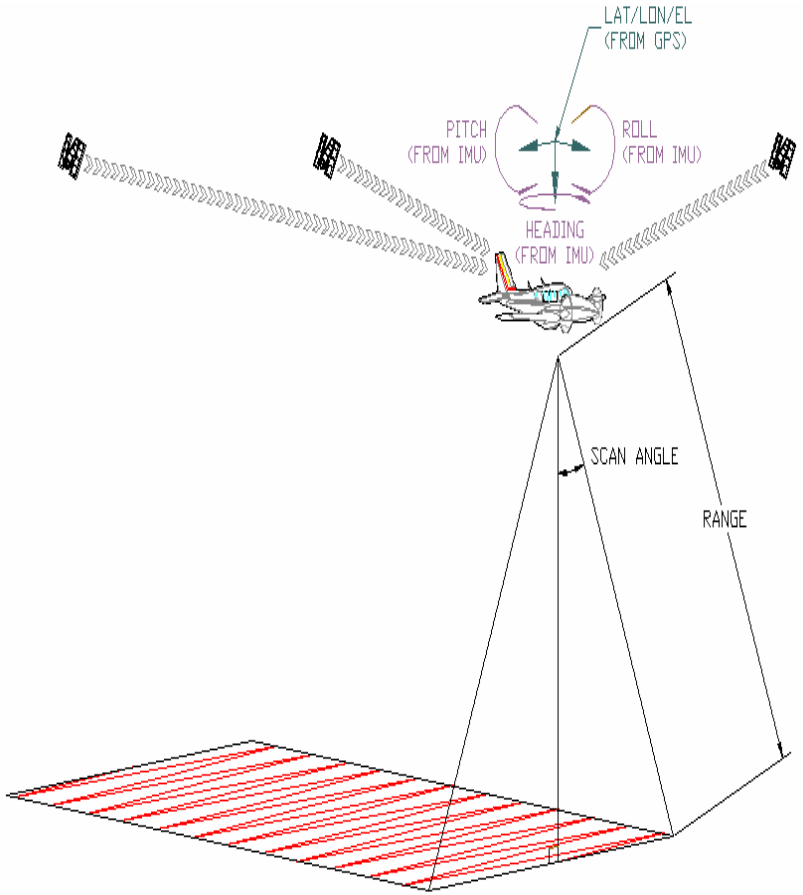
空間資訊擷取、驗證及地質應用

張國楨

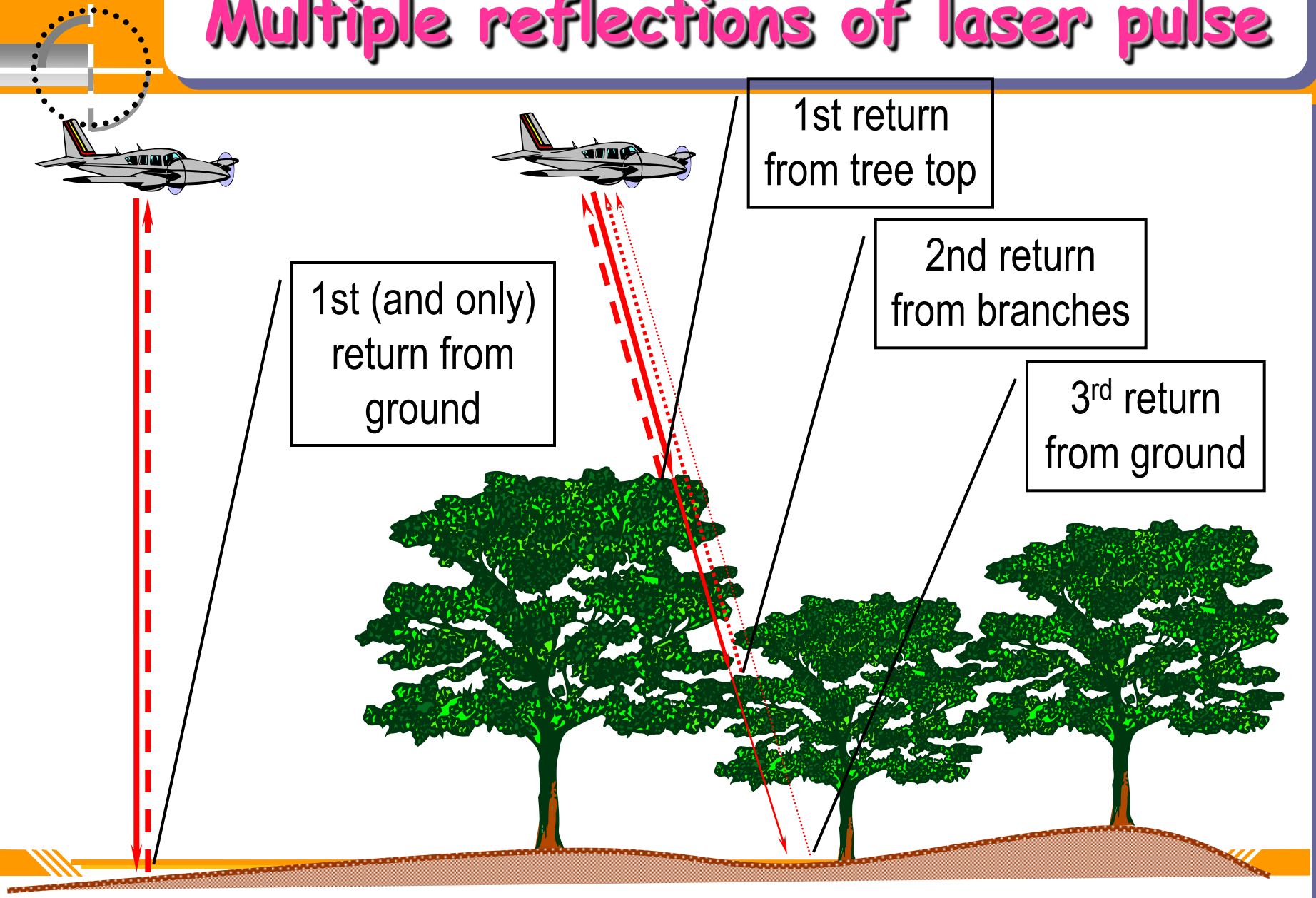
台北科技大學土木系

What is LiDAR & how does it work?

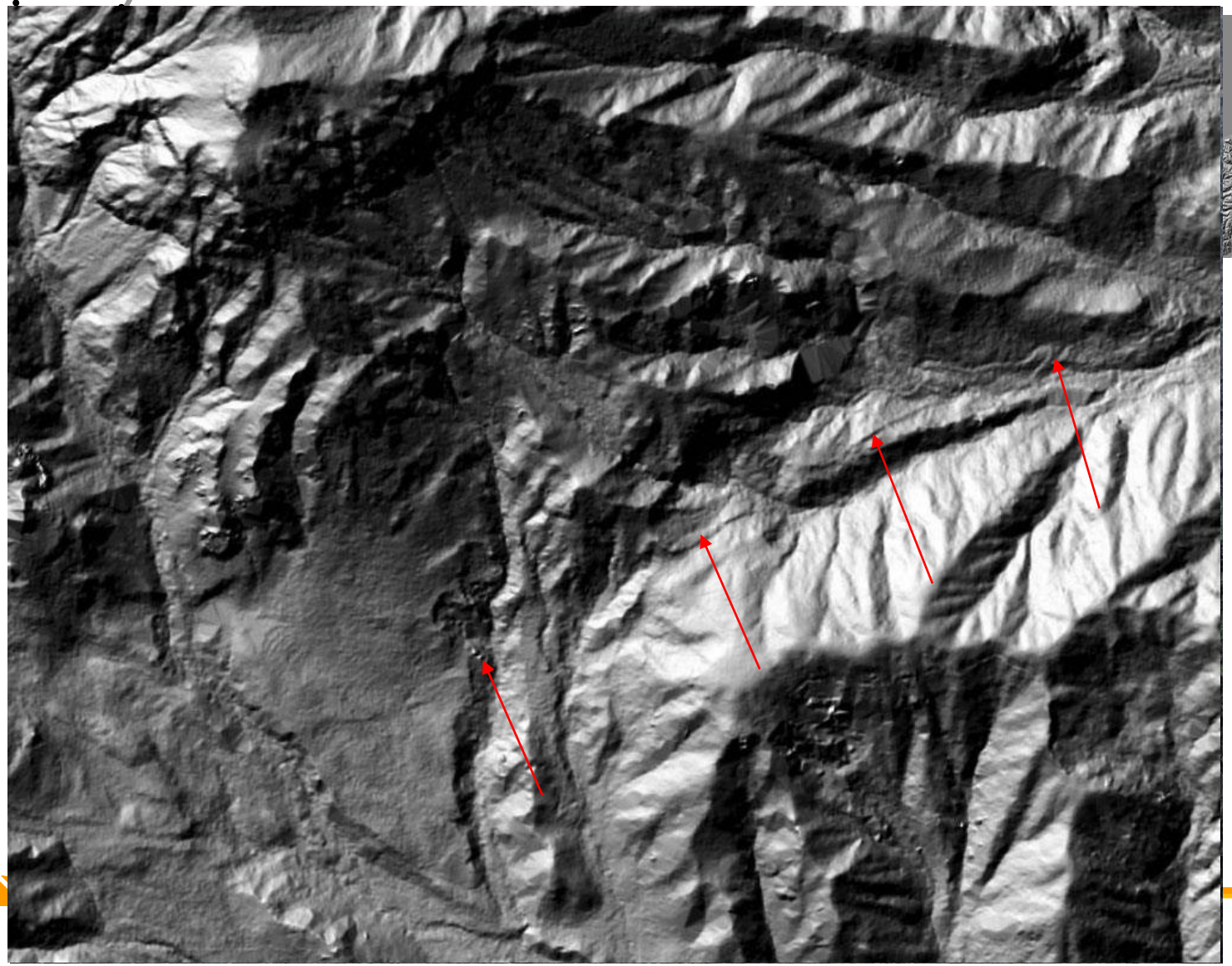
- Acquire lat/lon/el/intensity ground data sets based on:
  - aircraft position (GPS)
  - aircraft orientation (IMU)
  - Distance to target
  - return signal intensity
- Raw data recorded in air and on ground (DGPS base station)
- Recorded data post-processed on ground

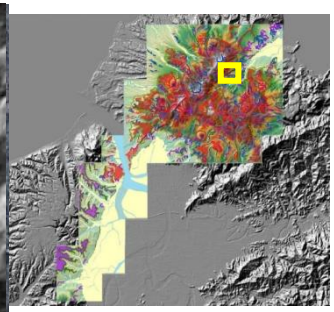


Multiple reflections of laser pulse

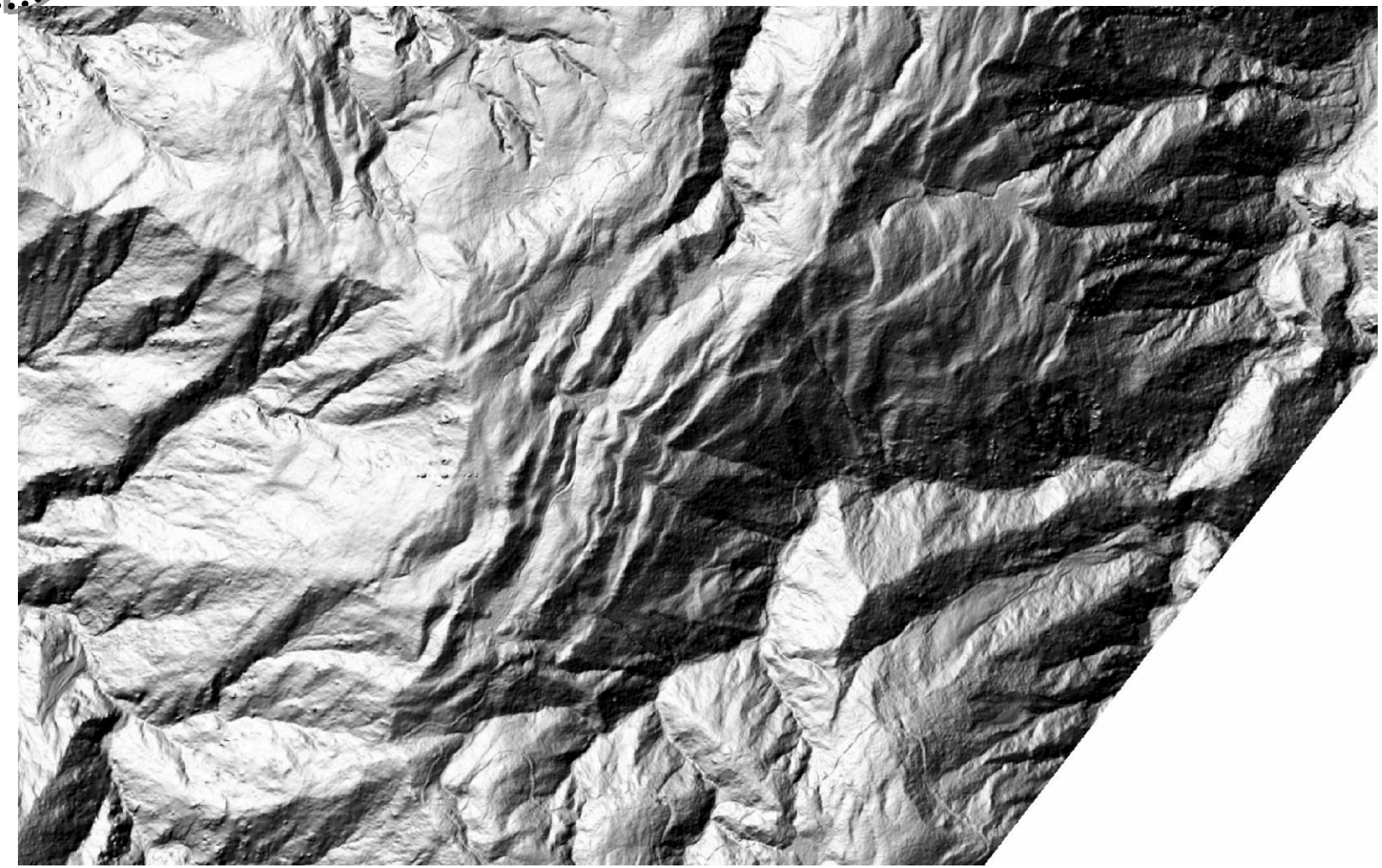


Normal Faults Traces Discovered by the LiDAR DTM in the Chutzeshan Region

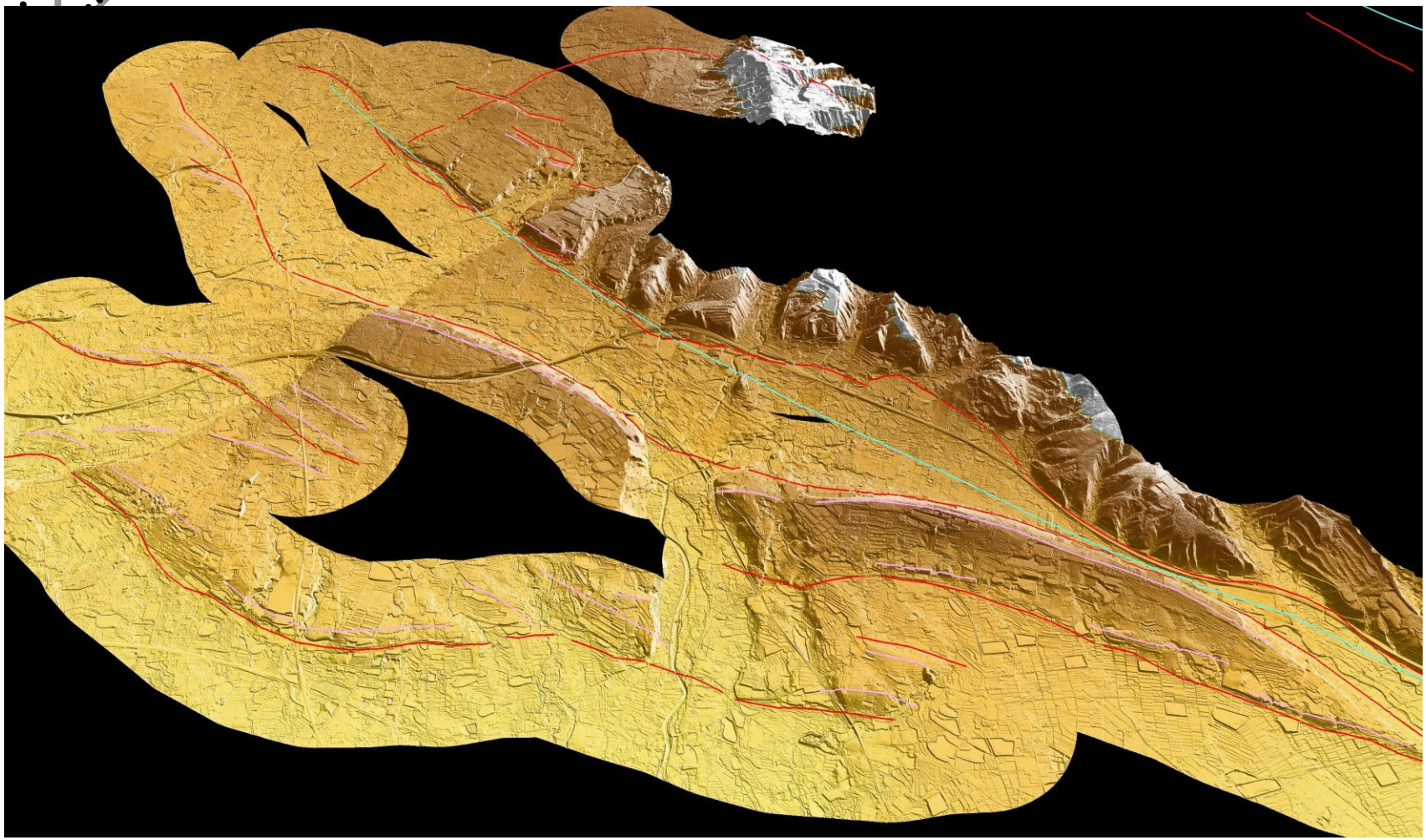




Landslide identification and fault mapping

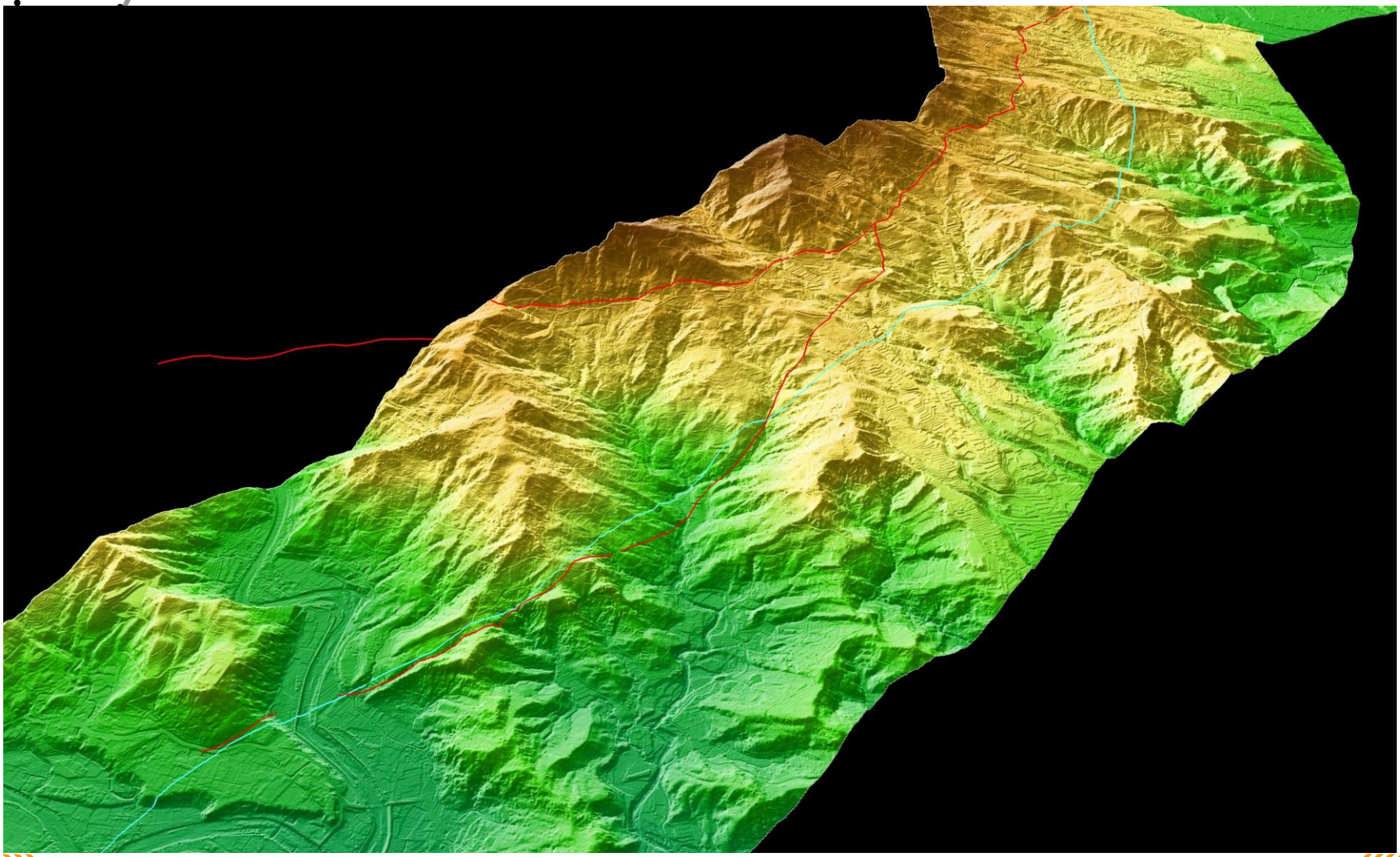


LiDAR構造線形－湖口斷層



湖口斷層東段線形：中壢－楊梅

構造線形－雙冬斷層

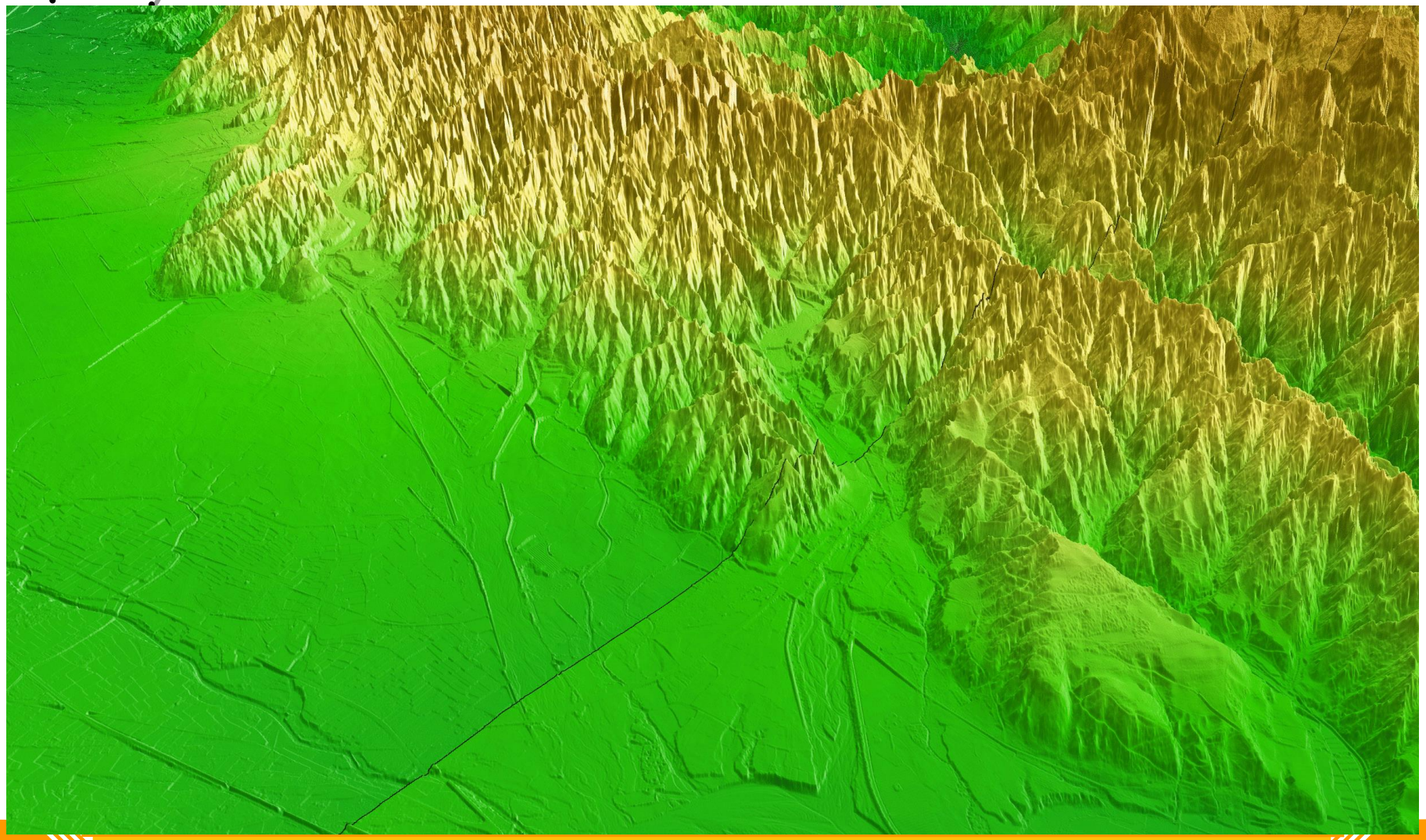


雙冬斷層南段線形－哮貓、油車坑附近

雙冬斷層野外露頭

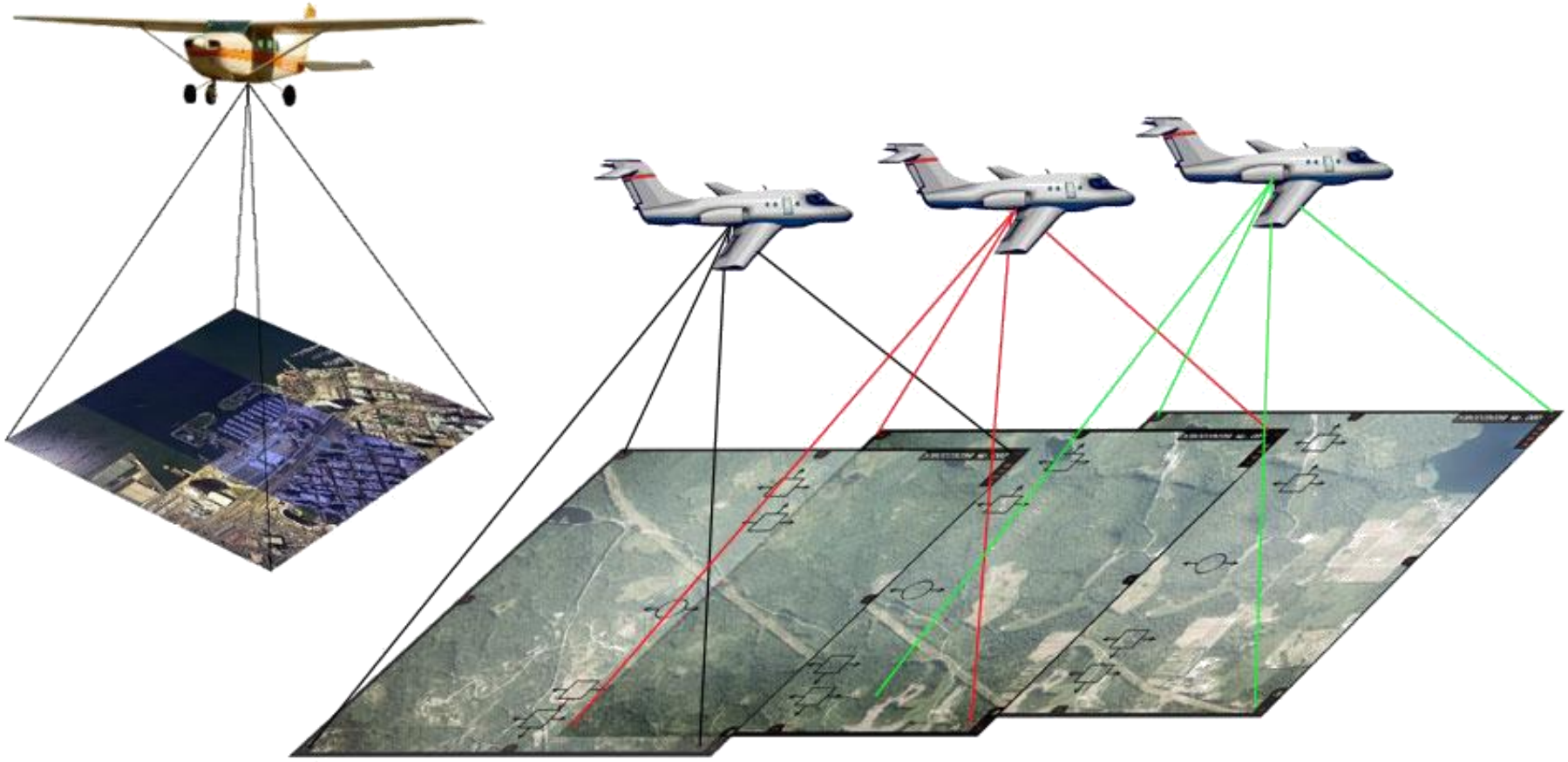
斷層野外露頭

LiDAR 構造線形－瑞穗斷層

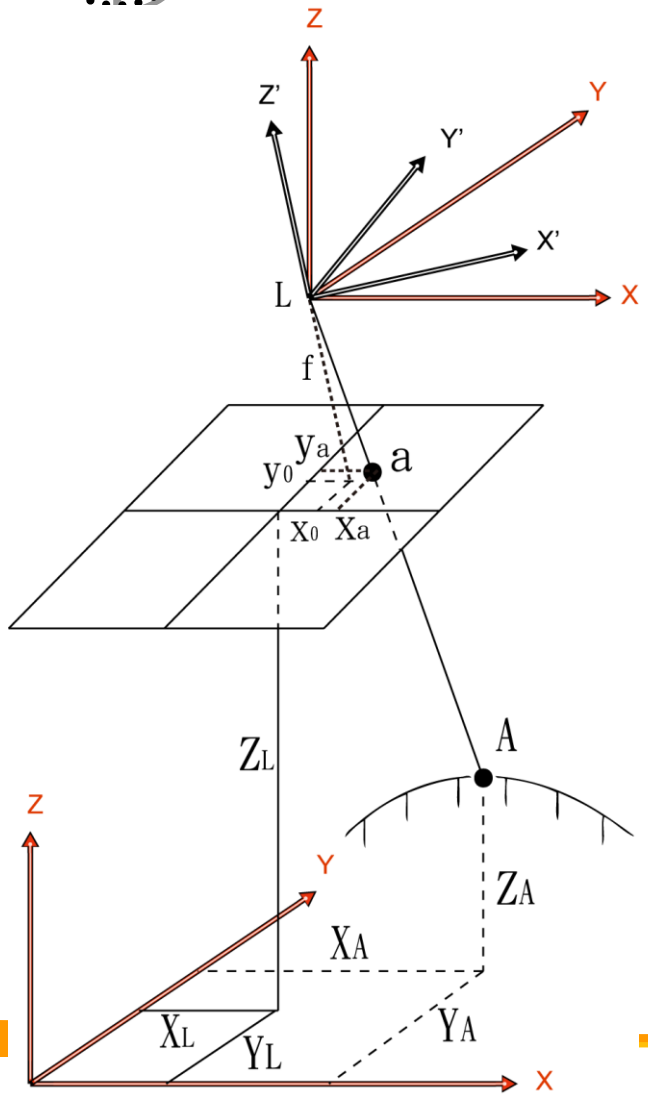


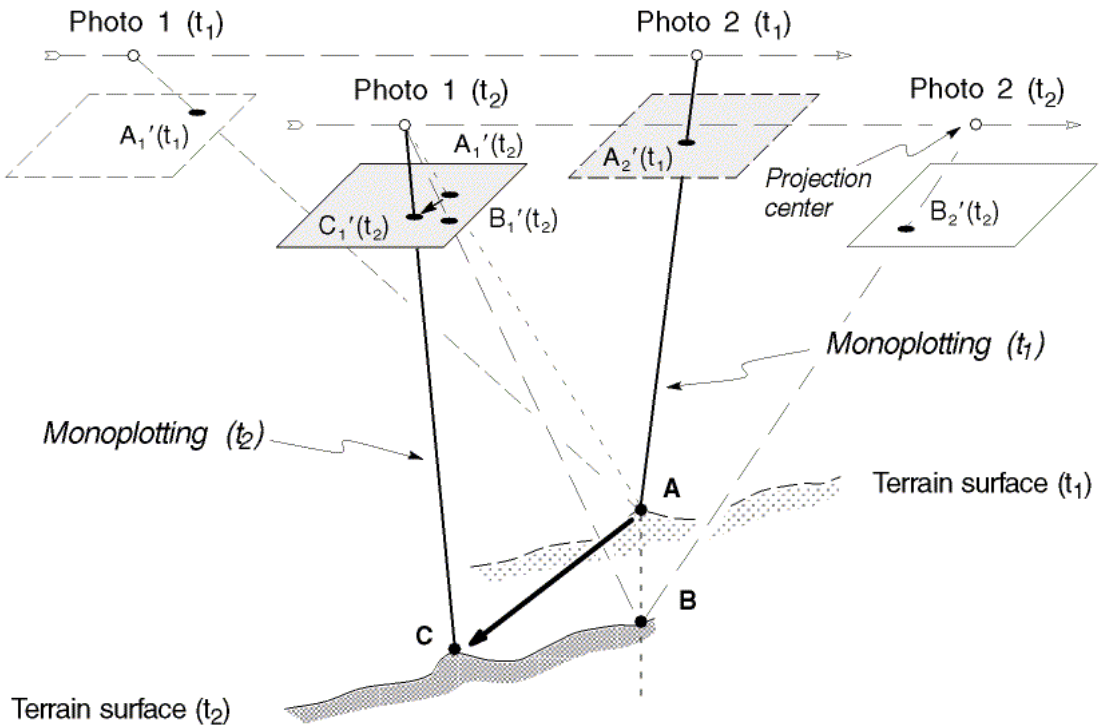
瑞穗斷層野外露頭

Aerial Photography



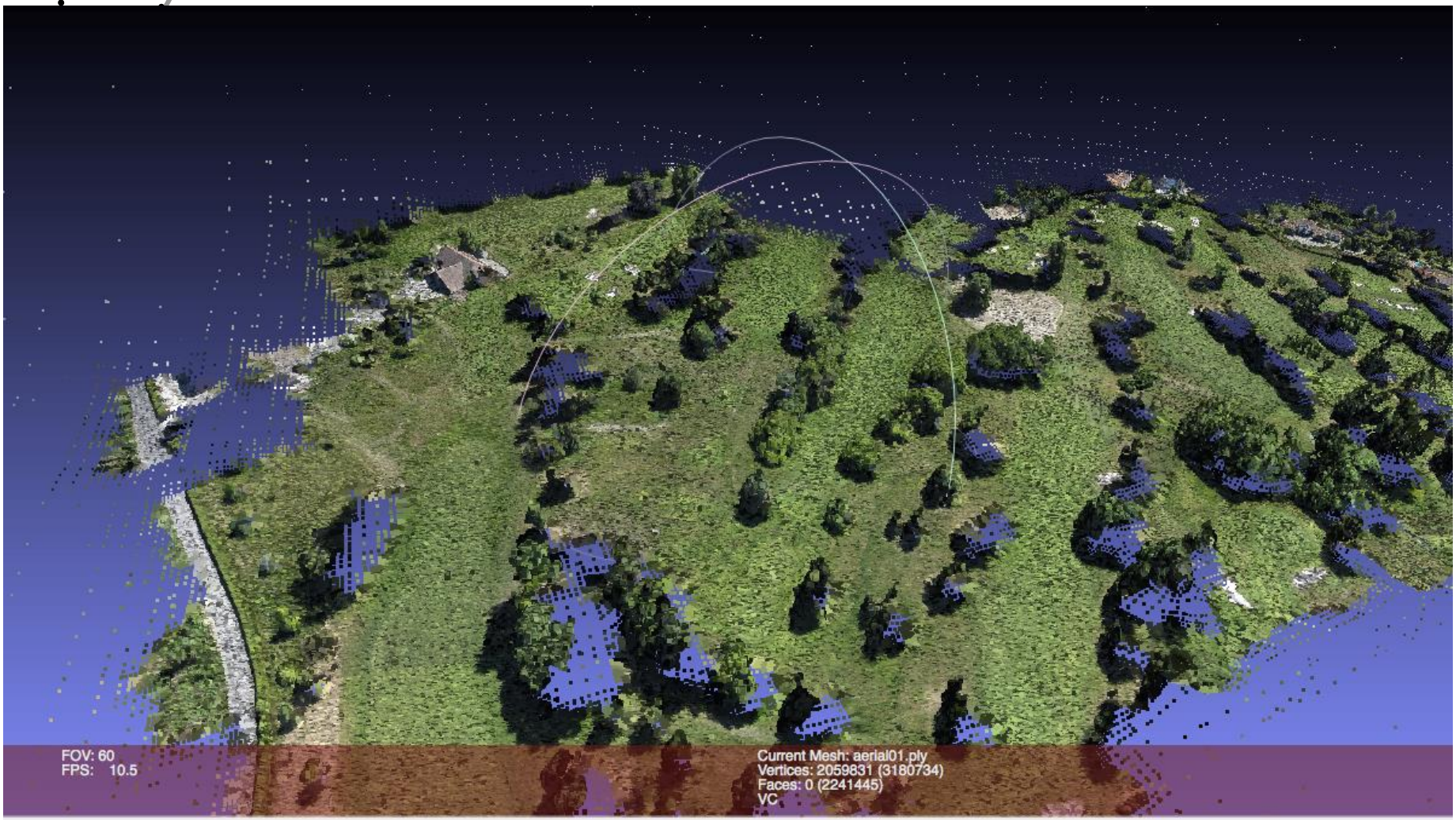
Photogrammetry



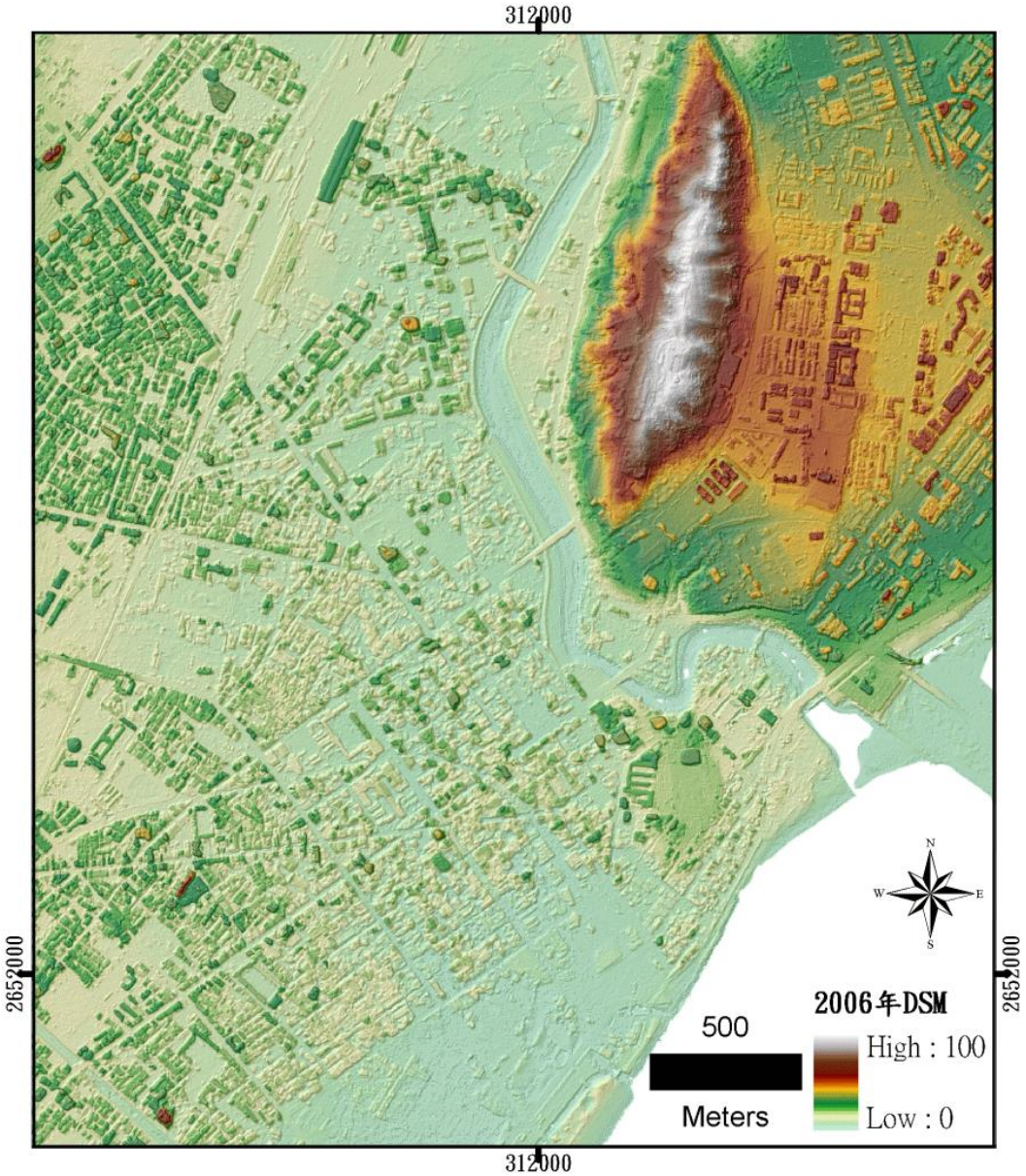


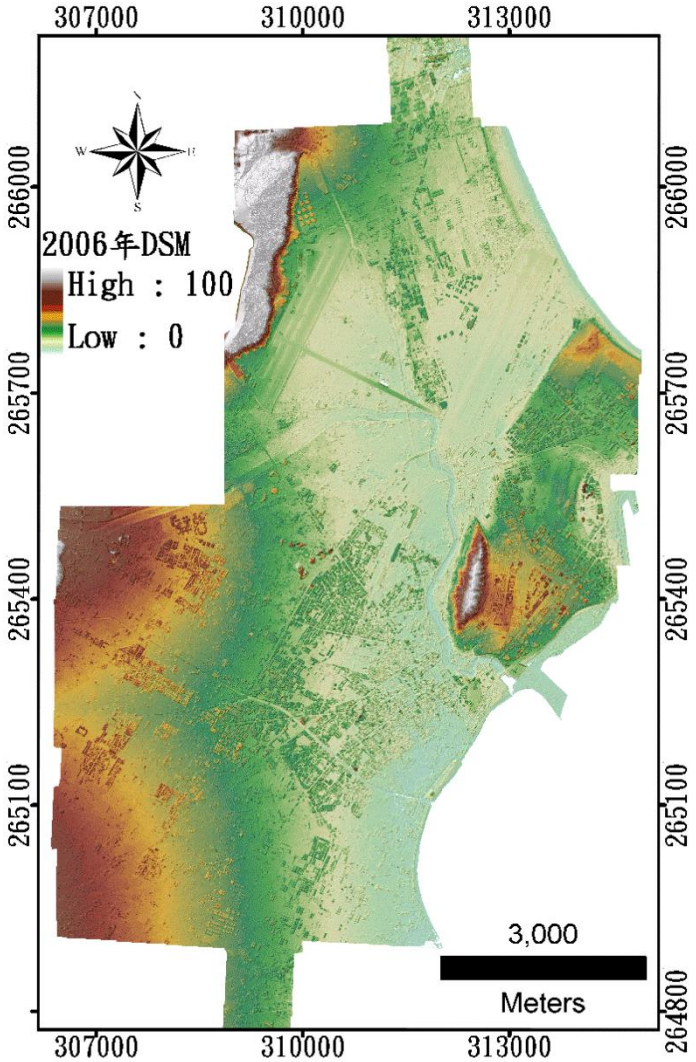
Aerophotogrammetry

Digital photogrammetry



Aerial photogrammetry





DTM quality assessment

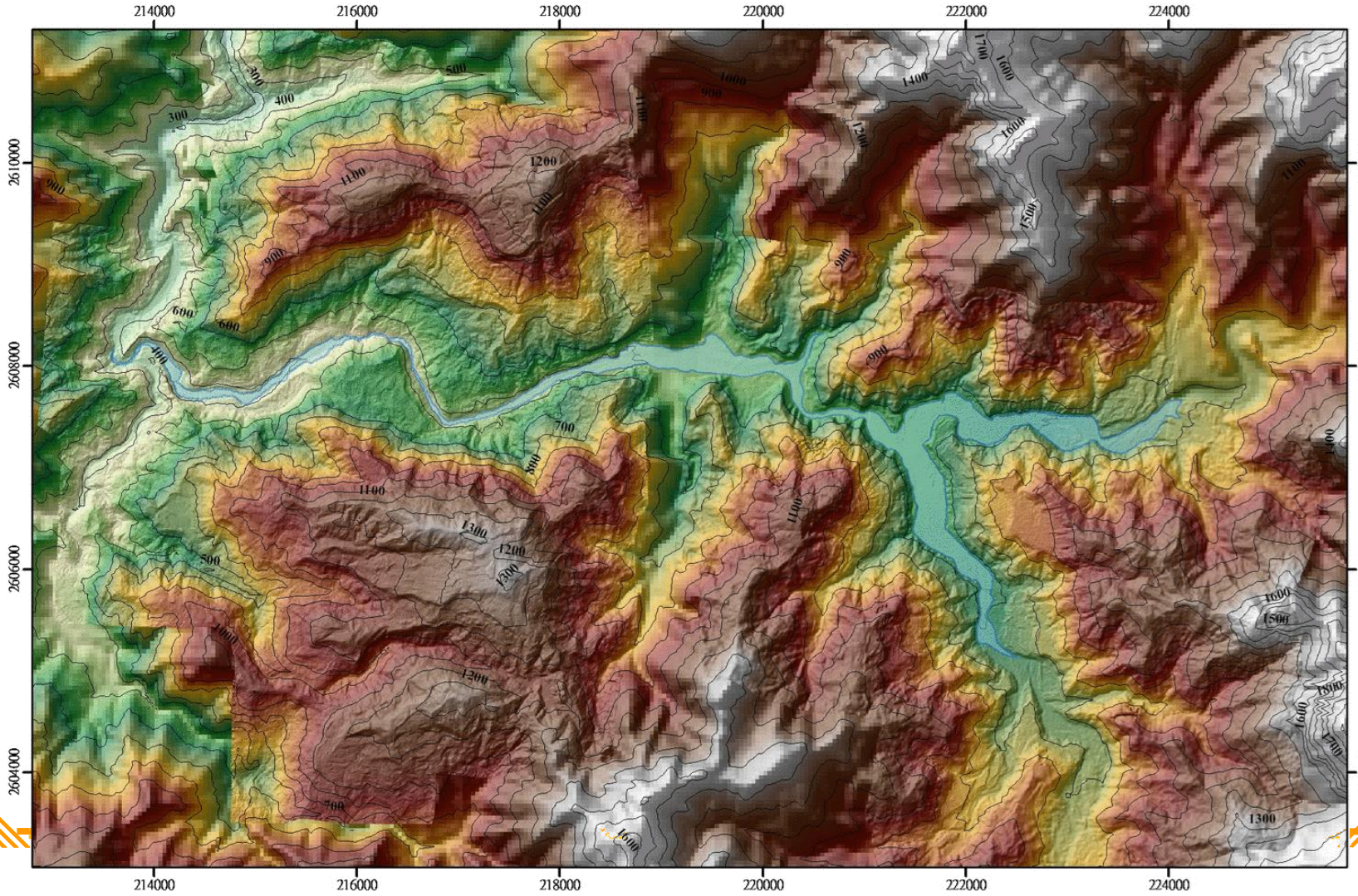
DTM comparison

Tasoling landslide event

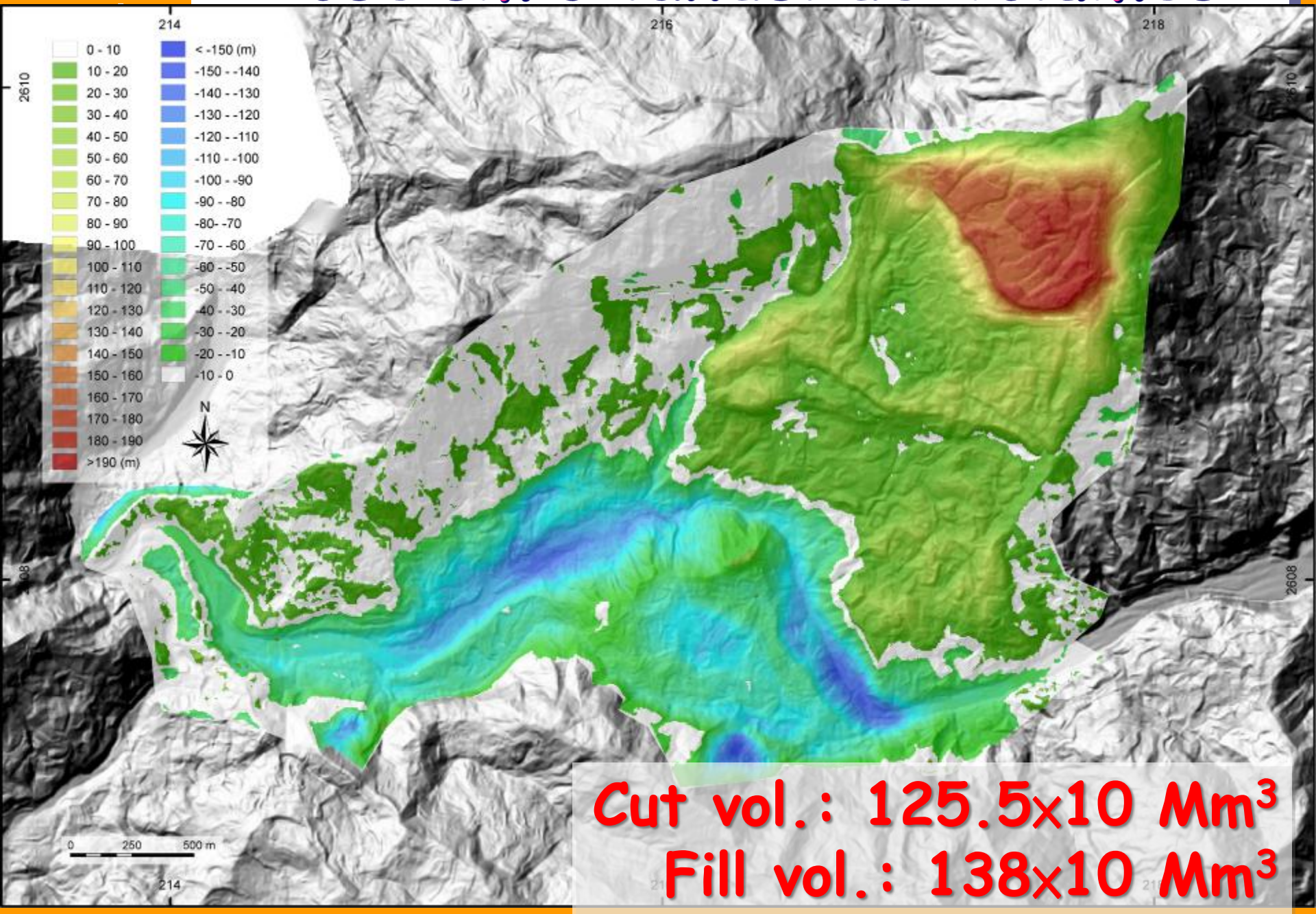
Time	Trigger	Landslide process		
		Slide Vol. (Mm^3)	Dam Height (m)	Effects
1862/06/06	Earthquake (M_L=6-7)			formation of landslide dam
1898/?/?	Rainfall			breakage of the 1862 landslide dam
1941/12/17	Earthquake (M_L=7.1)	~10	70-140	36 persons killed, 59 houses damaged; landslide dam formed
1942/08/10	Rainfall (776mm)	~15	140-170	1 person killed, 1 house damaged; the dam enlarged
1951/05/18	Rainfall (770mm)	120	140-200	137 (74 ?) persons killed, 200 houses damaged, dam broken
1979/08/15	Rainfall (327mm)	26	90	formation of landslide dam
	Rainfall (624mm) 1979/08/24	40		breakage of landslide dam
1999/09/21	Earthquake (M_L=7.3)	125	45	39 persons killed

DTM construction

1998 2mDTM



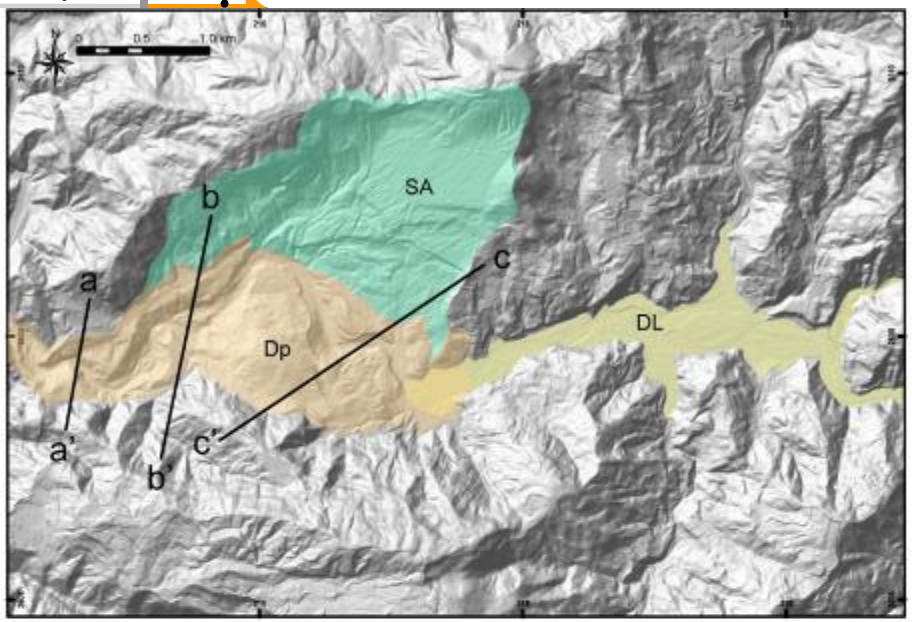
Coseismic landslide volumes

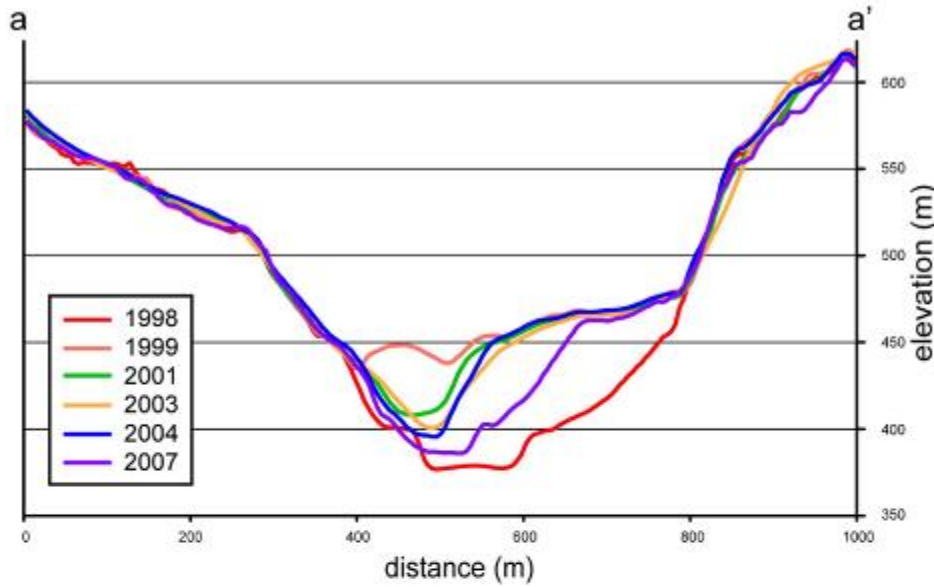


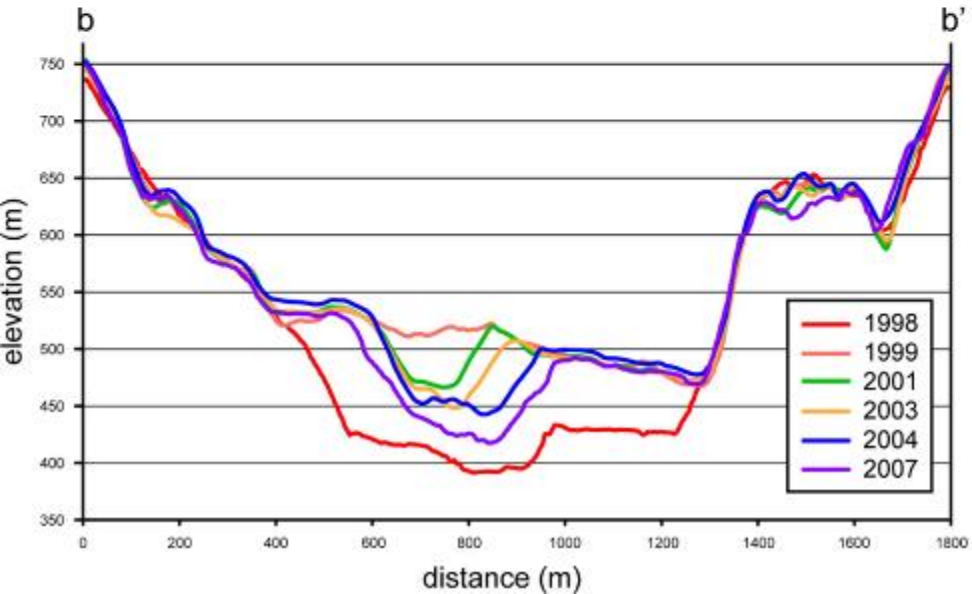
Cut vol.: 125.5x10 Mm³

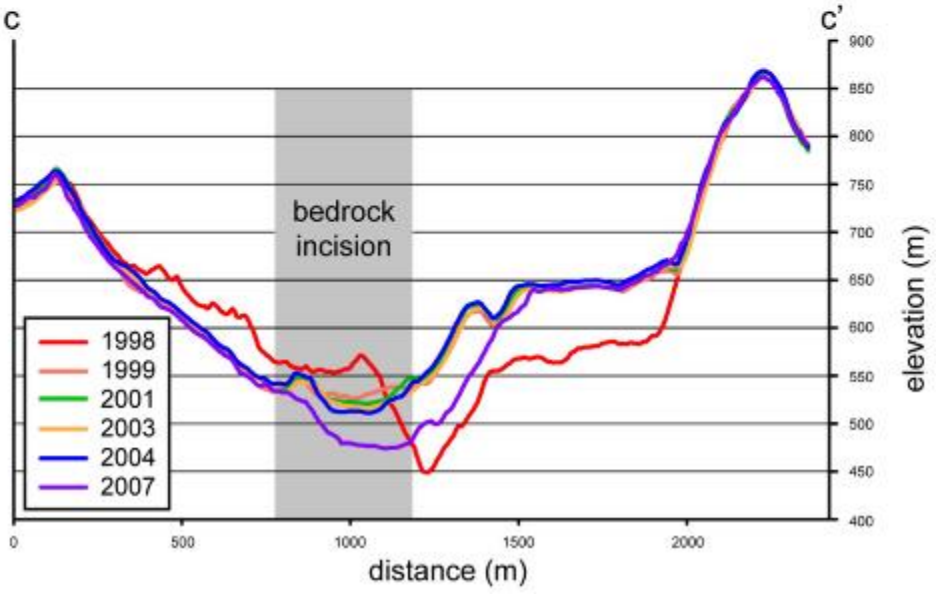
Fill vol.: 138x10 Mm³

River bed erosion & incision

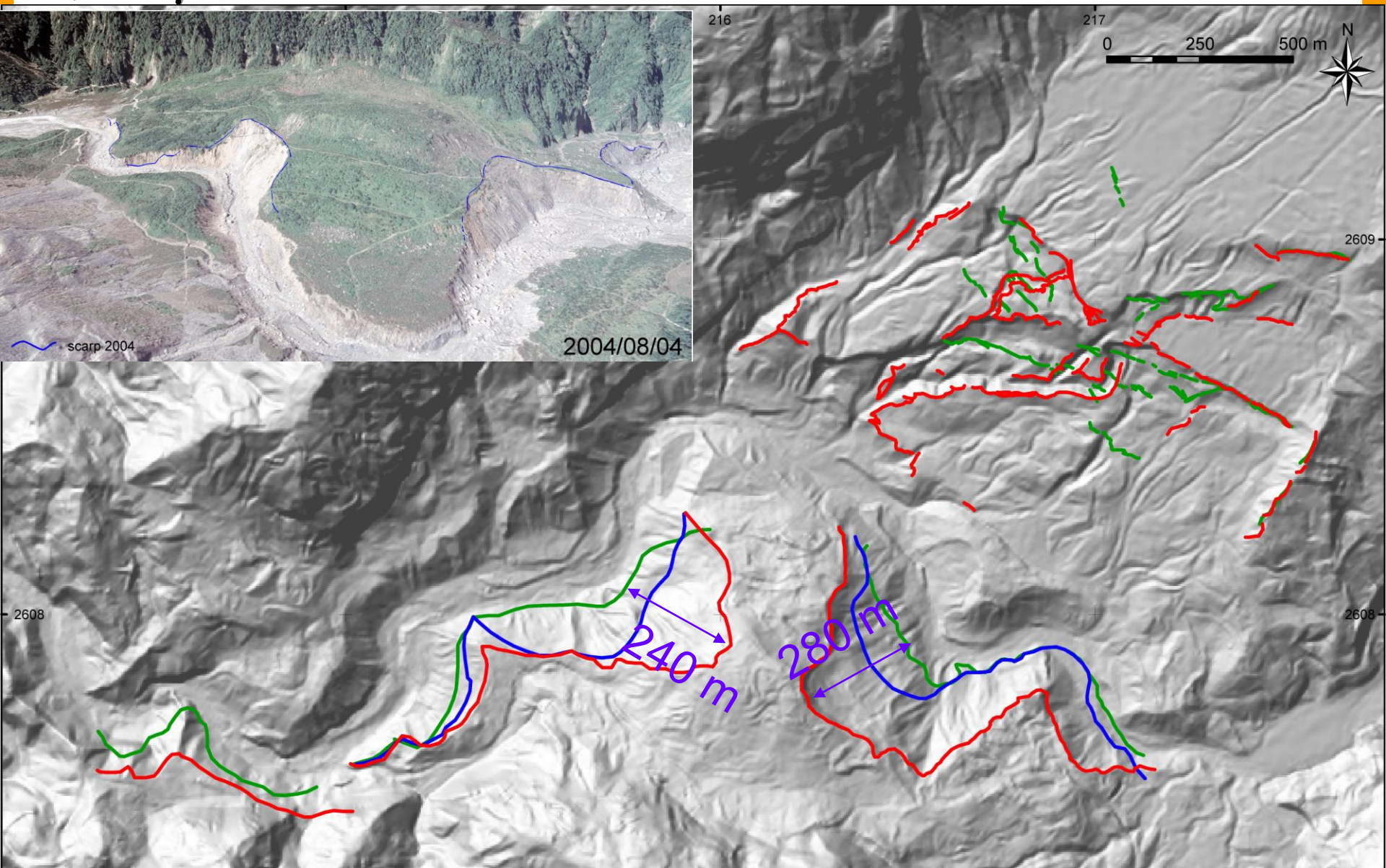




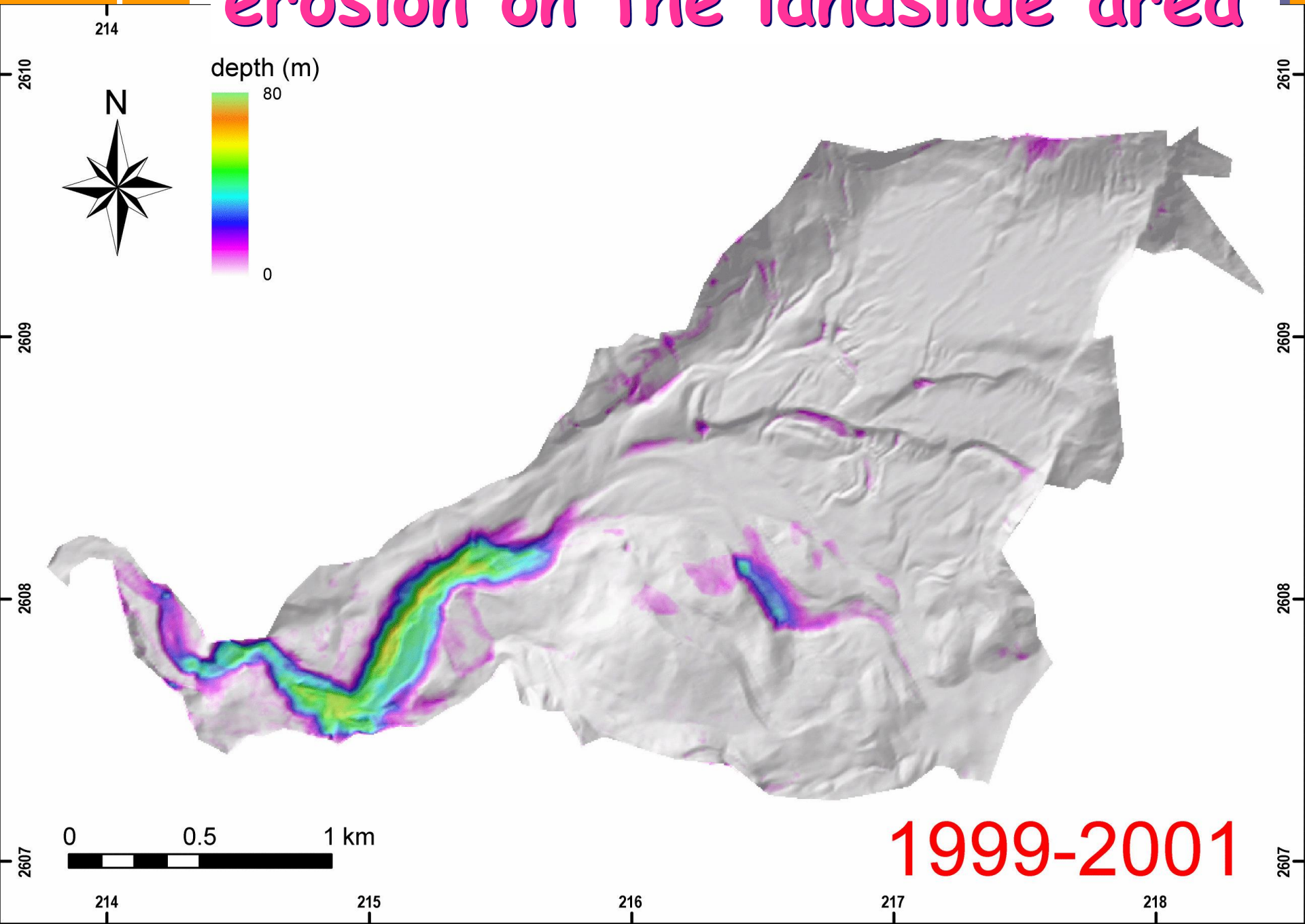




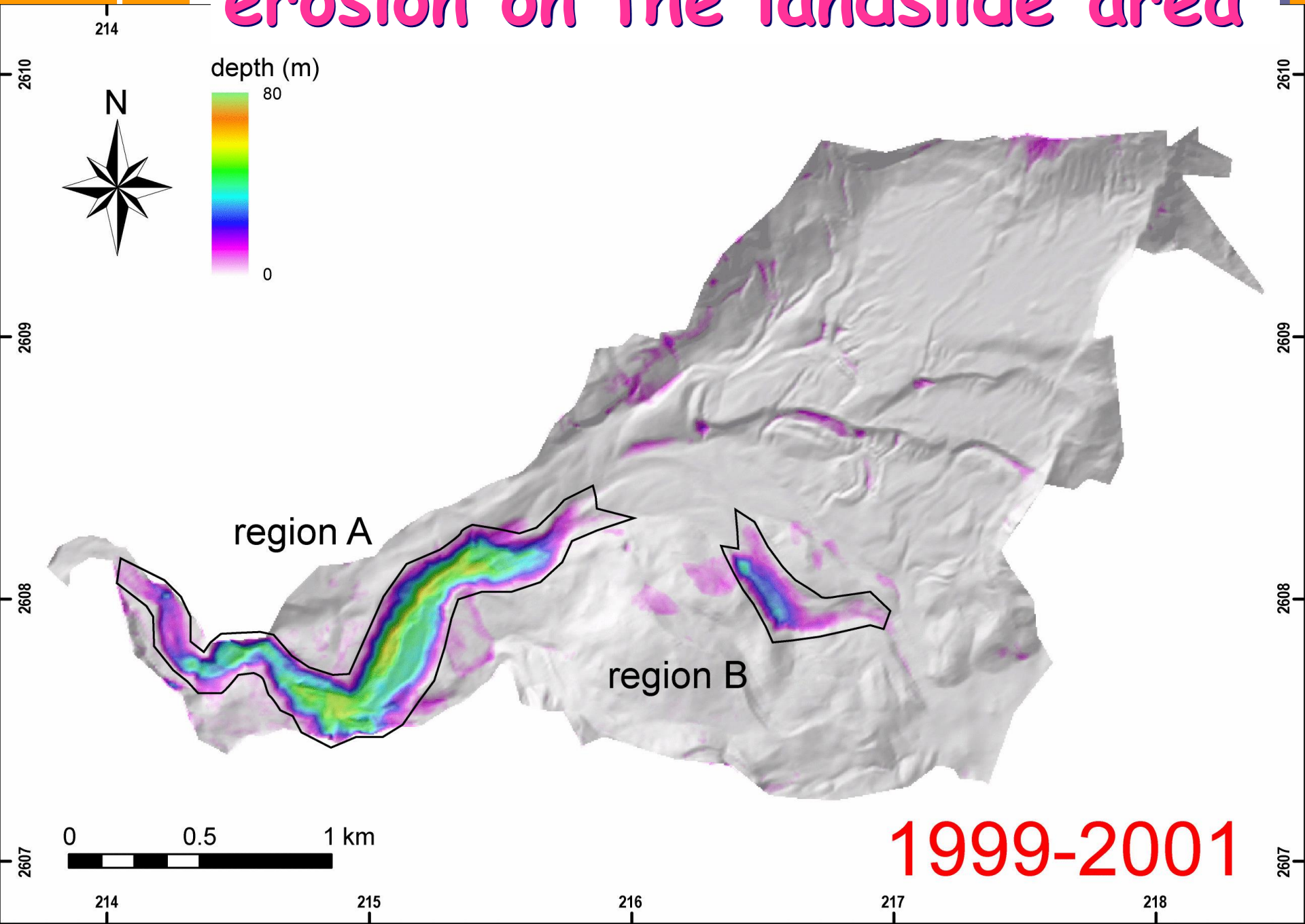
River lateral erosion & incision



erosion on the landslide area



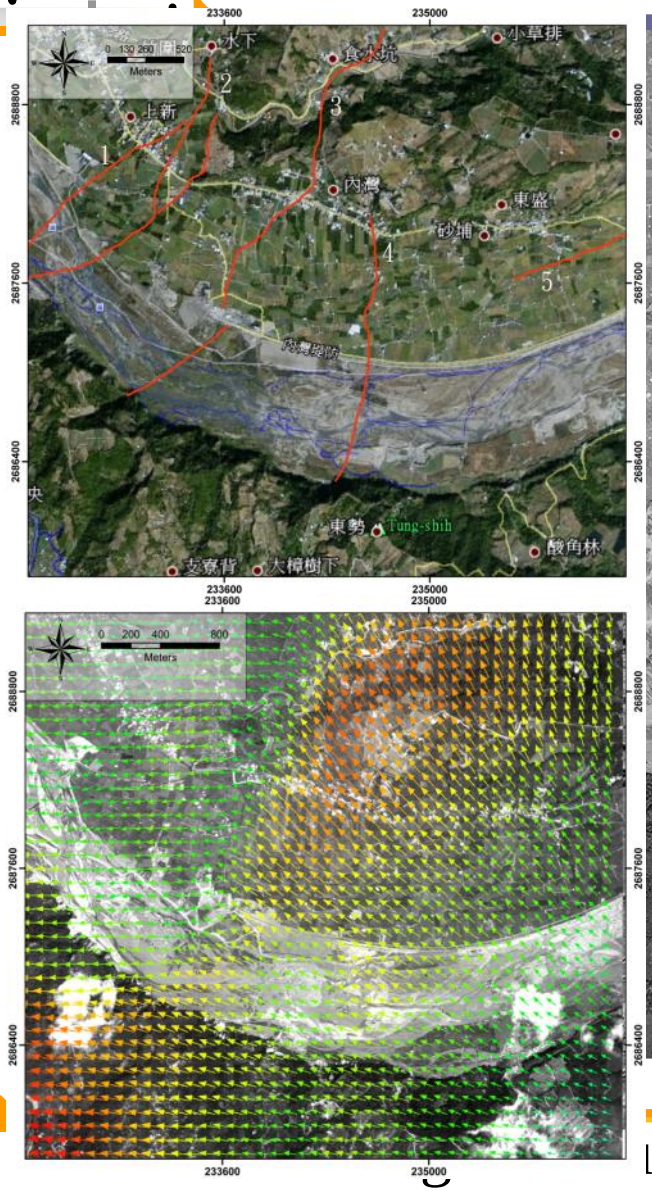
erosion on the landslide area

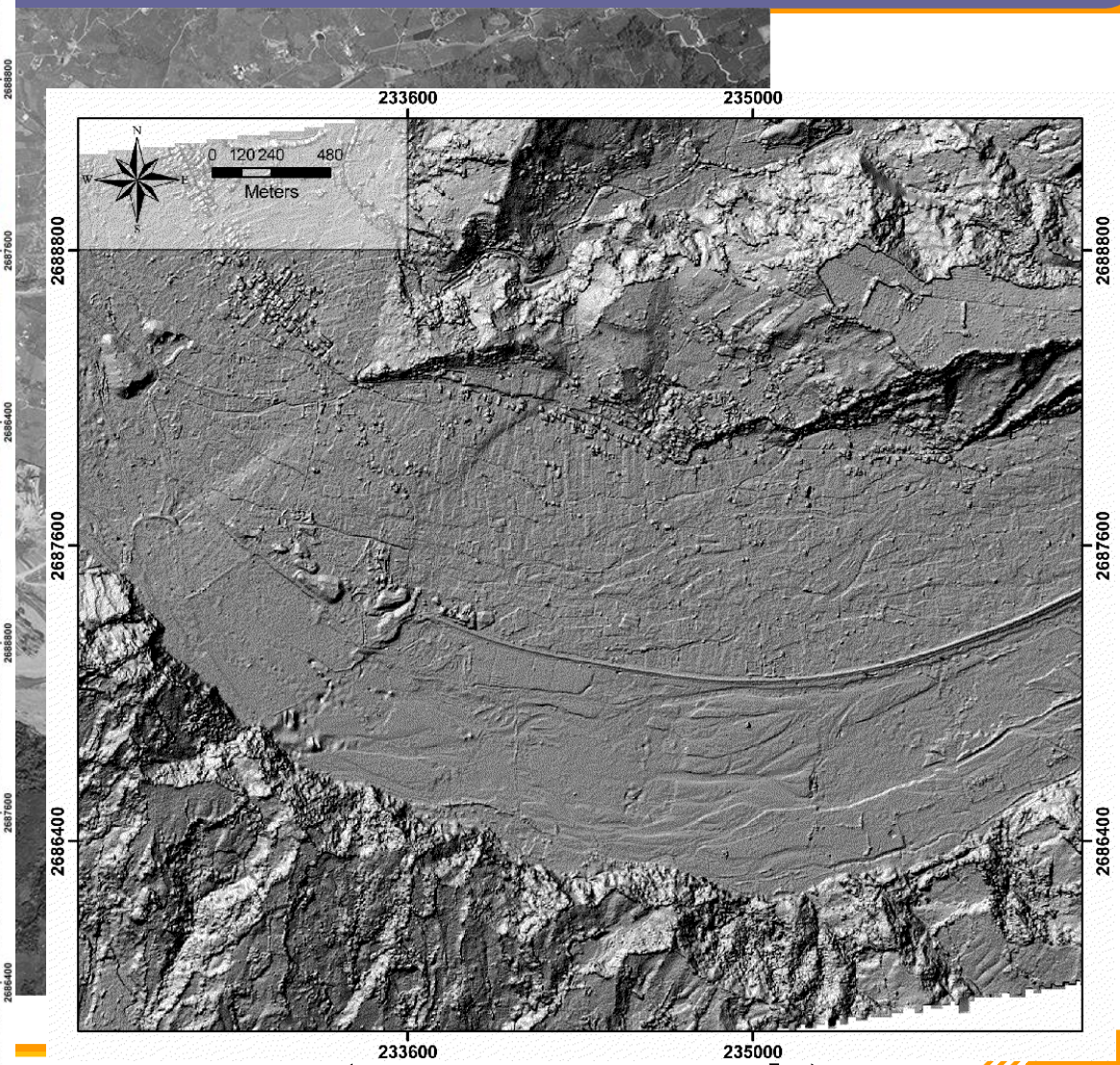


Post-seismic erosion

Region	Surface (hectare)	Volume (Mm^3)	Maximum depth (m)
A	42	11.76	58
B	6.7	1.02	37
C	45.2	6.35	43
D	10.8	1.03	26
E	54.2	7.7	83
F	7.2	1.08	33
G	140.3	43.23	74
H	8.2	1.62	30

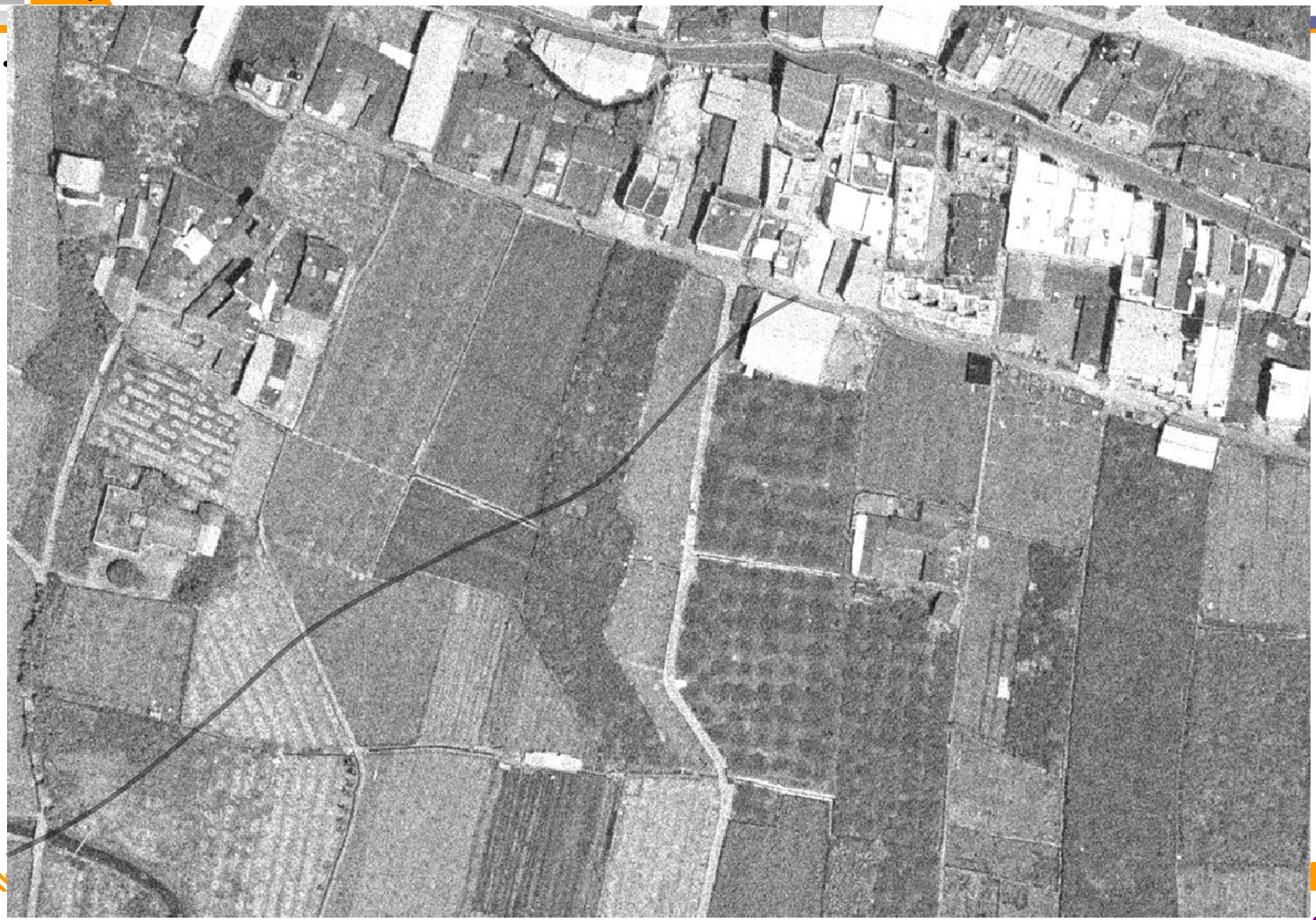
Coseismic horizontal deform.



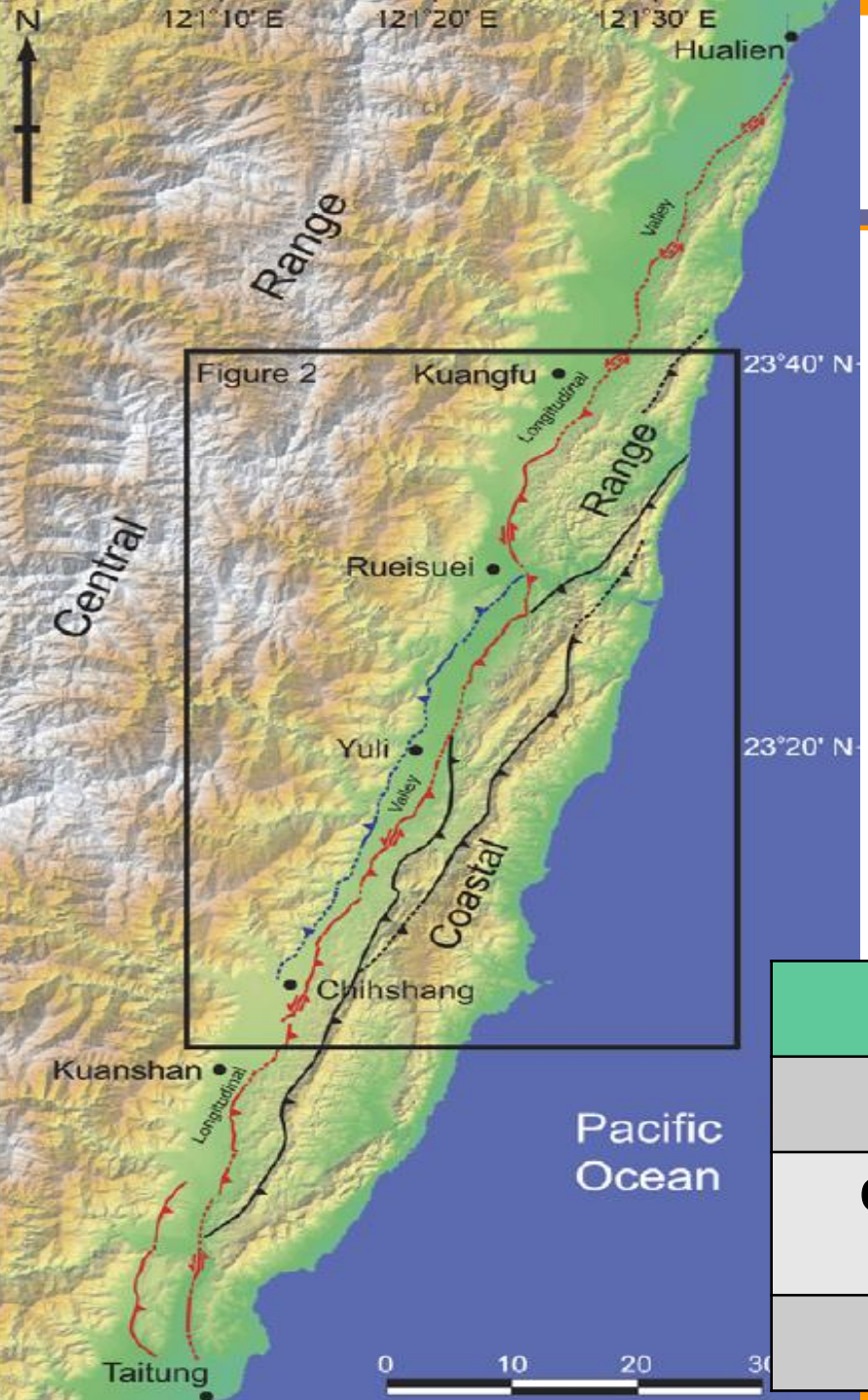


tion：1.4m (2803x2609 pixels)

Displacement comparison



1951 earthquakes

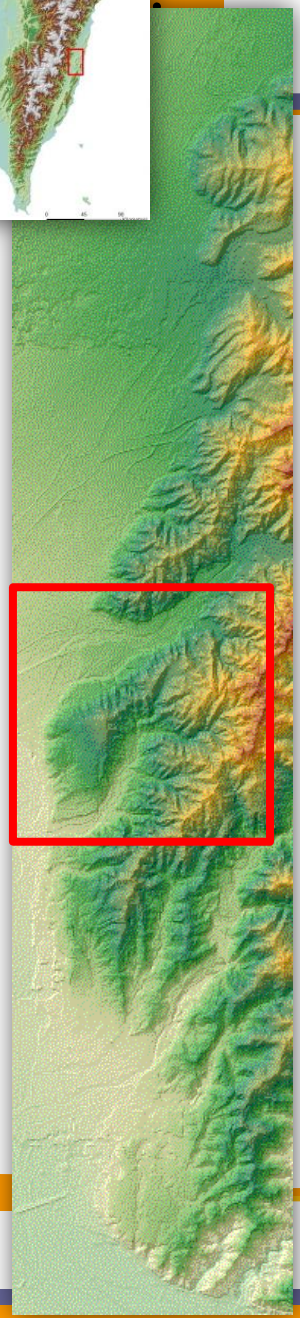


1951	Mag.	Location
Oct. 22	7.3、7.1、7.1	Hualien
OCT. 25	6.1、7.3	Chihshang-Yuli
Dec. 05	5.8	Taitung

1945年正射影像

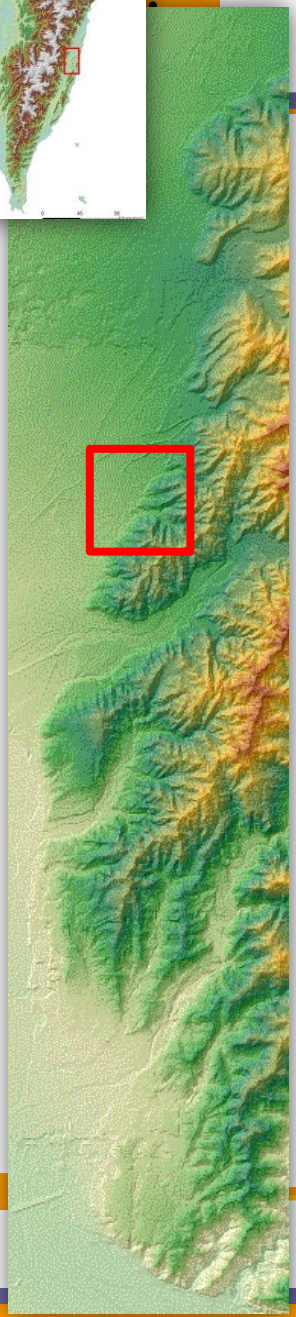
Quality assessment

1945 vs. LiDAR 2M



LiDAR DEM_2m

Quality assessment
1948 vs. LiDAR 2M



0 100 200
Meters

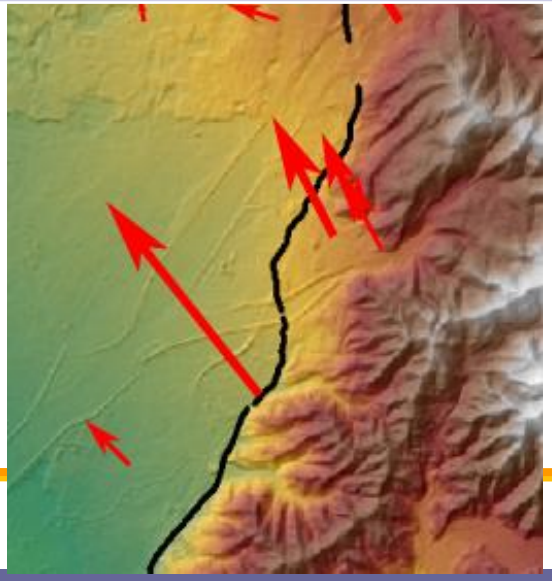
LiDAR DEM_2M

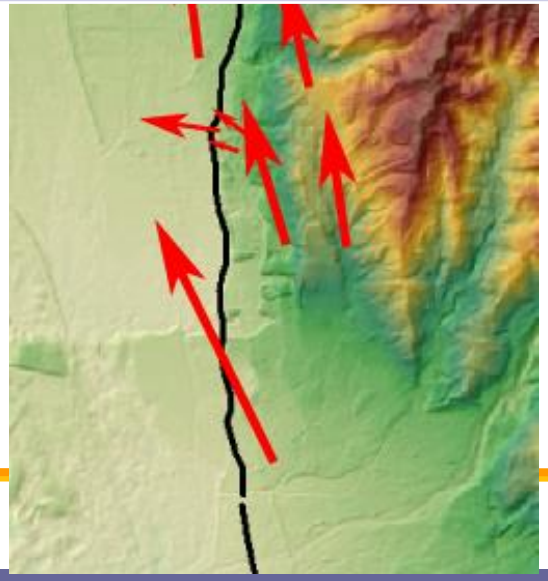
Horizontal Disp. Rueyshui F.

North seg.

South seg.

Mean disp. (m)	Max disp.(m)
3.66	5.77

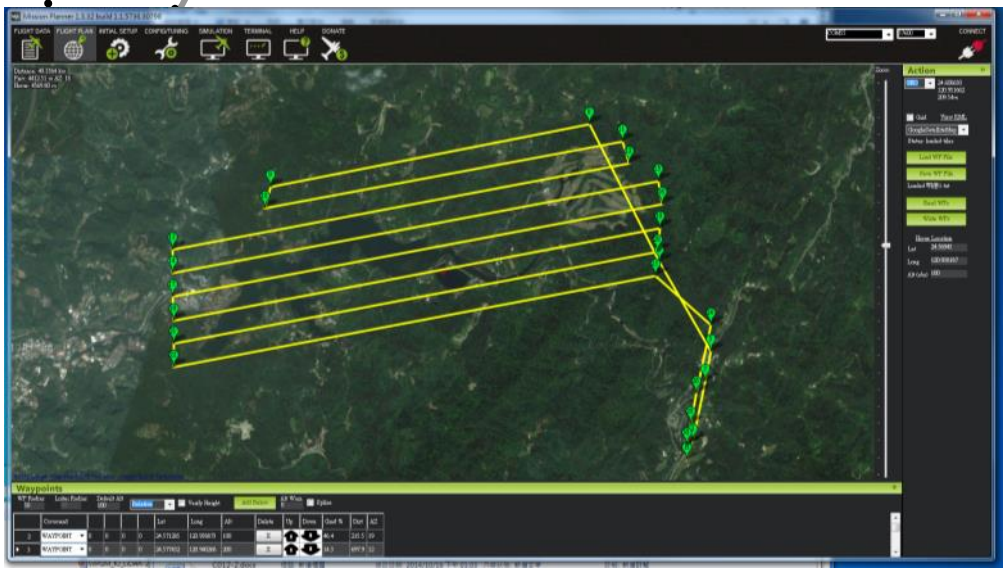


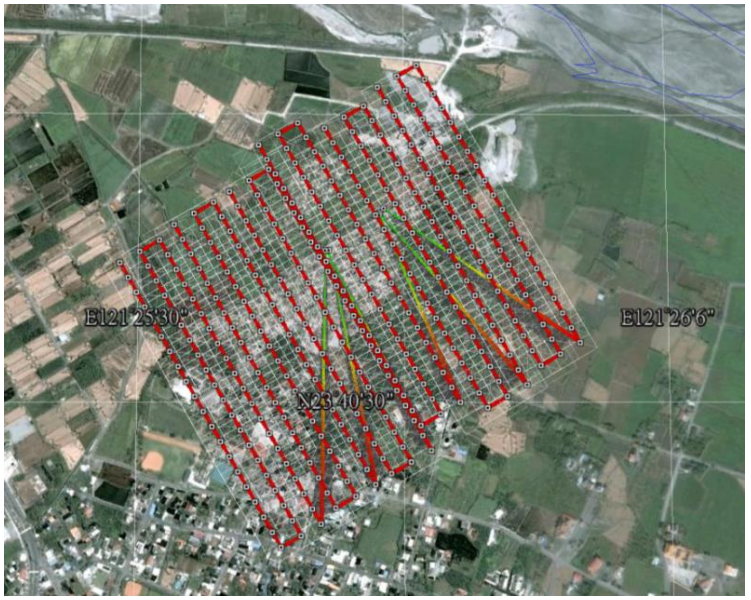


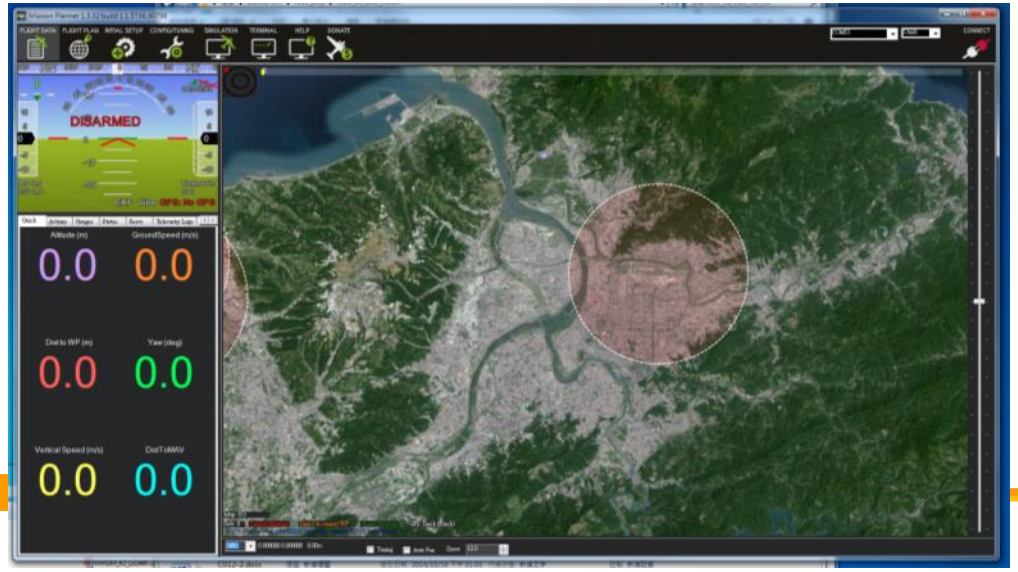
3m disp.

Photogrammetric Drones @ NTUT

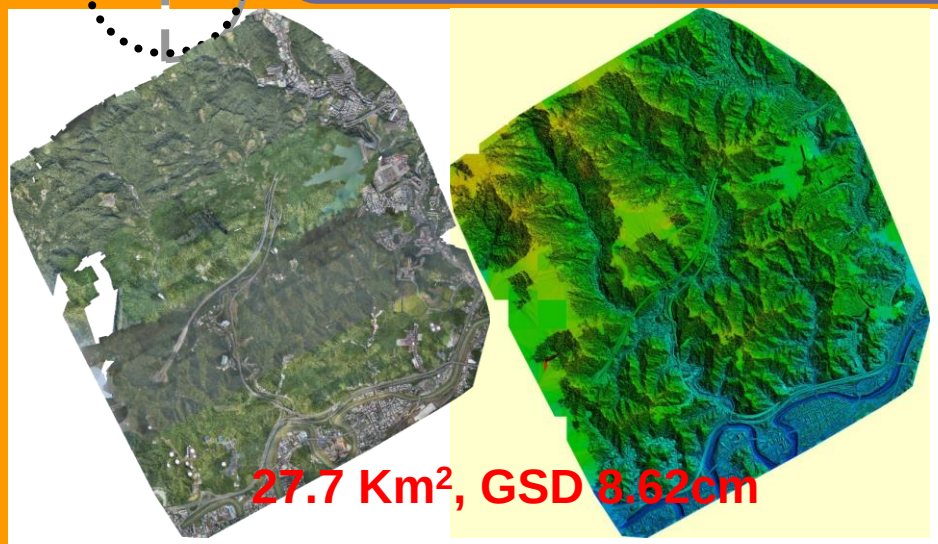
航線、航點規劃及拍照點檢核



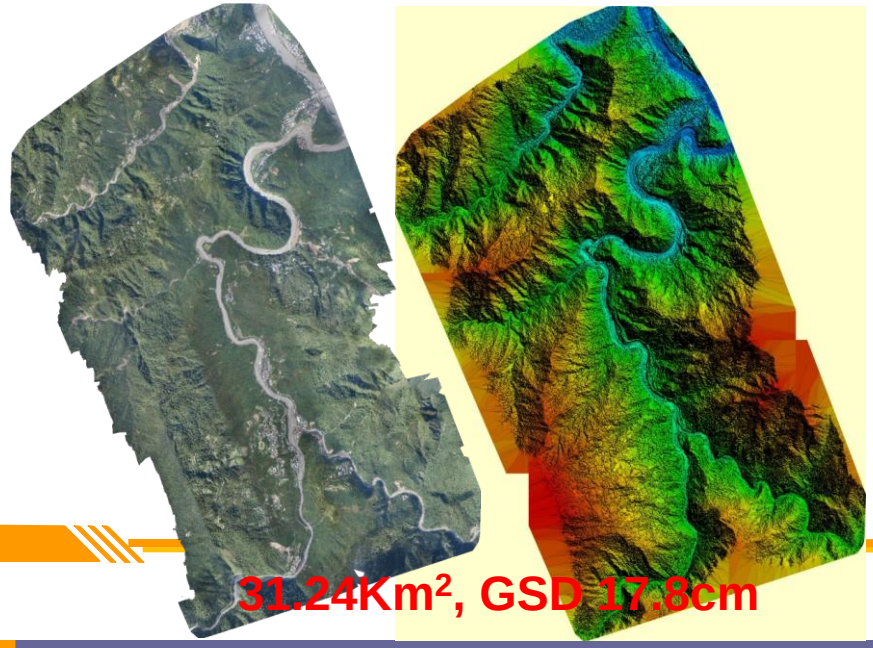




DSM建模成果

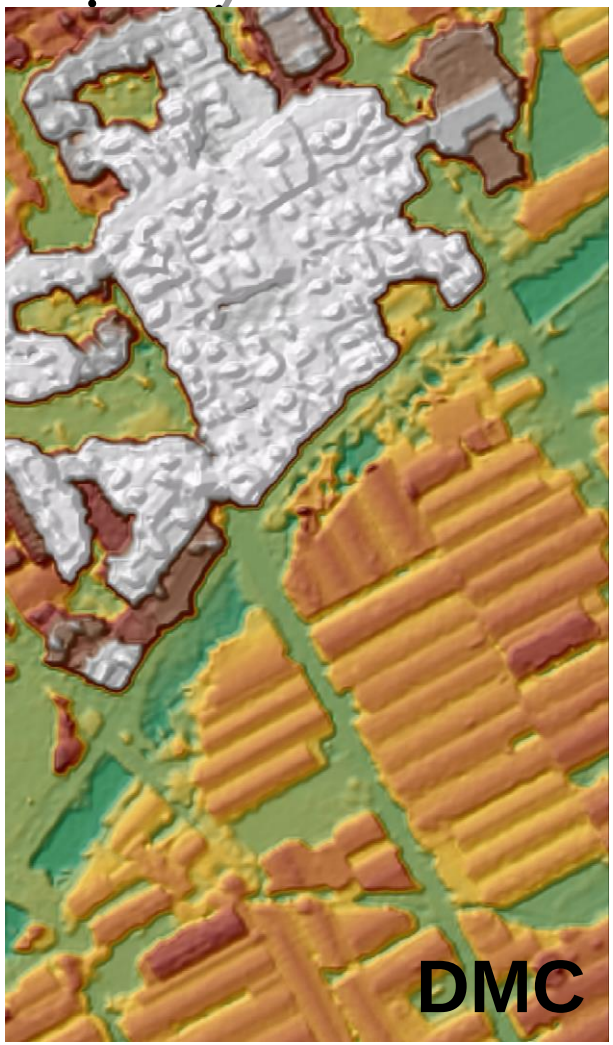


27.7 Km², GSD 8.62cm

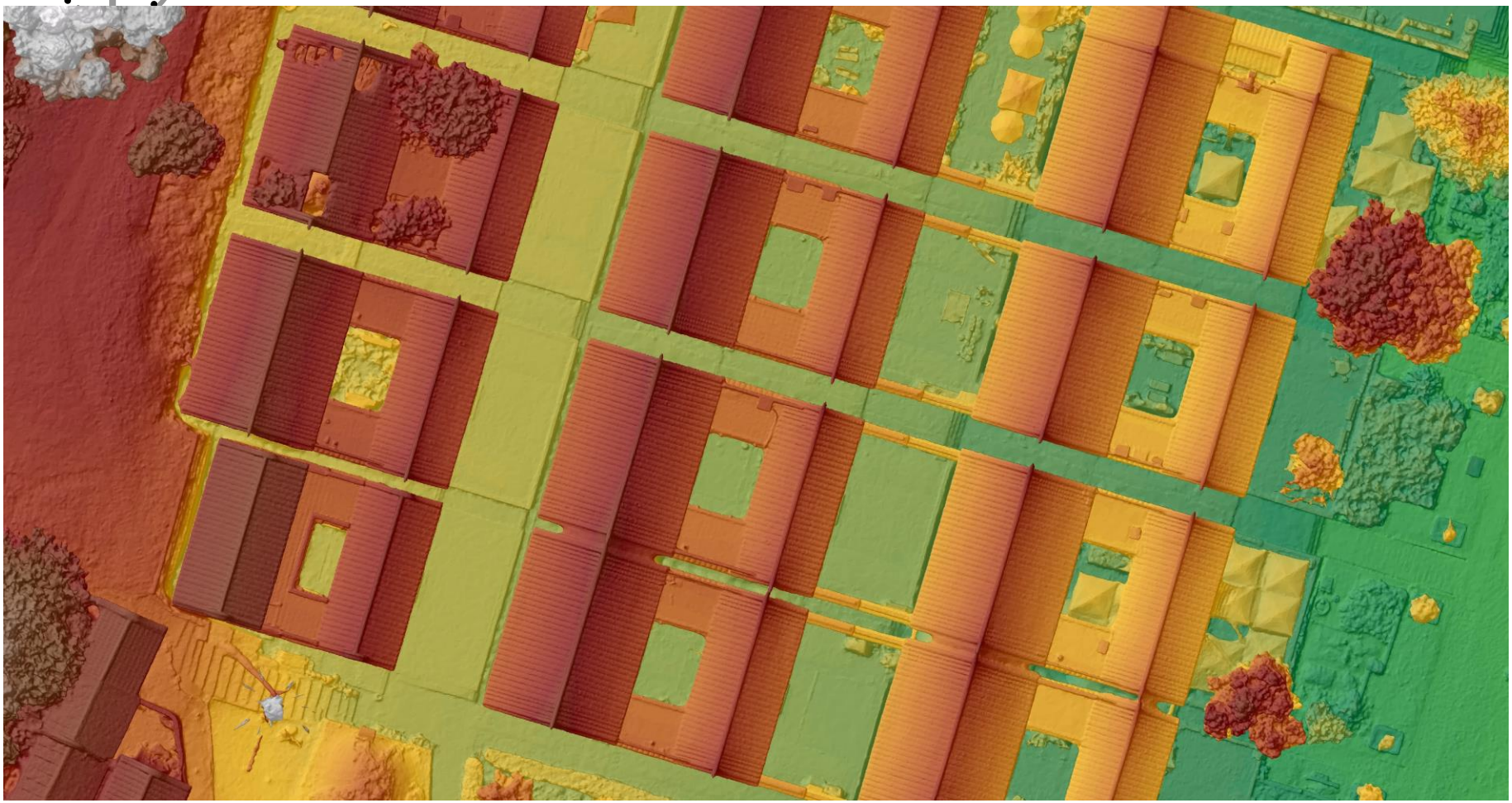


31.24Km², GSD 17.8cm

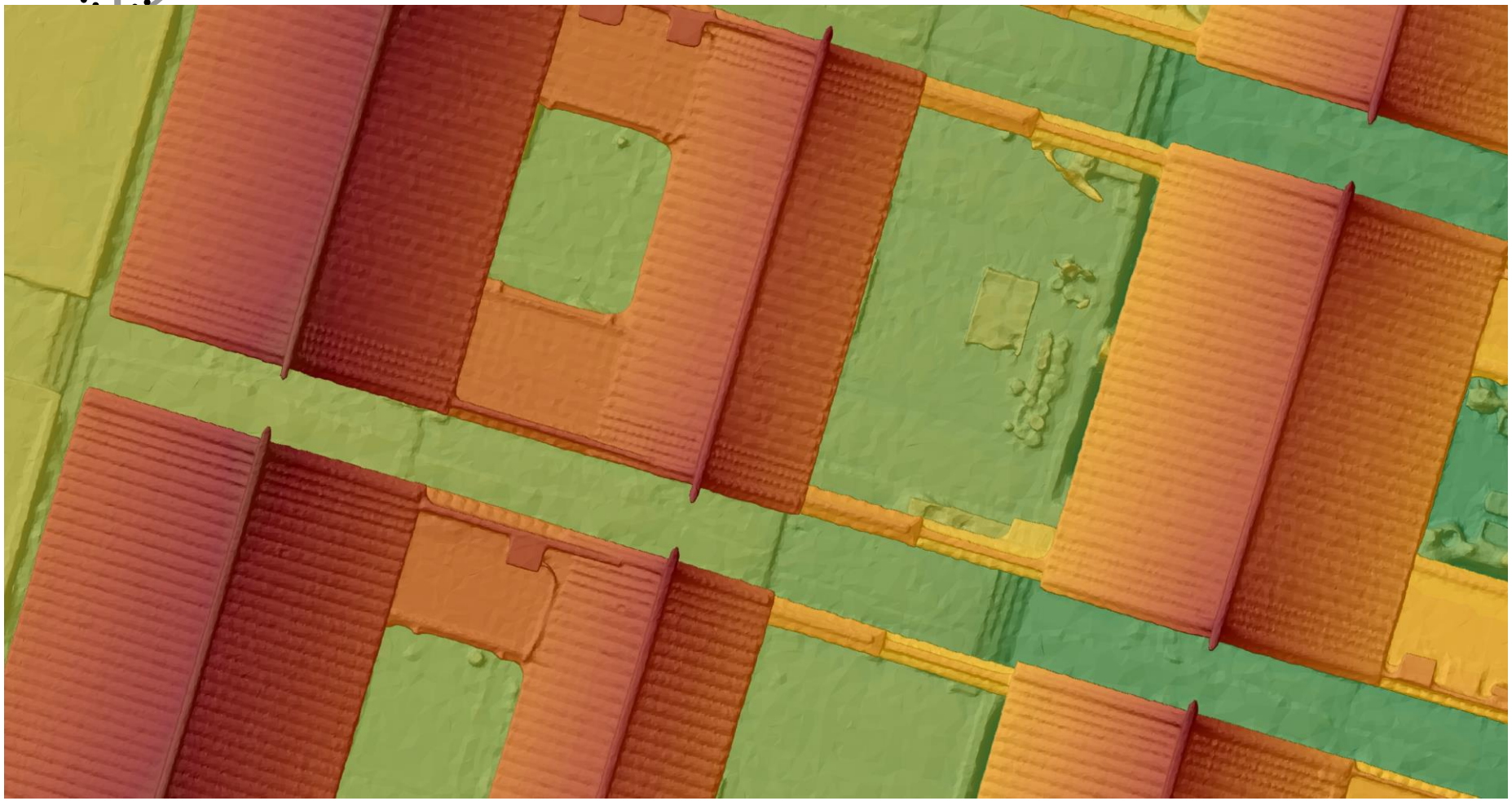
DMC, LiDAR vs. UAV



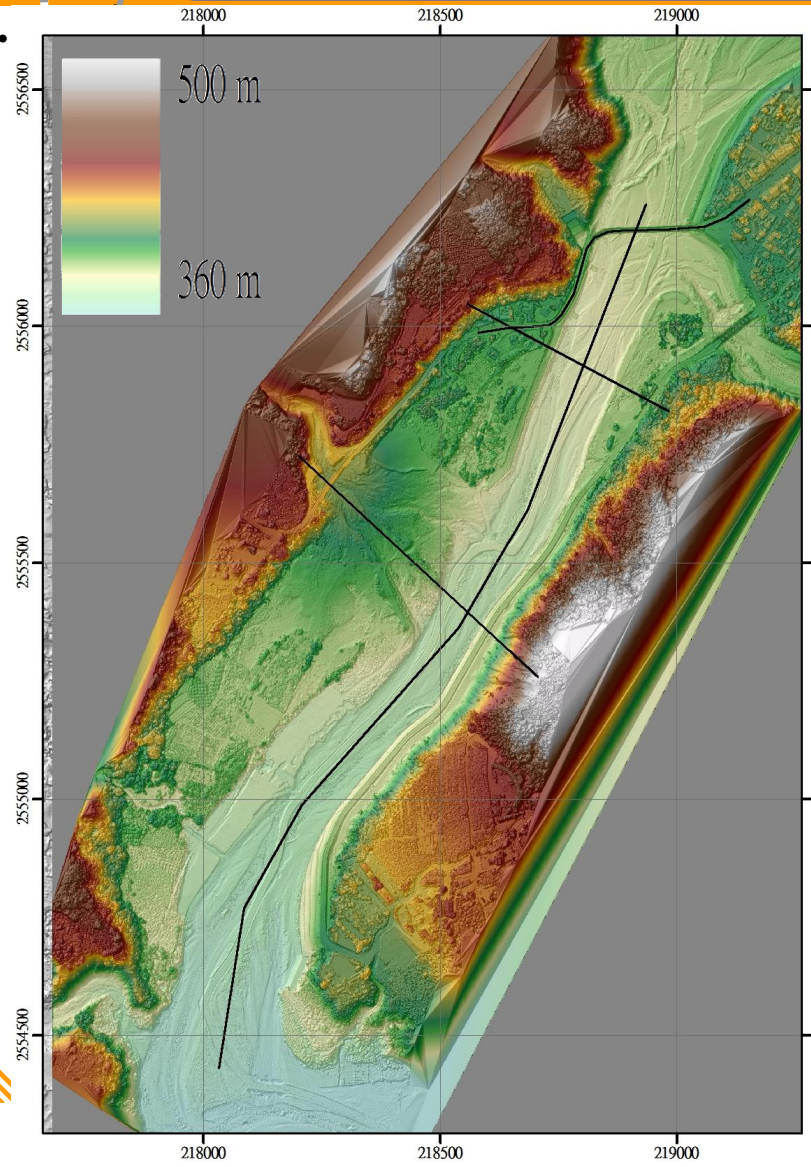
Data Comparison

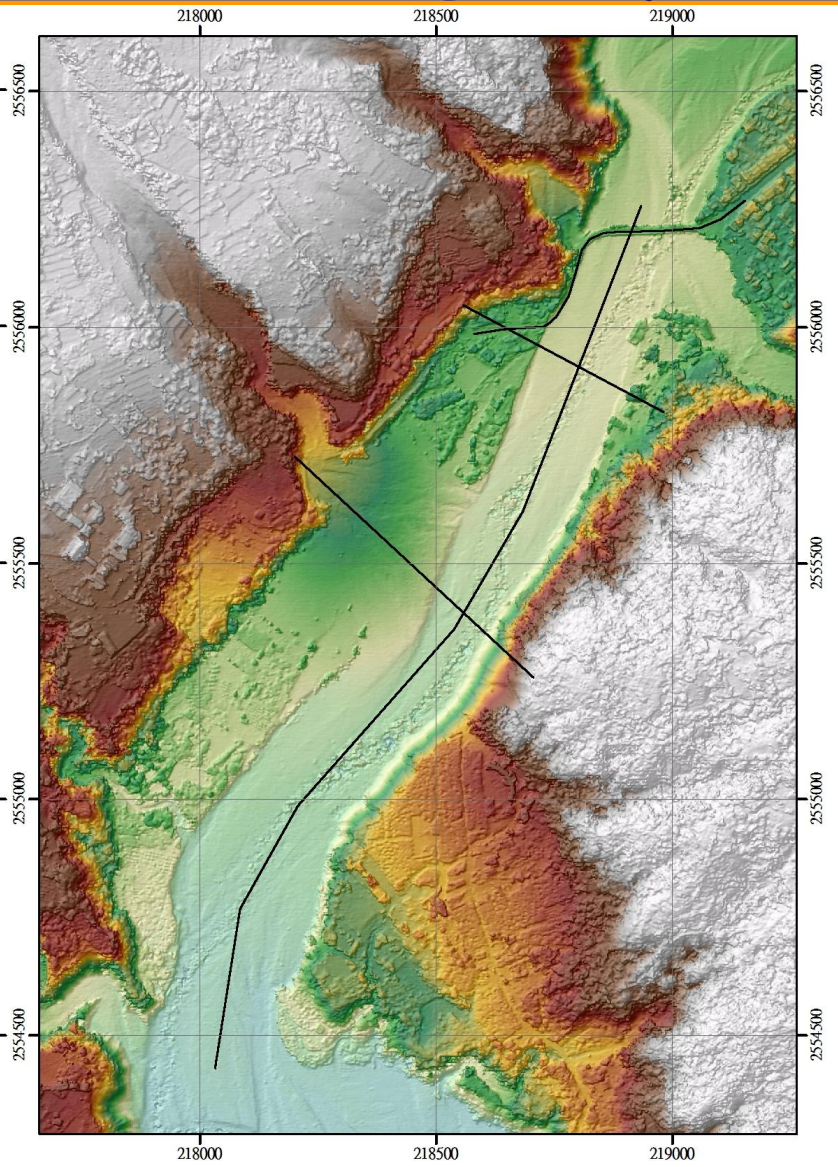


Data Comparison

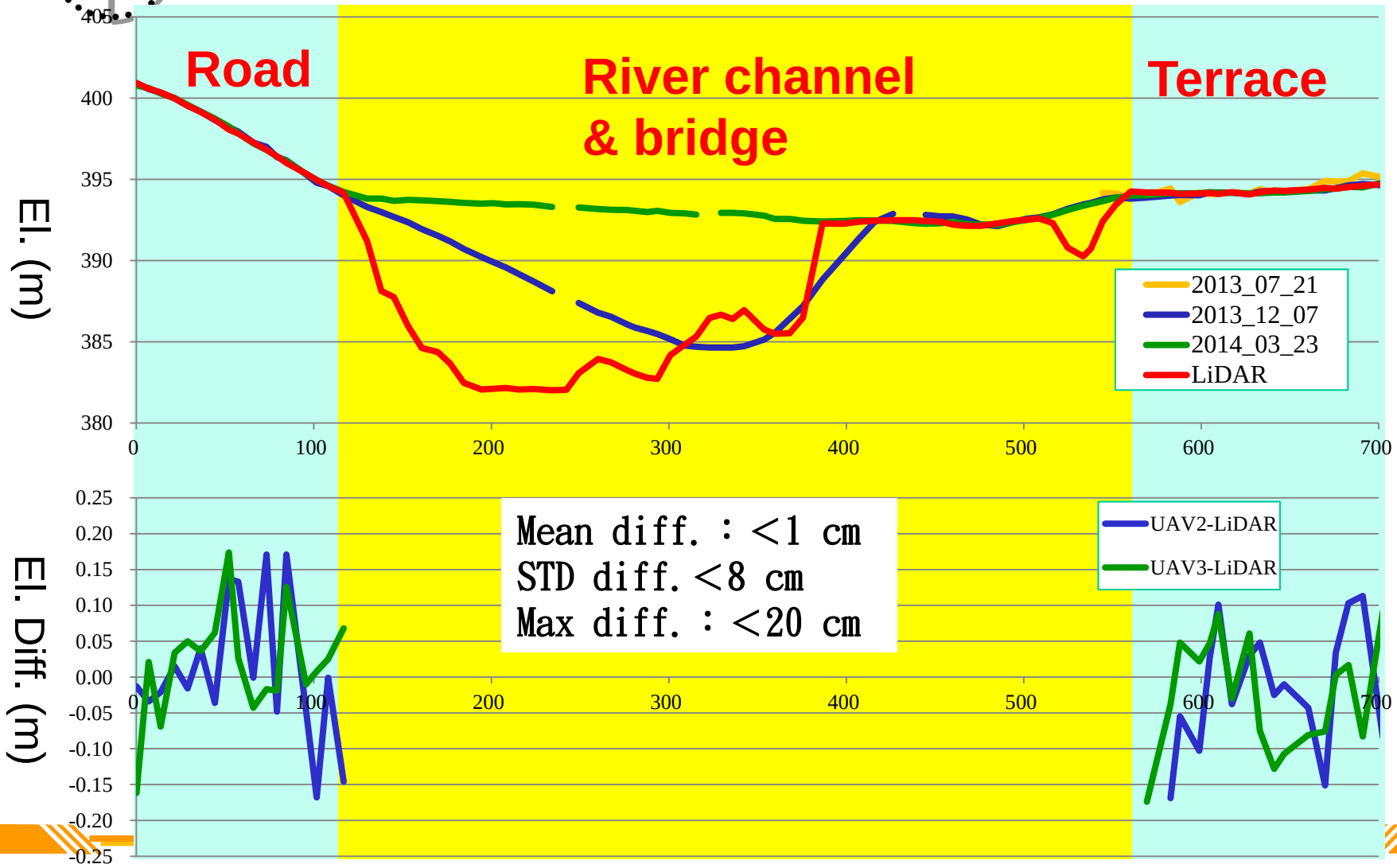


UAV Data Acquisition @ S Cross Island Highway

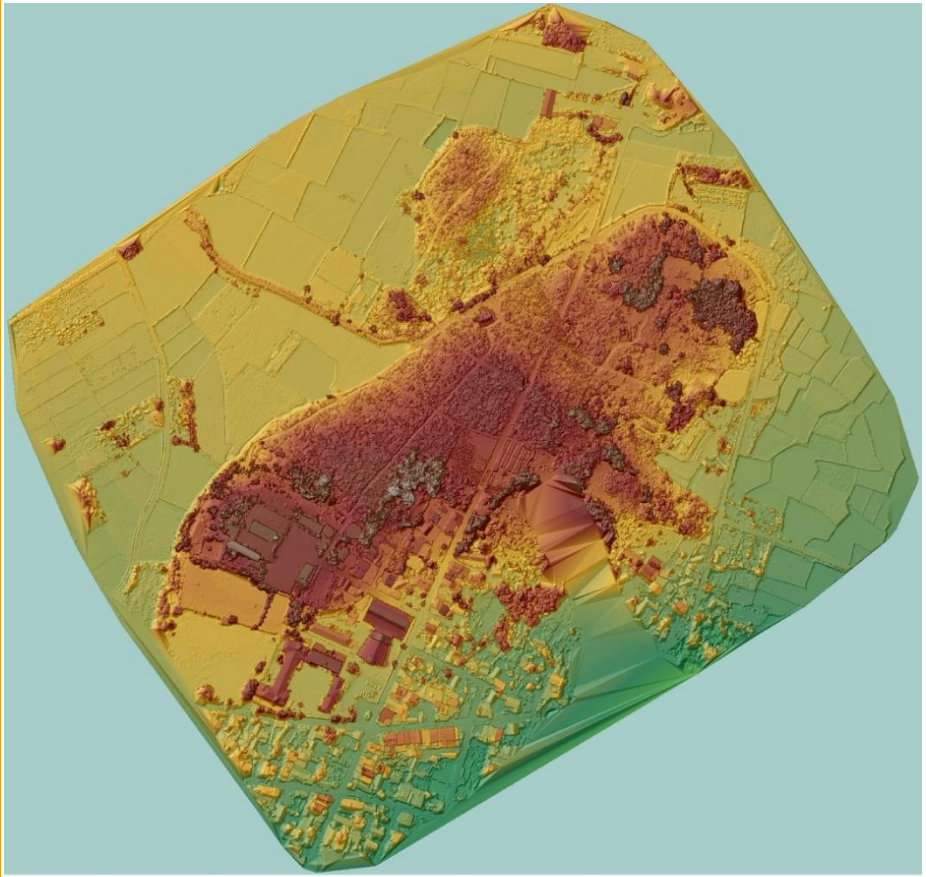


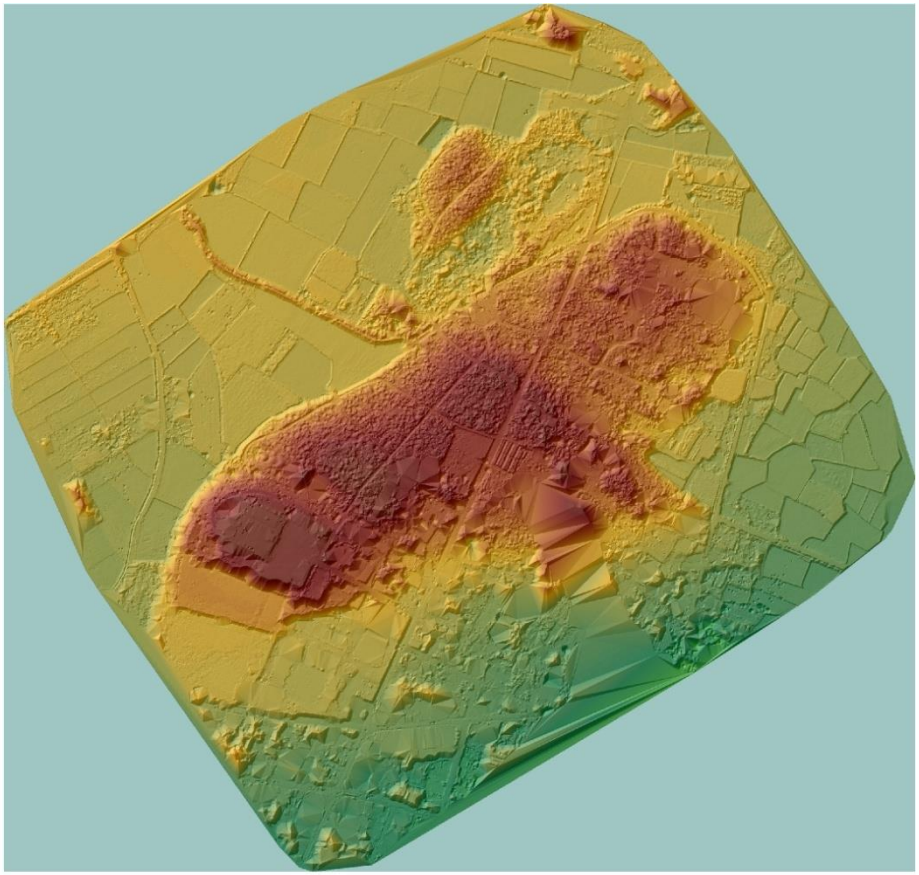


River Bed Changes

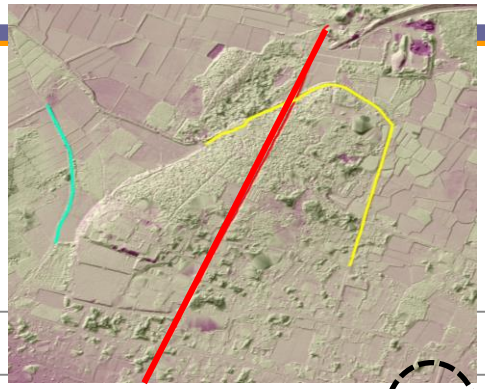


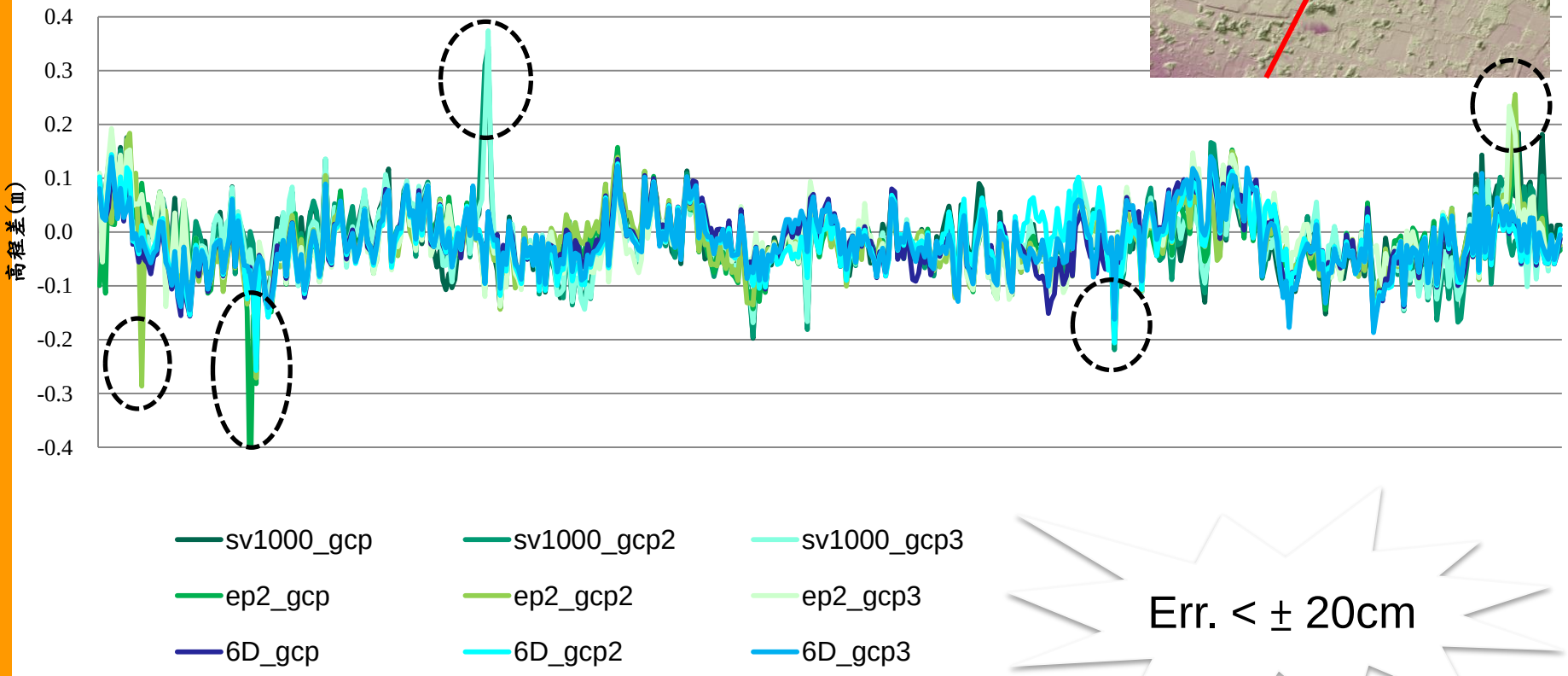
UAV DSM vs. UAV DEM





DTM Quality Evaluation

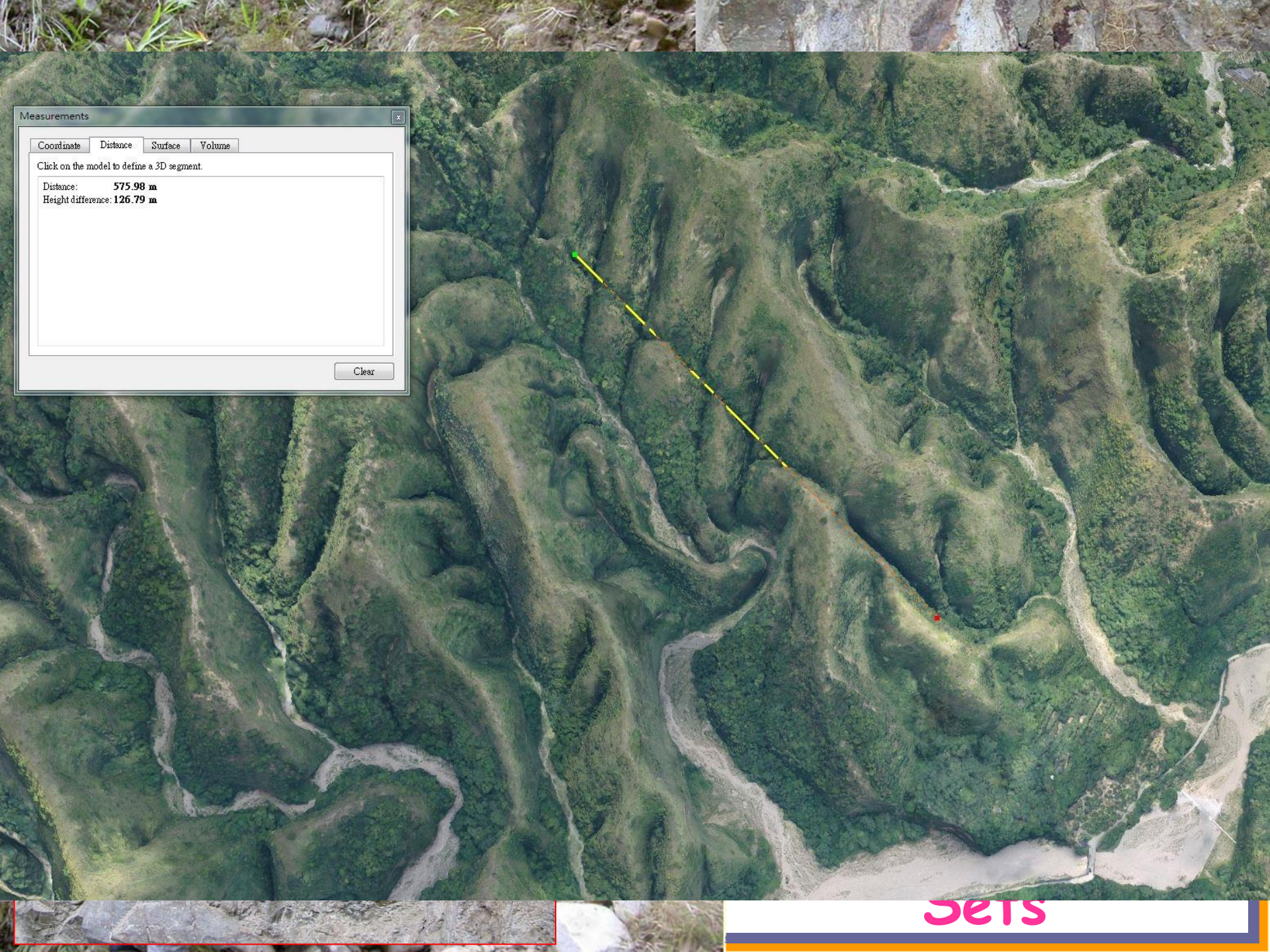




Err. < ± 20cm

Faults

Folds


Measurements
Coordinate
Distance
Surface
Volume
Click on the model to define a 3D segment.
Distance: 575.98 m
Height difference: 126.79 m
Clear

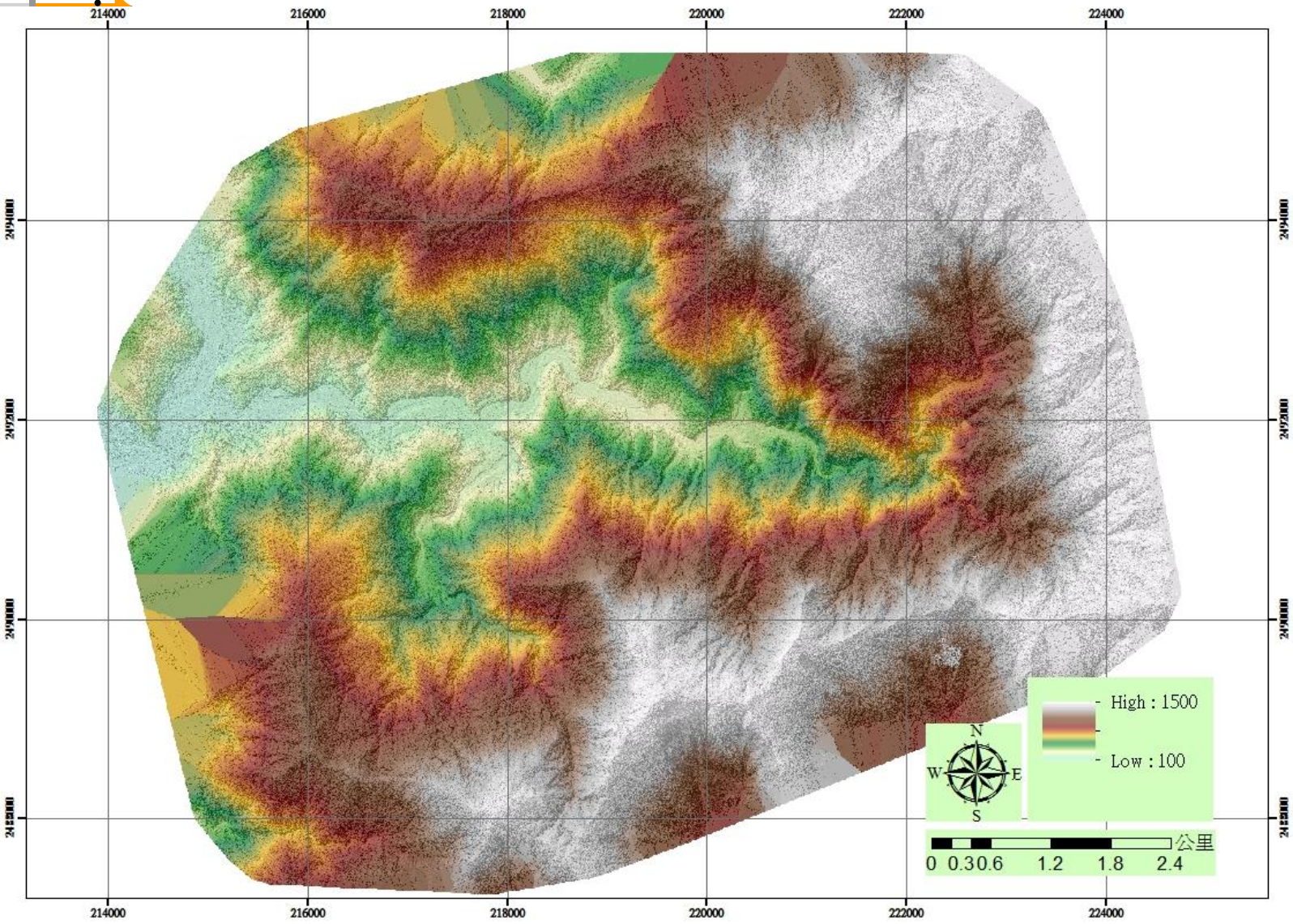
Hazard Analysis

Before and After Typhoon, Peisha Bridge, Central Cross-Island Highway

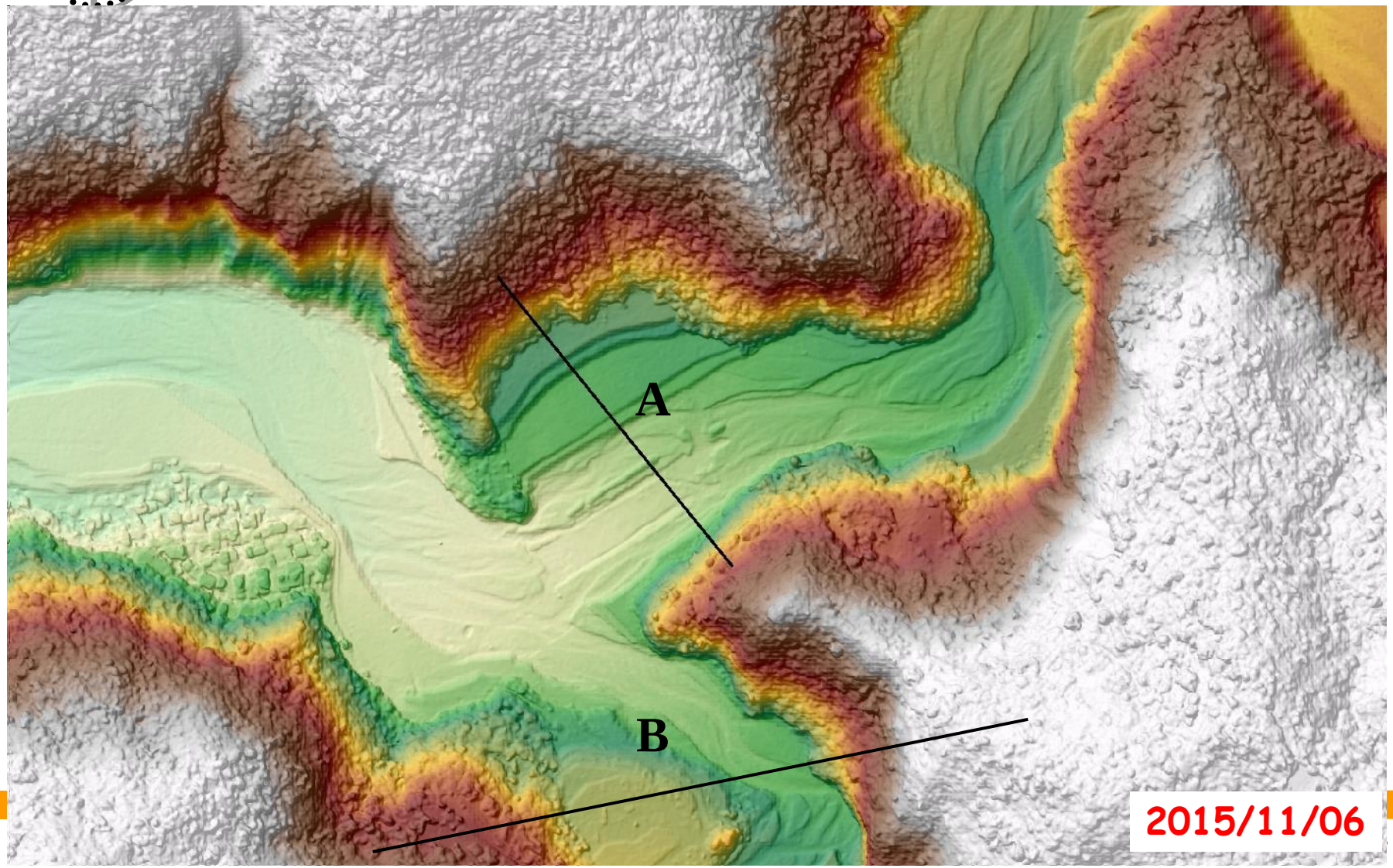
來義地區多期影像數據資料

Date	2009 04/10	2009 08/28	2010	2011	2013/ 03	2013 07/30	2014 05/17	2015 01/23	2015 05/21	2015 11/06
Source	Air photo	ADS 40	LiDAR	LiDAR	DMC	UAV	UAV	UAV	UAV	UAV
Area (km^2)	80	32	>150	30	120	1.5	2.2	67.5	22.5	69.8
Image res.	30cm	15cm	--	--	20cm	8cm	10cm	15cm	12cm	15cm
DTM res.	2m	2m	1m	2m	2m	8cm	12cm	17cm	15cm	20cm

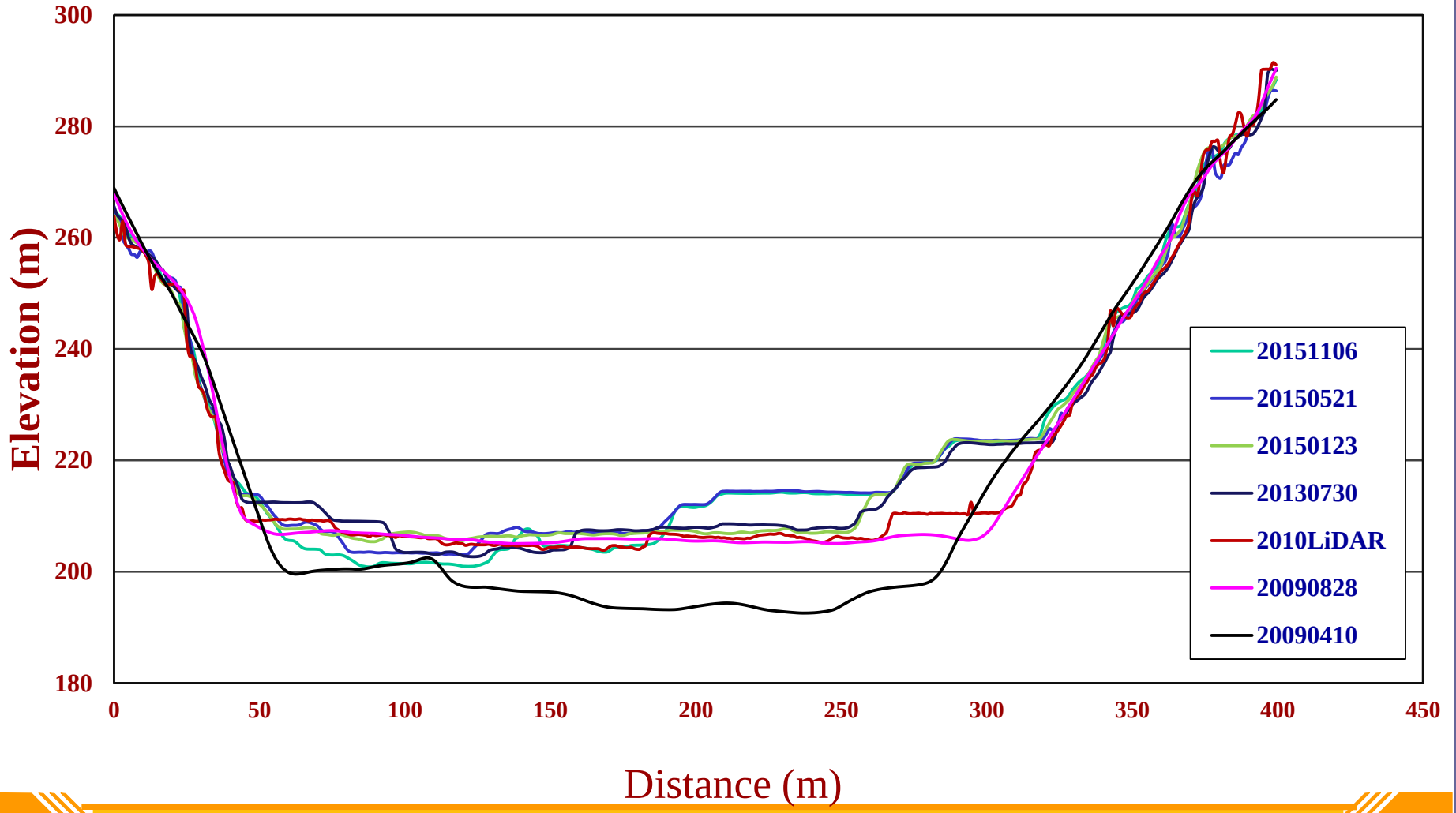
OrthoMosaic & DSM 2015/01/23



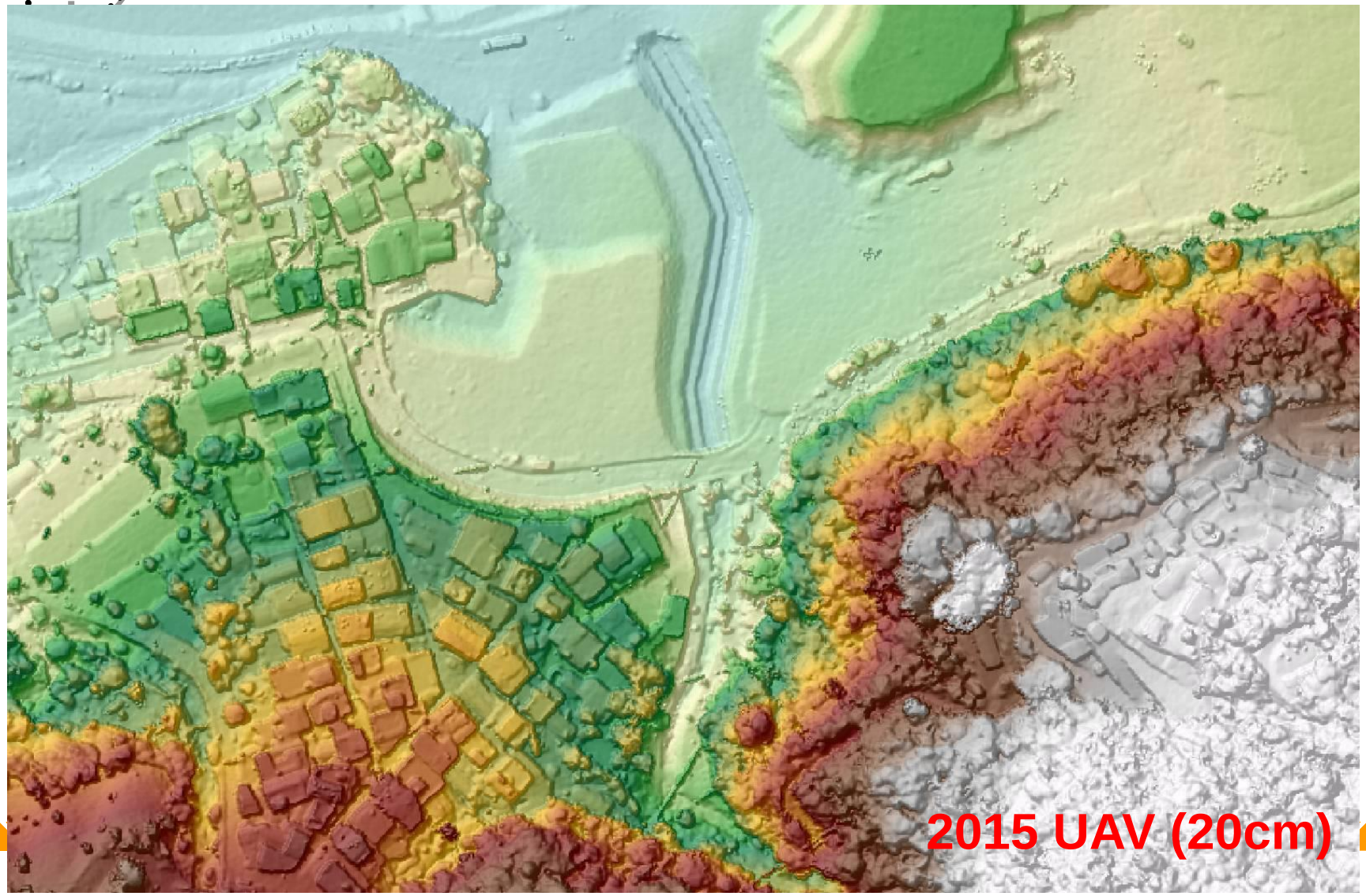
DSM Quality Evaluation



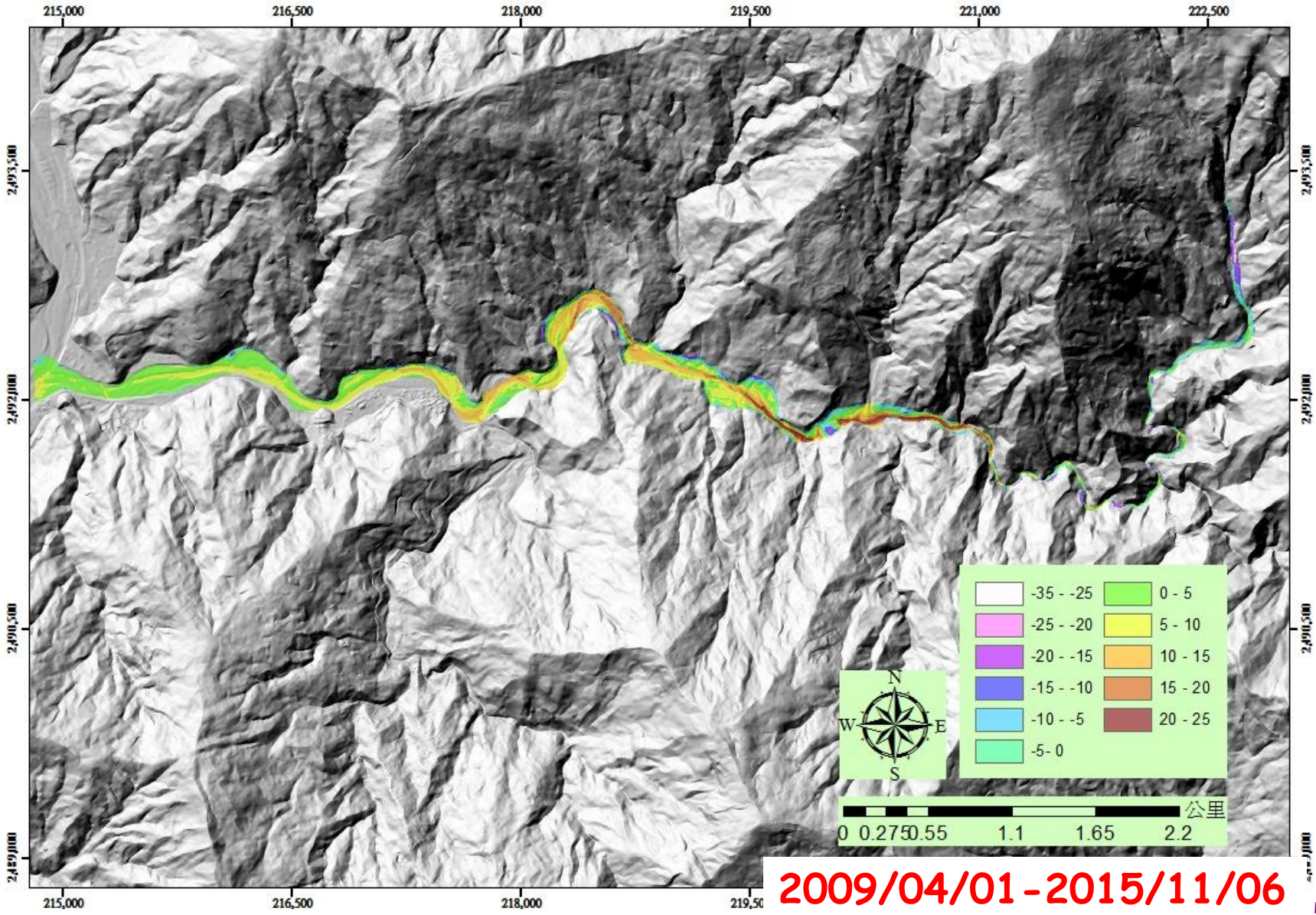
DSM Quality Evaluation– Profile A



Data Comparison: UAV vs. LiDAR

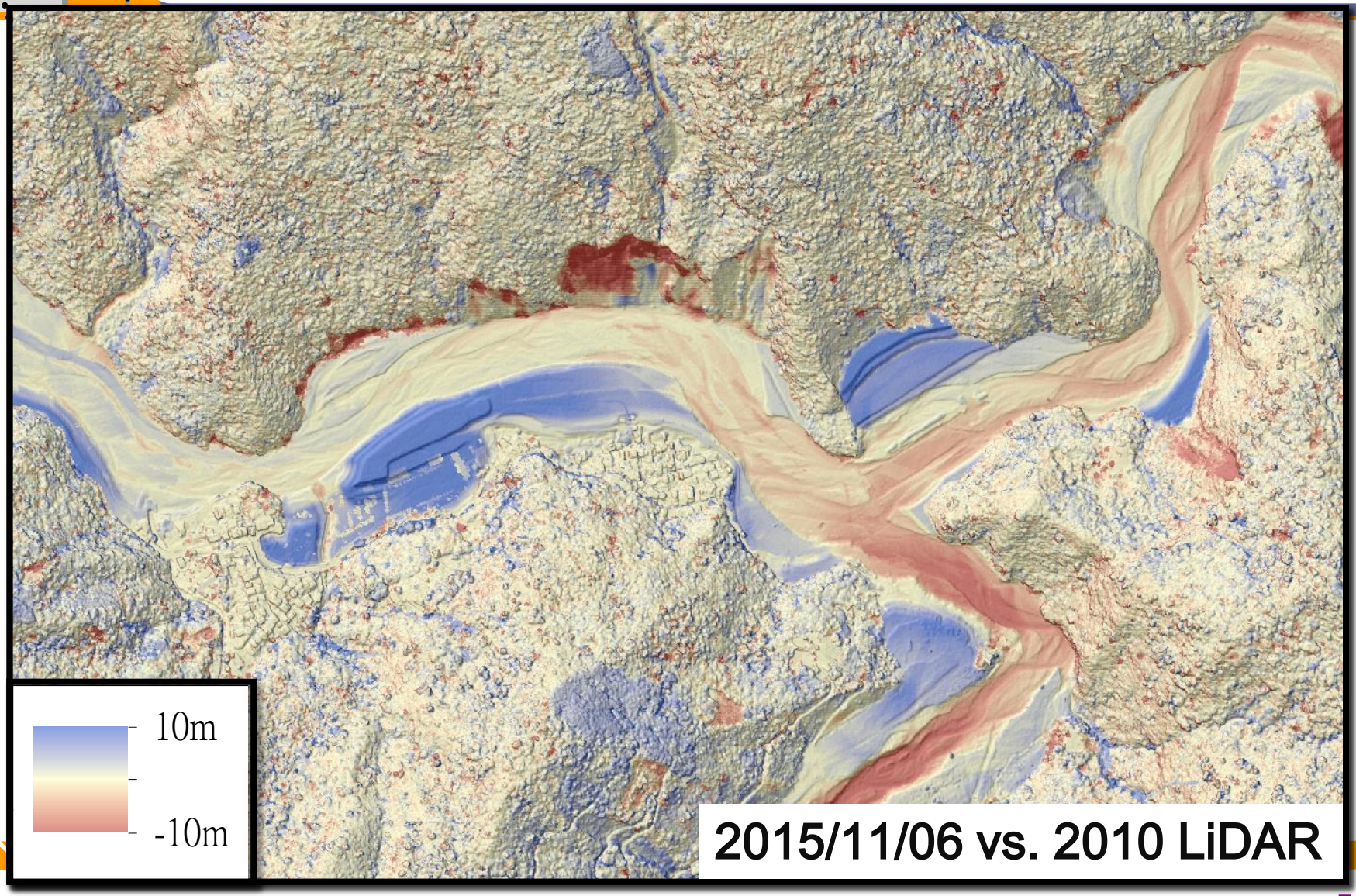


Riverbed Accumulation

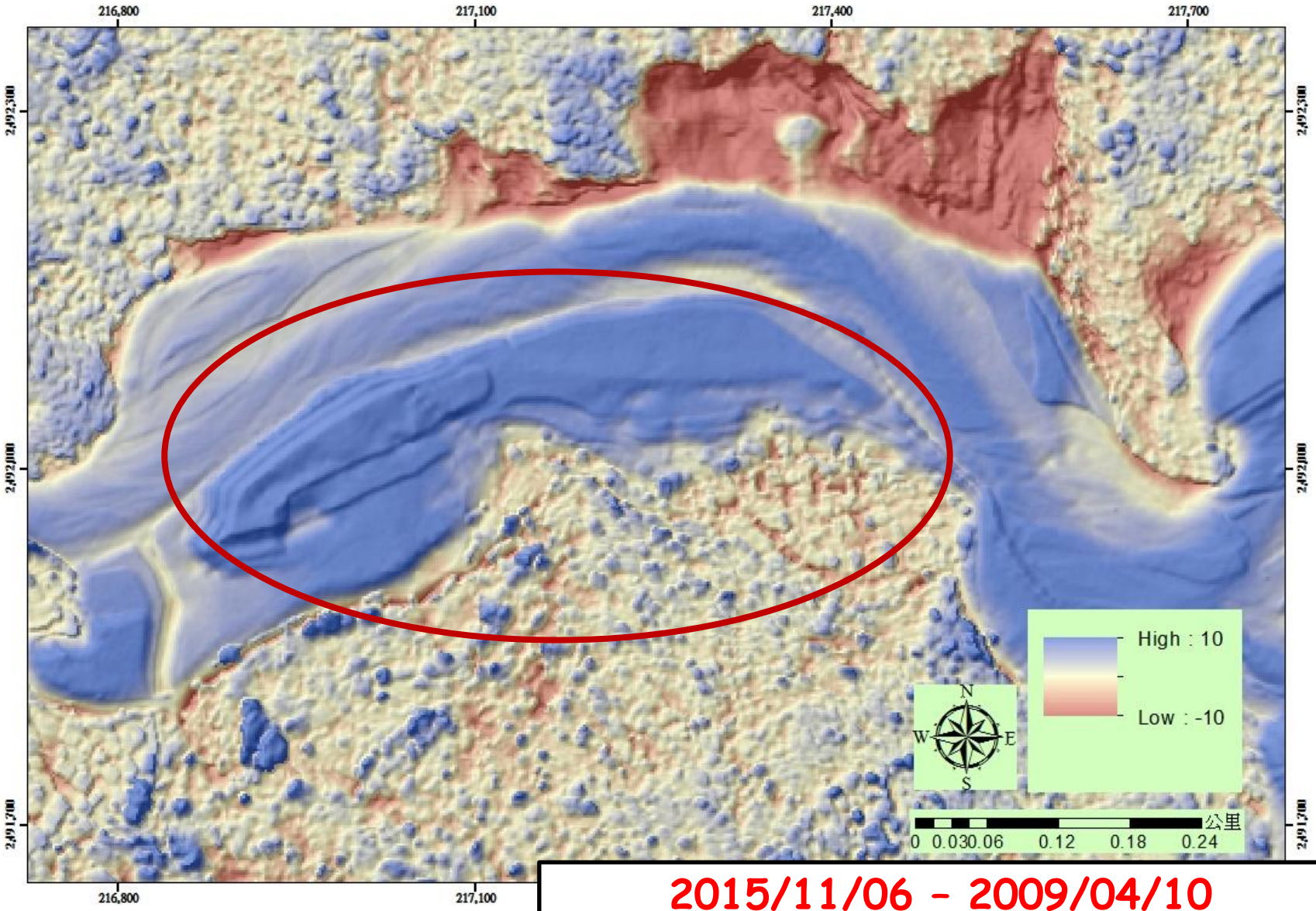


2009/04/01-2015/11/06

Riverbed Change in 2015

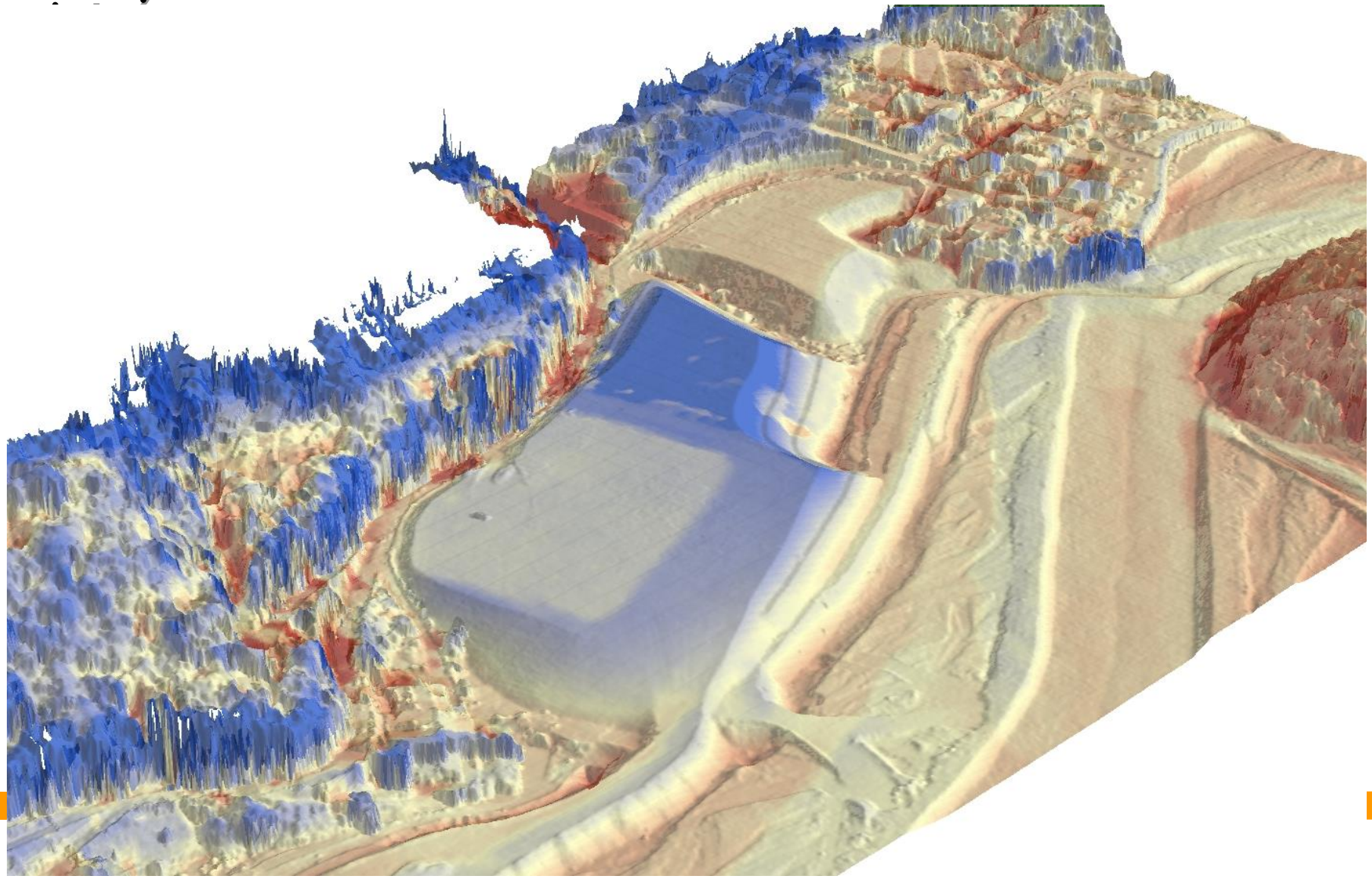


Topographic Change

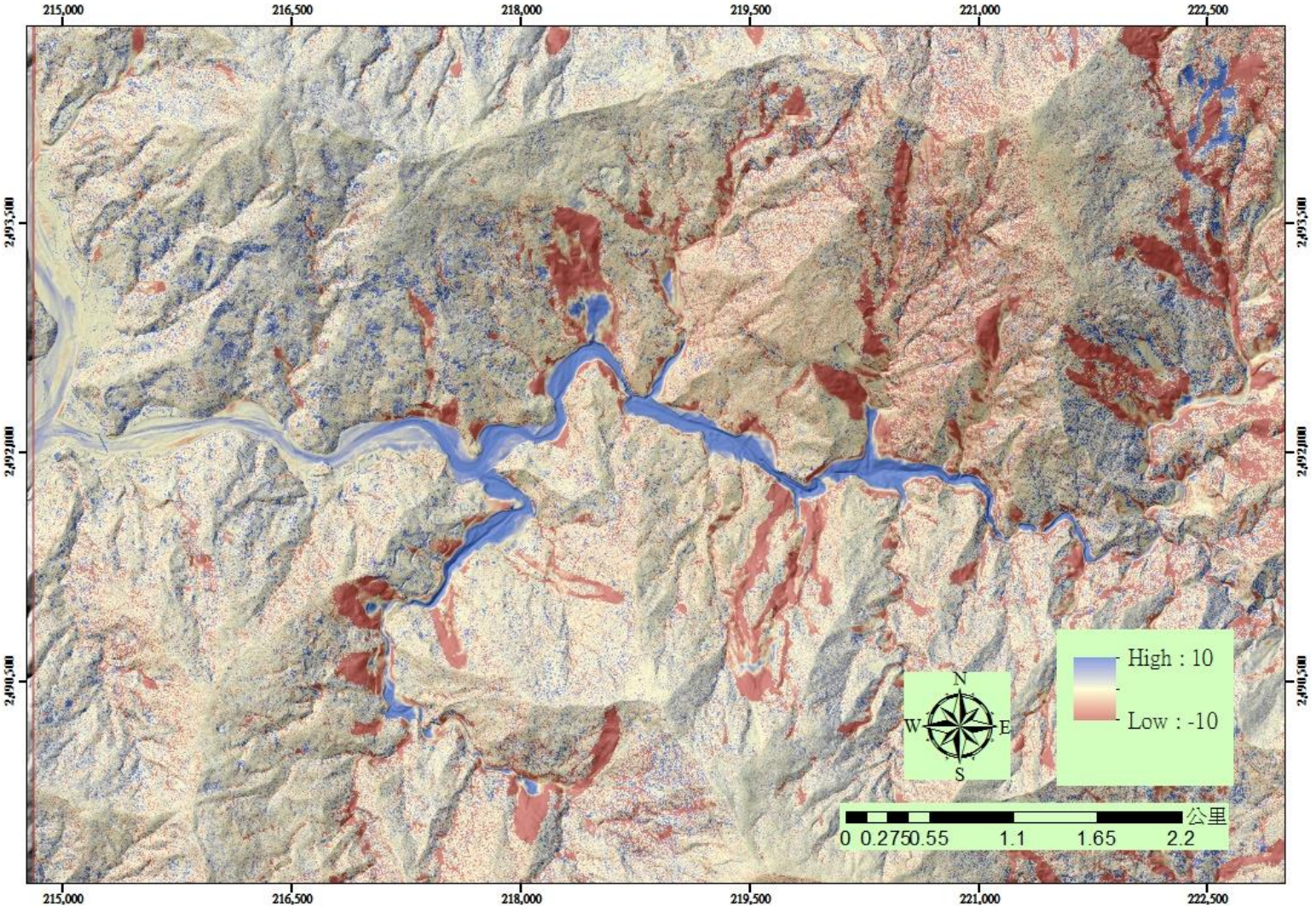


2015/11/06 - 2009/04/10

Debris Deposit @ E Laiyi Village



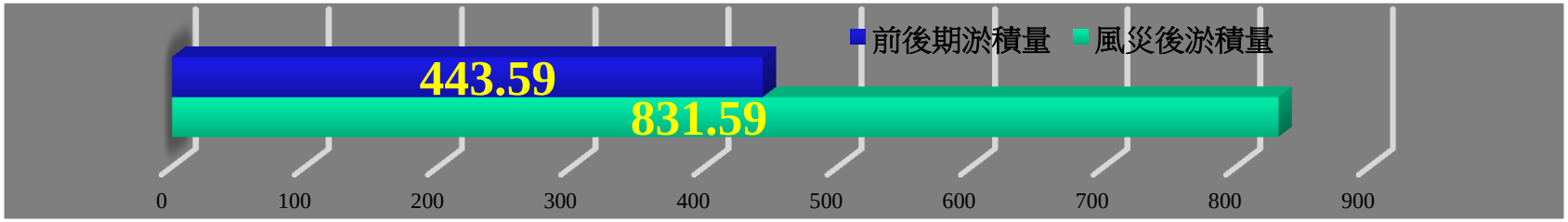
Riverbed Changes



2009/04-2010 LiDAR (Accumulation, Erosion)

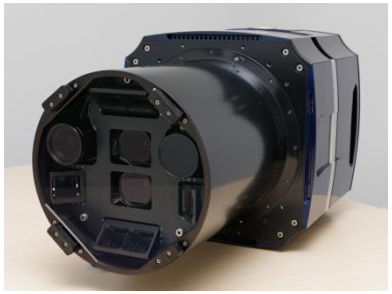
Sediment Budget at LaiShe River

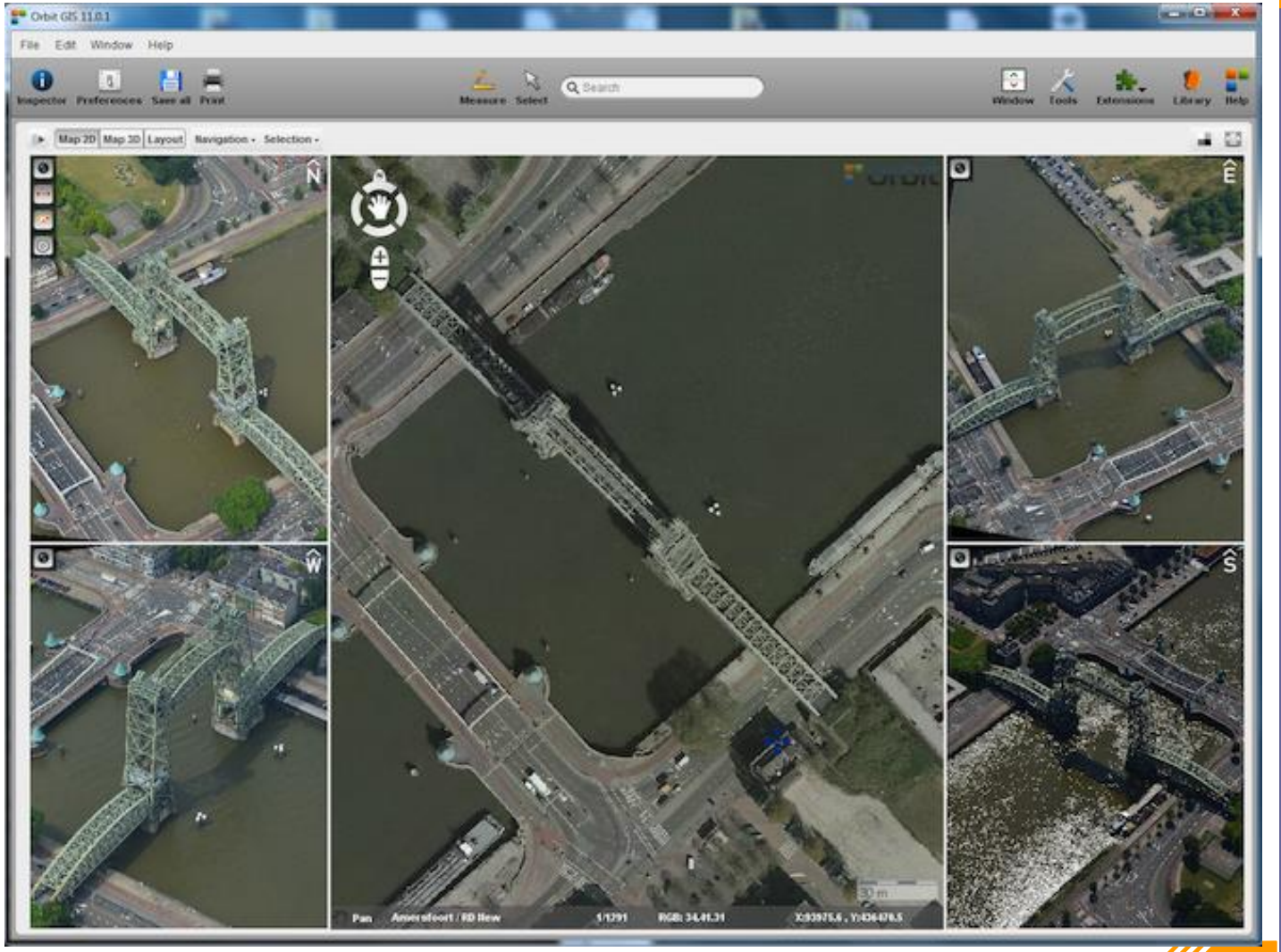
區段	風災後河道淤積總量(萬 m^3)	風災前至2015年11月河道淤積總量(萬 m^3)	風災後侵淤深度(m)	風災前至2015年11月侵淤深度(m)
上游三段	-28.04	-50.63	-2.33	-5.44
上游二段	257.19	73.24	13.79	6.55
上游一段	279.63	133.10	11.10	5.47
東部落段	240.19	169.32	8.14	6.91
西部落段	53.81	74.24	2.84	4.02
義林段	28.81	44.32	2.54	3.26
總和	831.59	443.59		



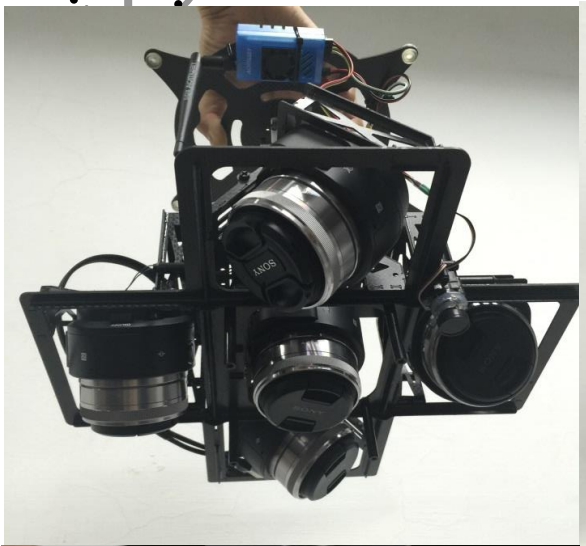
2.5D vs. True 3D Model

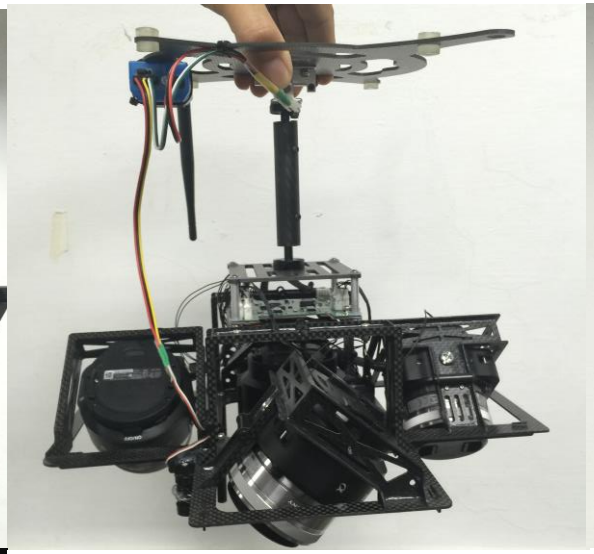
Oblique Photogrammetry

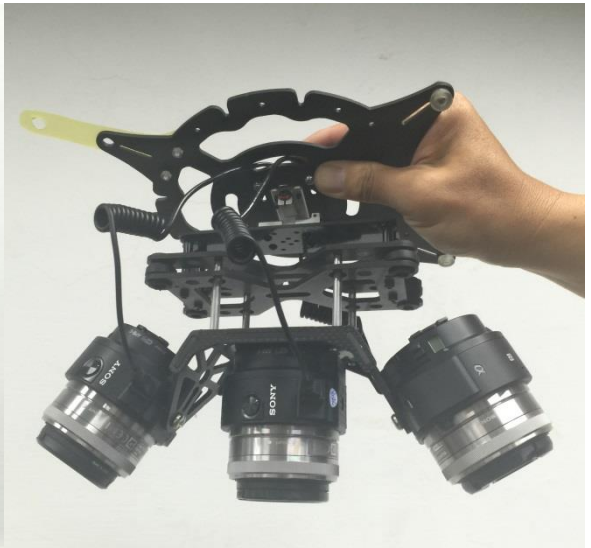




多相機傾斜攝影

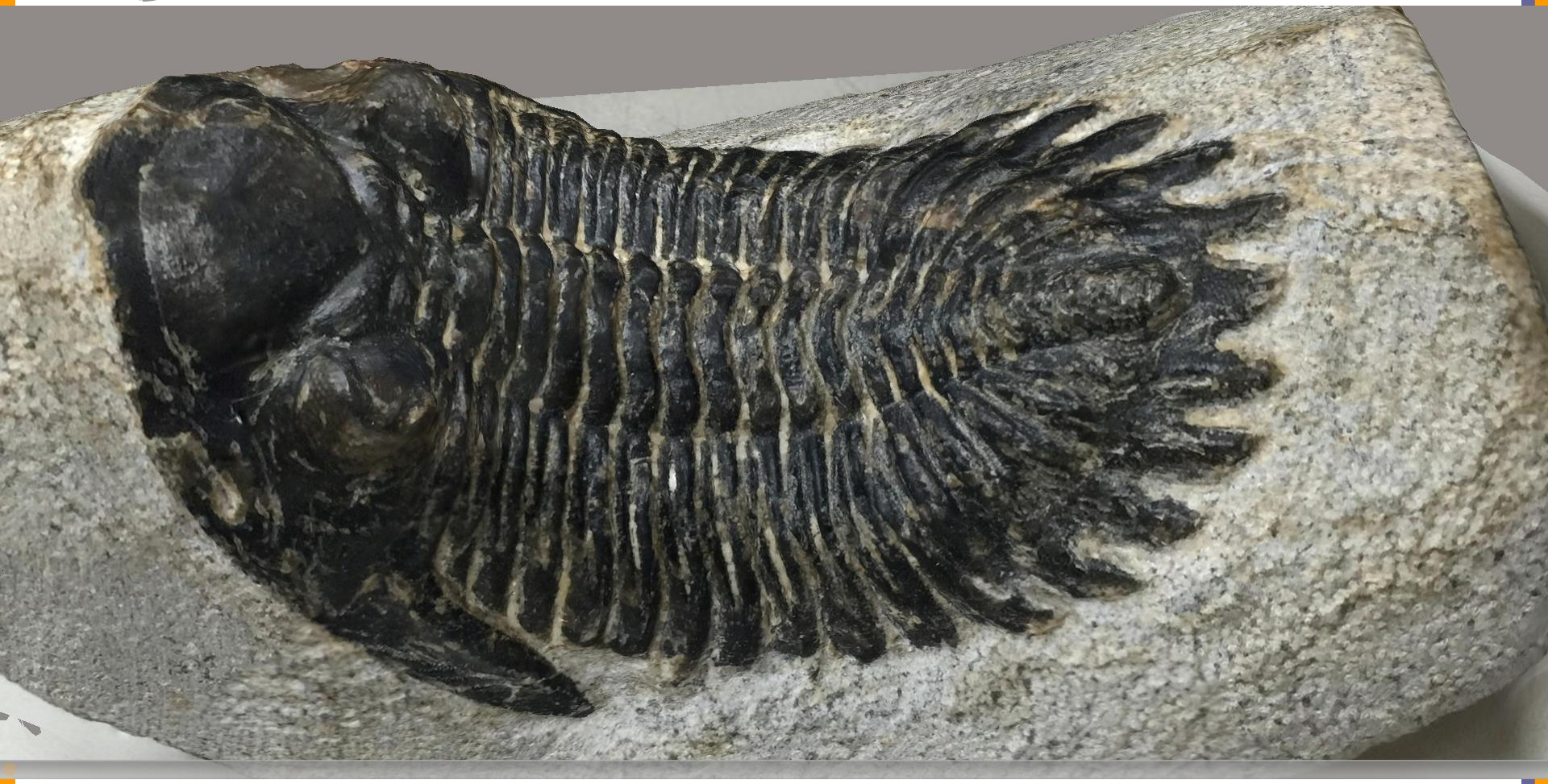




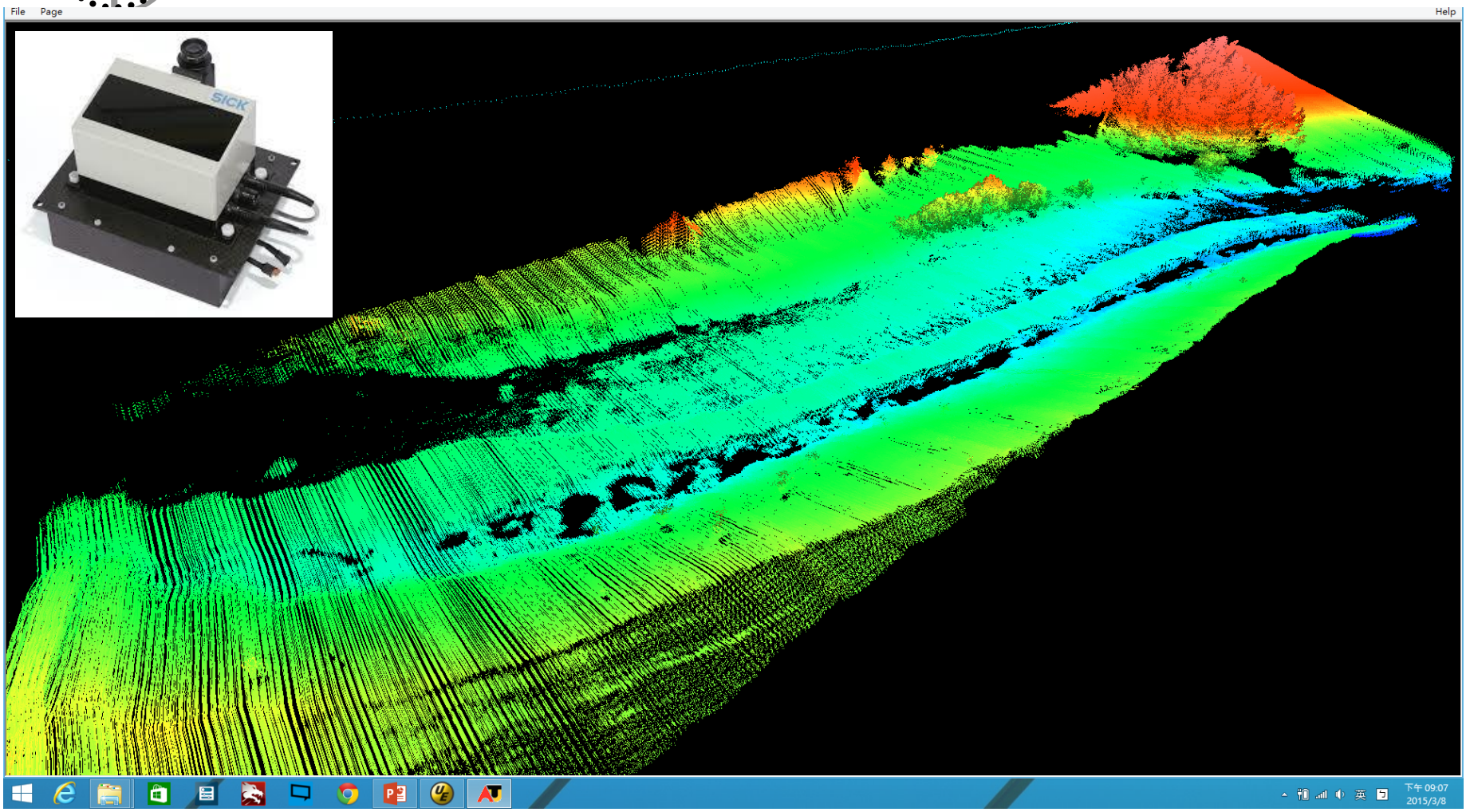


3D Model of Monuments

Close-Range Photogrammetry



UAV Laser Scanner

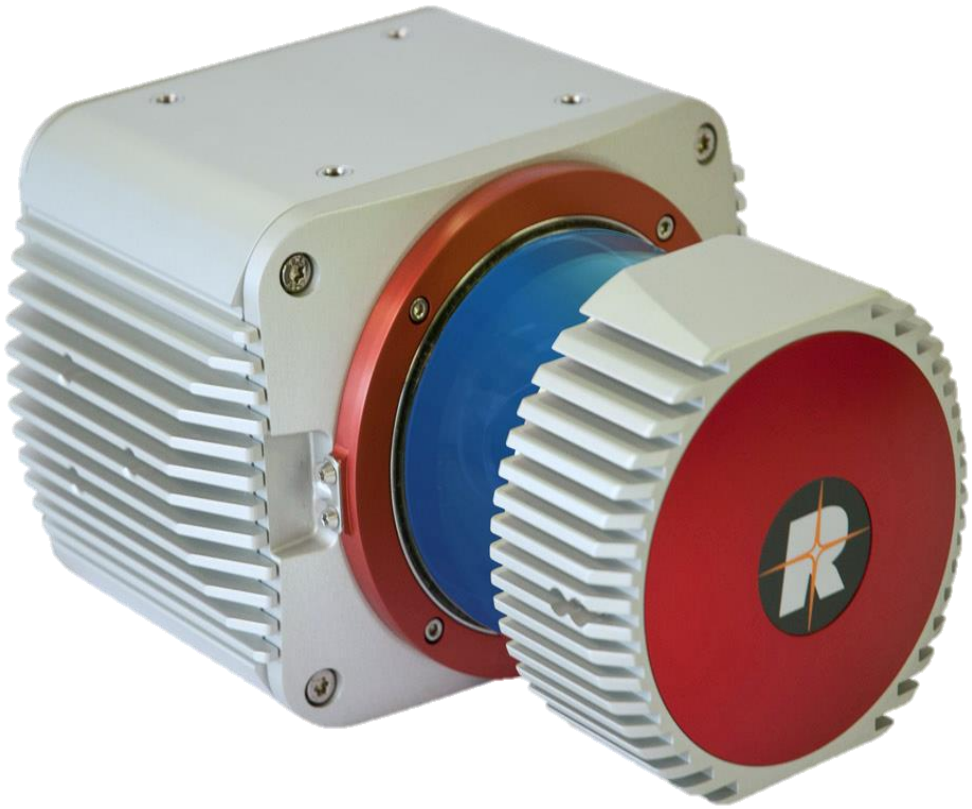


Pulse Aerospace Vapor 55

自身重量 (kg)	8.6
最大承載 (kg)	15
飛行時間 (min)	60
懸停時間 (min)	45
遙控距離 (km)	8
飛行速度 (m/s)	10/20
飛行高度 (m)	3600

Riegl VUX-1 UAV

重量 (g)	3,500
尺寸 (mm)	227*180*125
波長 (nm)	1,550 (近紅外光)
防水防塵	IP64
精度 (mm)	10
FOV (deg)	330
掃瞄速度 (scan/sec)	10-200
脈衝重複率 PRR (kHz)	550
建議高度 AGL (m)	50-350
最大測量範圍	920m (反射率60%) 550m (反射率20%)



Trimble AP20

Airborne Applications Parameter Accuracy (RMS ERROR)		
Process	RTX Post-Processed	SmartBase Post-Processed
Position (m)	< 0.1 H < 0.2 V	< 0.05 H < 0.1 V
Velocity (m/s)	0.01	0.01
Roll & Pitch (deg)	0.015	0.015
Heading (deg)	0.035	0.035

UAS LiDAR設備整合

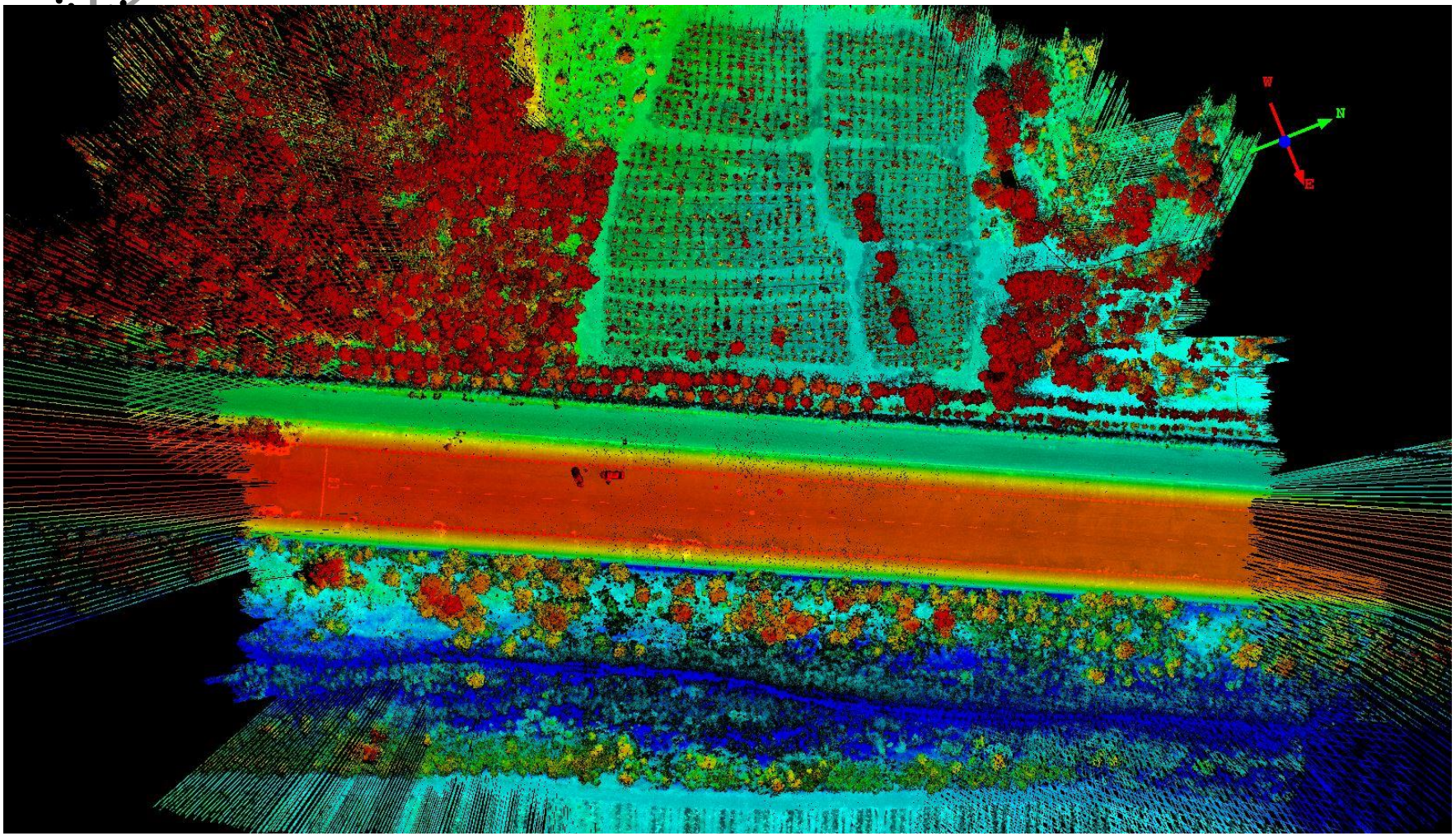
Riegl VUX-1 + Trimble Applanix AP20

儀器重量	3.75Kg	儀器照片
儀器大小	227x209x129 mm	
精度	10mm	
重複測量精度	5mm	
雷射發射功率	550kHz	
視場角(FOV)	330°	
最大測量距離	920m(目標反射率60%) 550m(目標反射率20%)	
最高雷射發射頻率	550000 points/s	
工作海拔高度	5500m	
儲存容量	240G SSD	
環境溫度	-20℃~50℃	

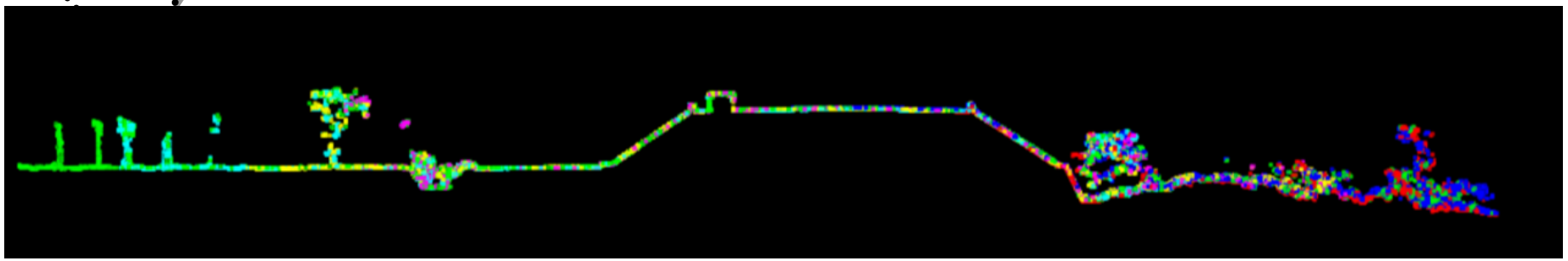
全球唯一長測距、輕量型光達雷射掃瞄儀

UAS LiDAR、可見光相機及現地測量

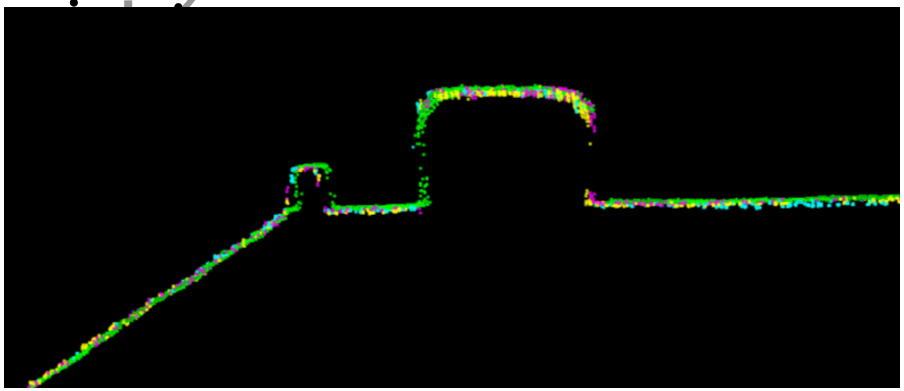
UAV LiDAR 點雲範例

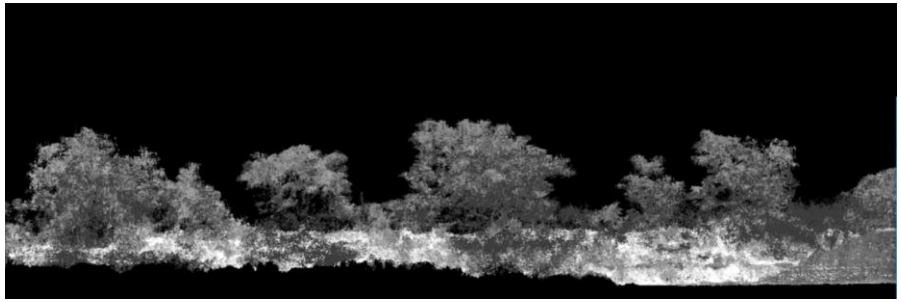


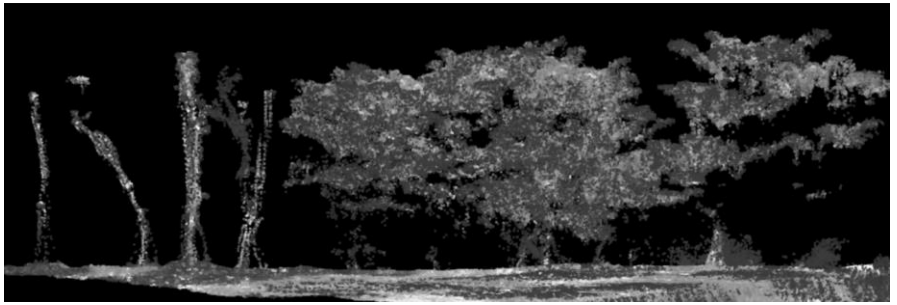
UAV LiDAR 平差後點雲

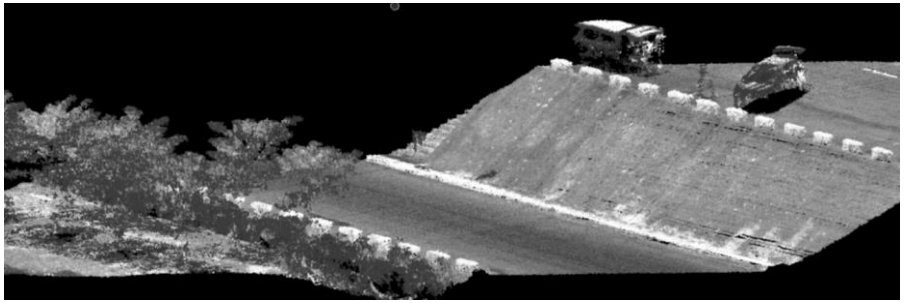


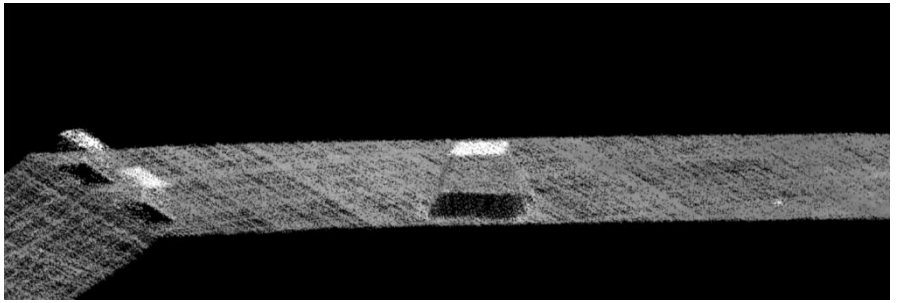
UAV LiDAR 平差後點雲



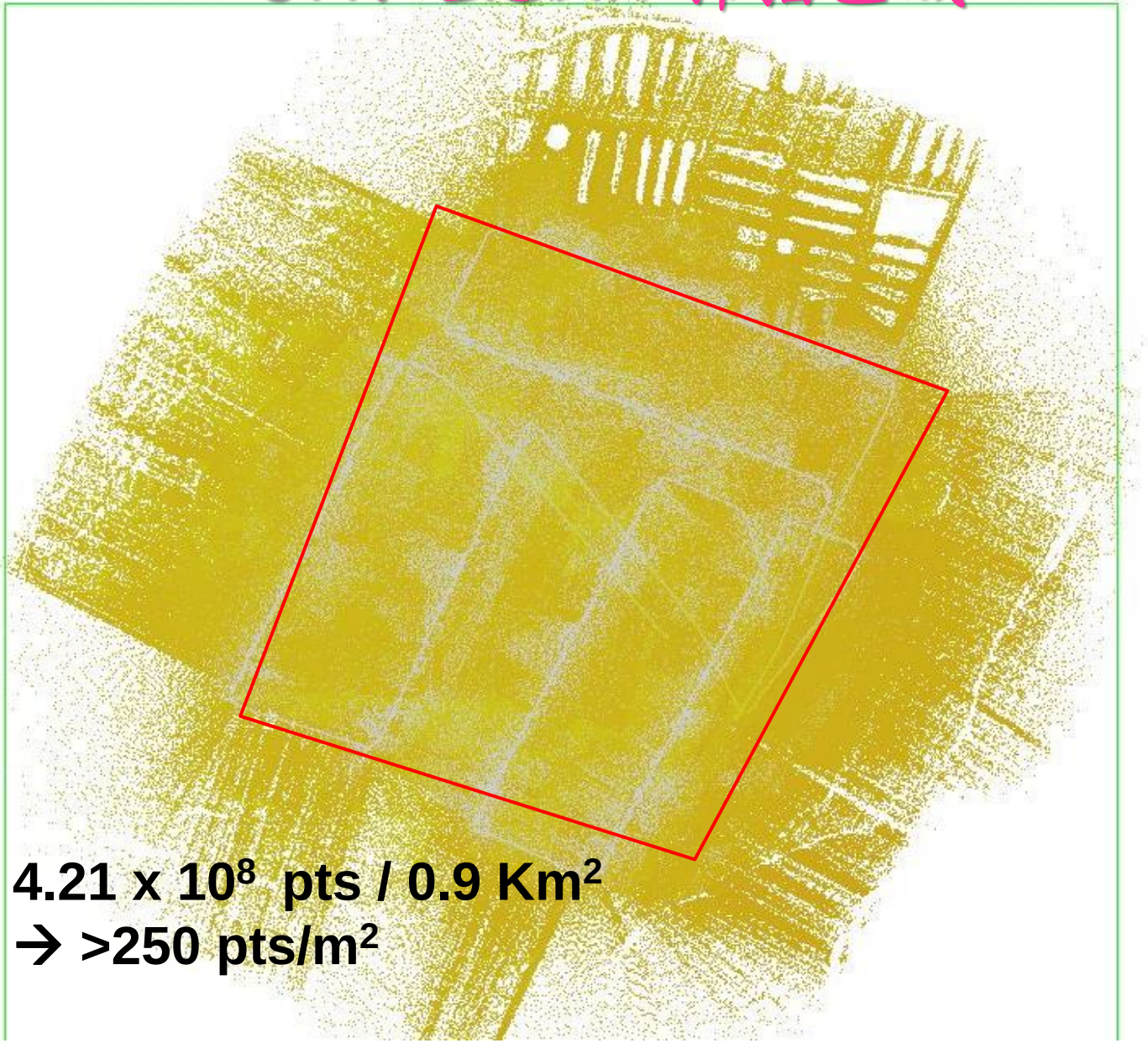








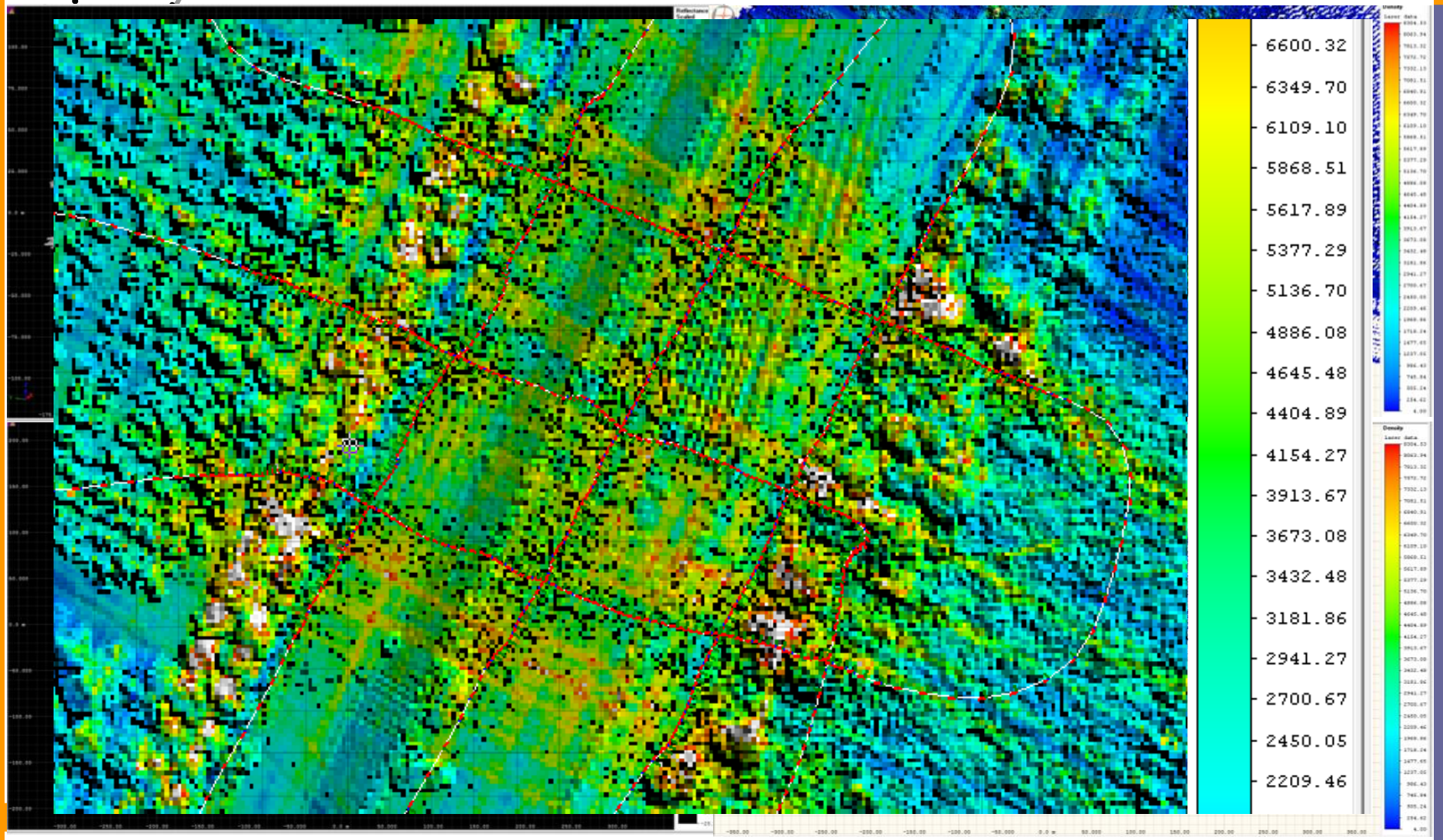
UAV LiDAR 掃描區域



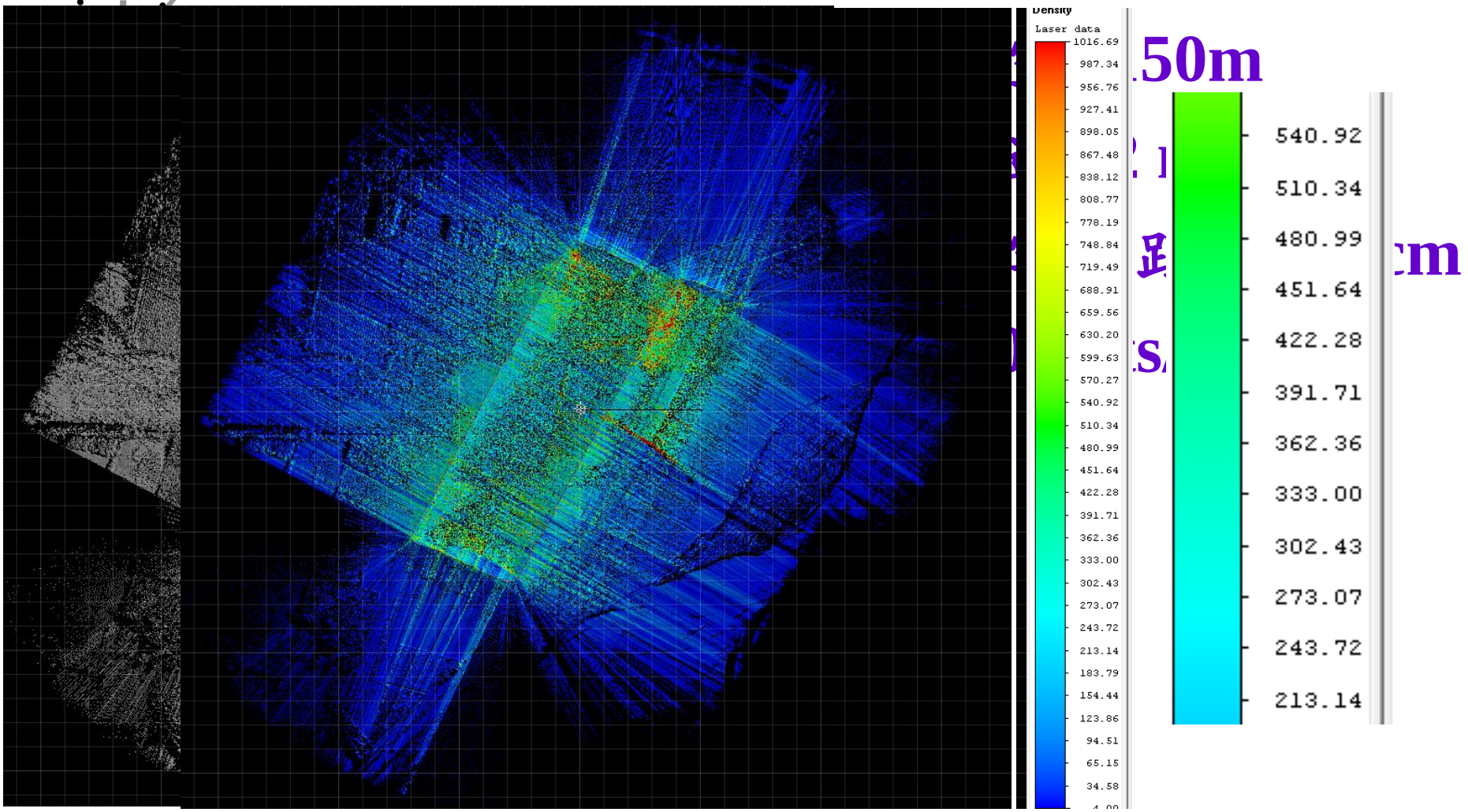
4.21×10^8 pts / 0.9 Km^2

→ >250 pts/m^2

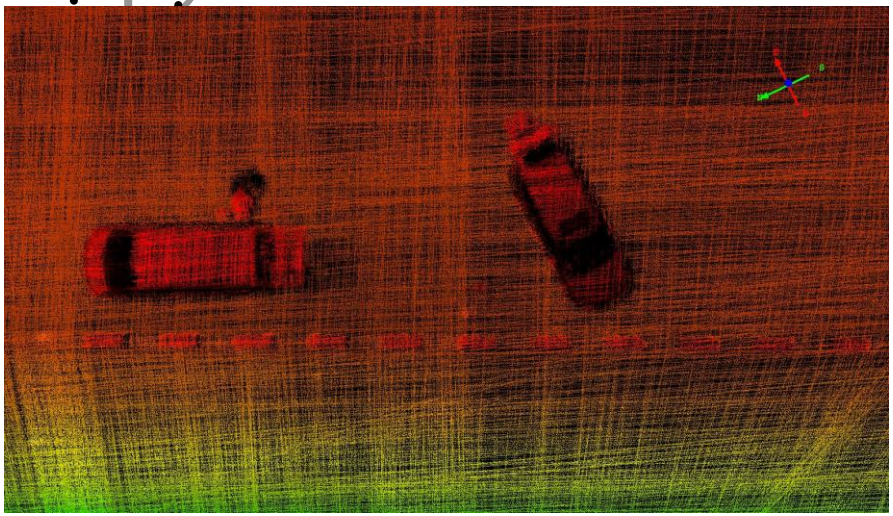
UAV LiDAR率定區點雲及點雲密度

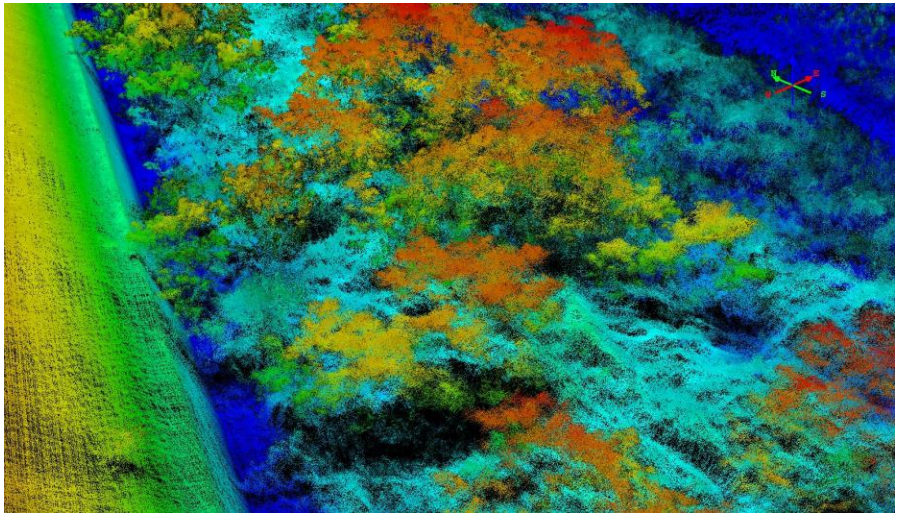


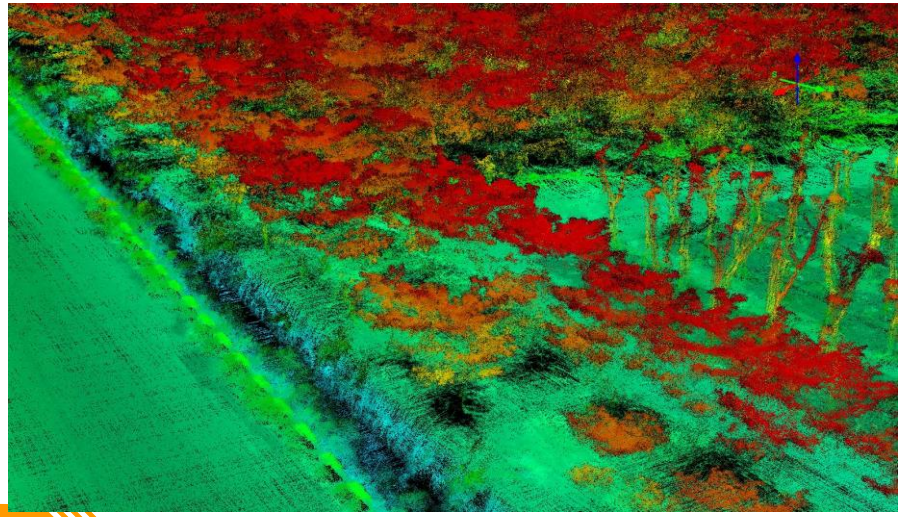
UAV LiDAR 航次一掃描資料

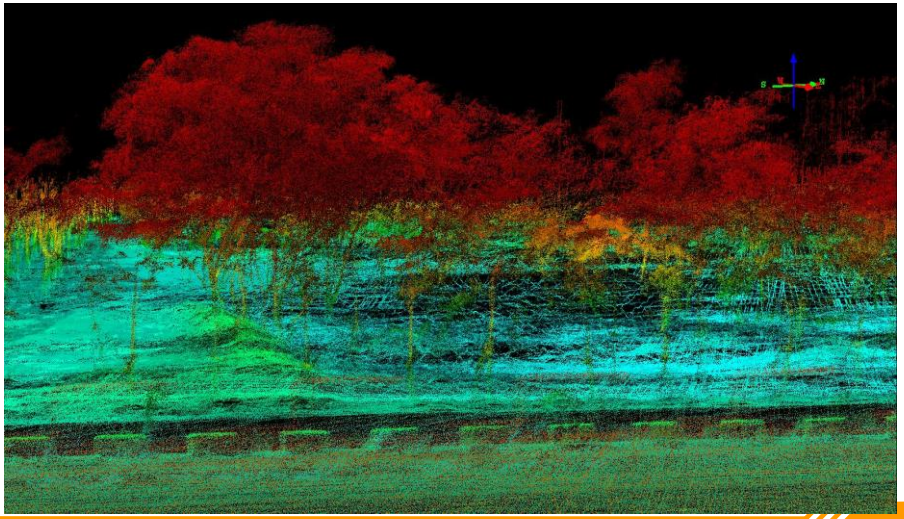


點雲範例 vs. 植被穿透





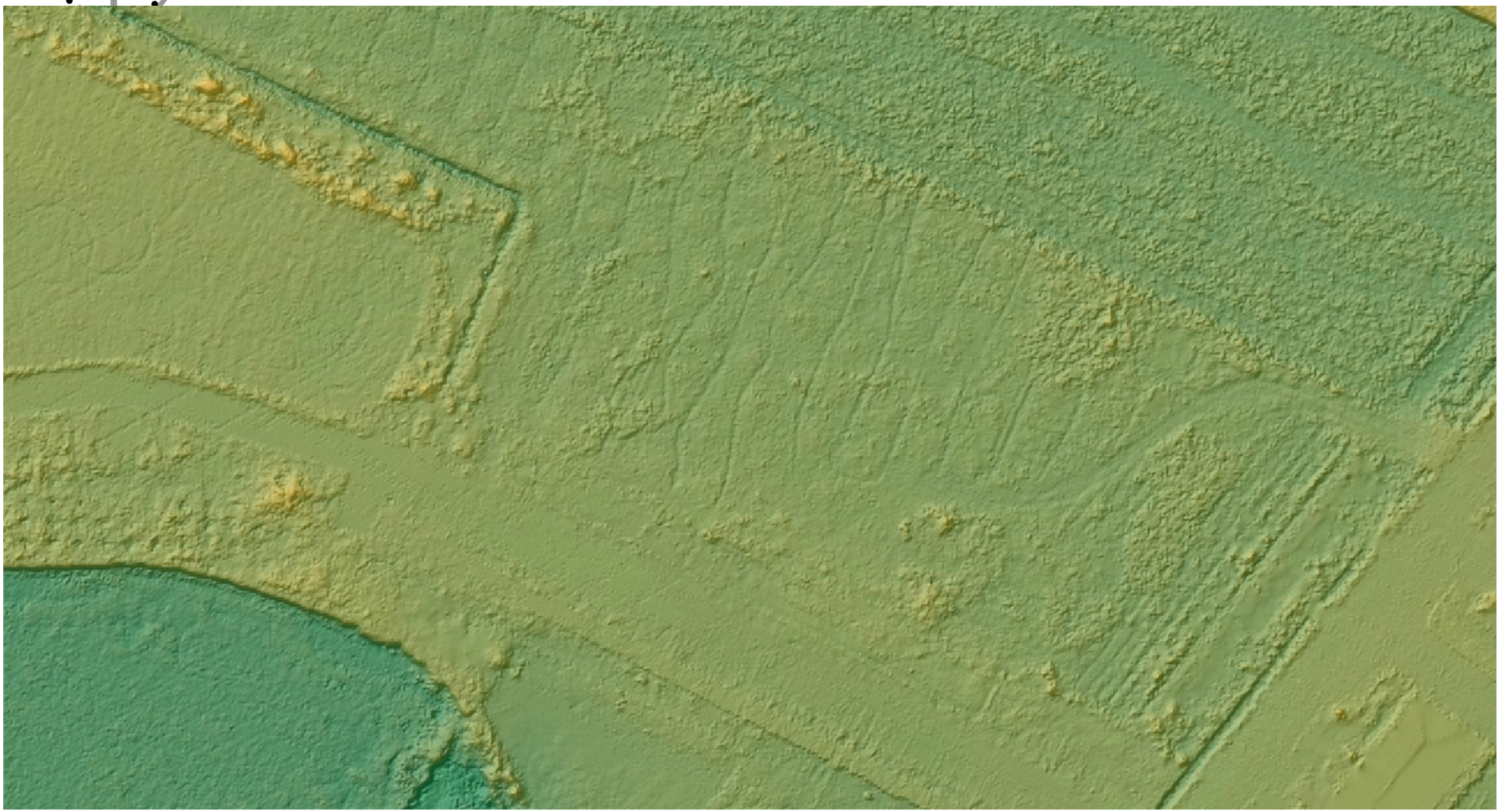




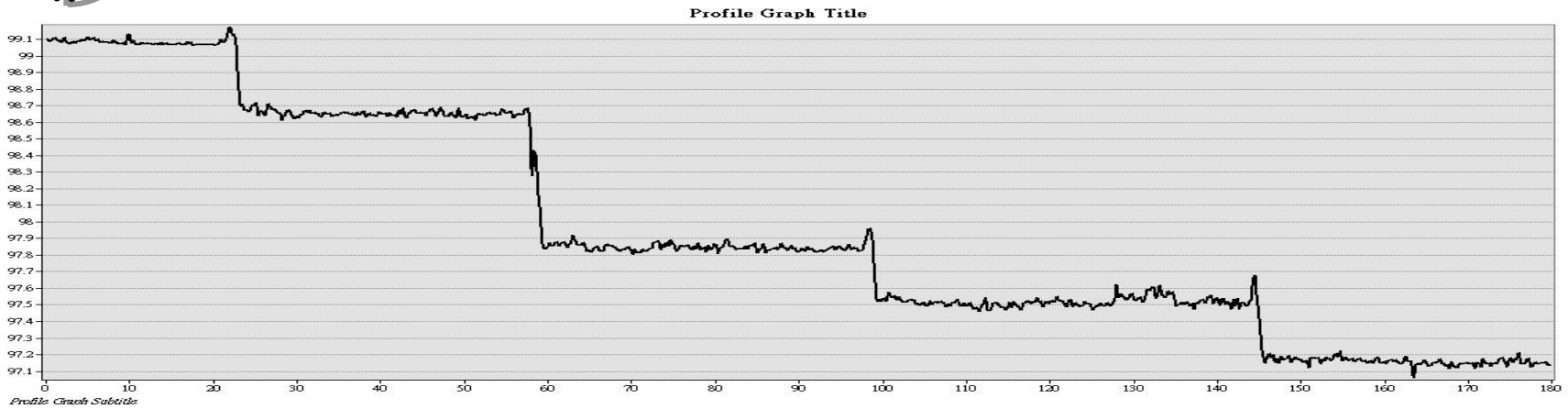
UAV LiDAR DSM vs. DEM

UAV LiDAR DSM vs. DEM

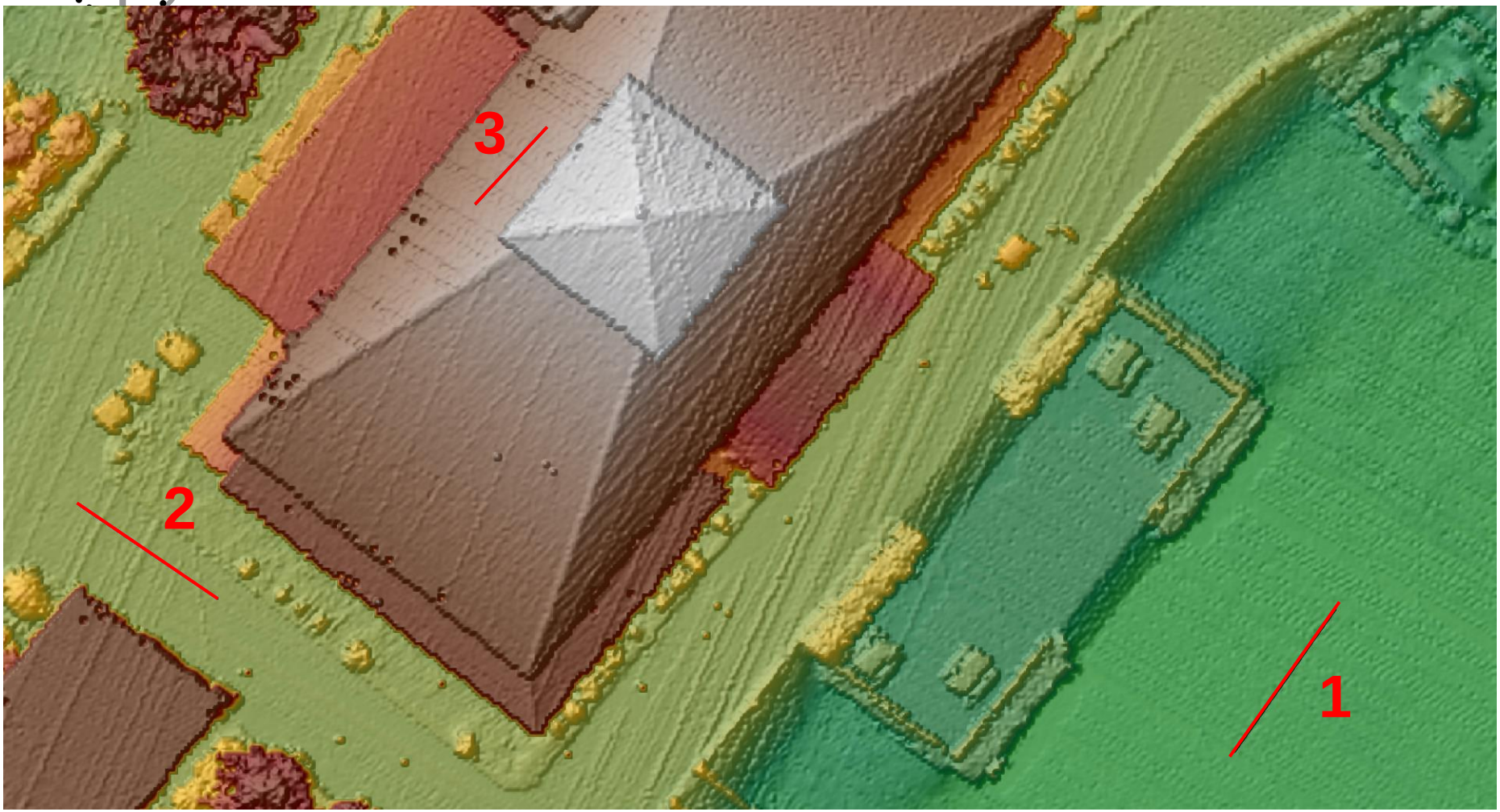
UAV LiDAR DSM vs. DEM



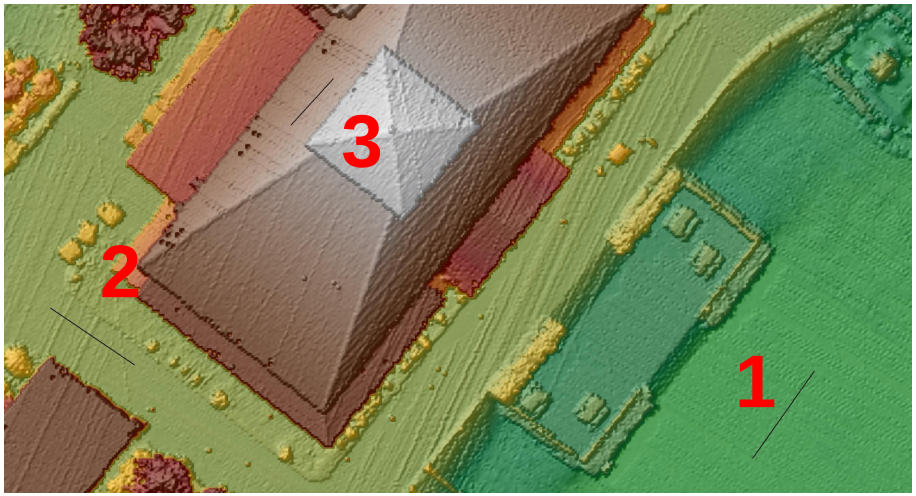
Topographic profiles

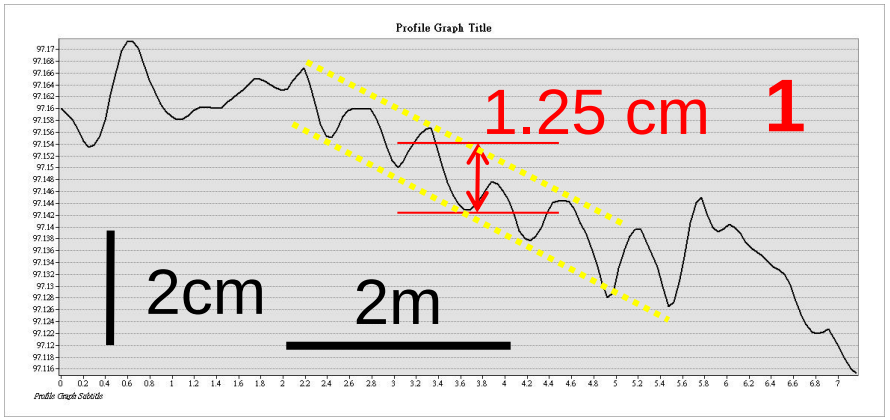


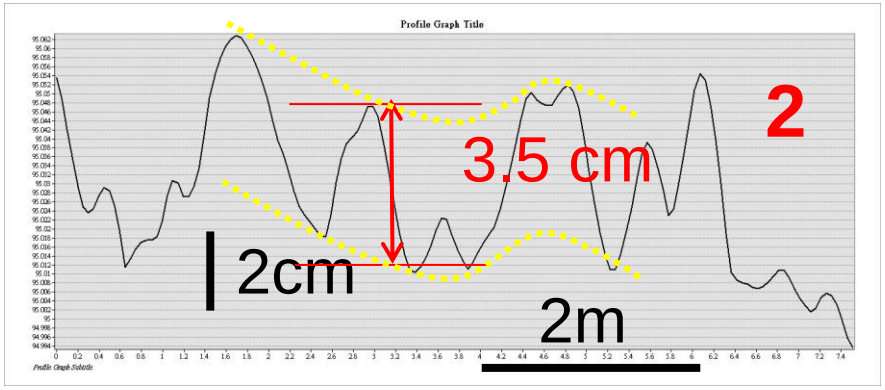
Data Validation

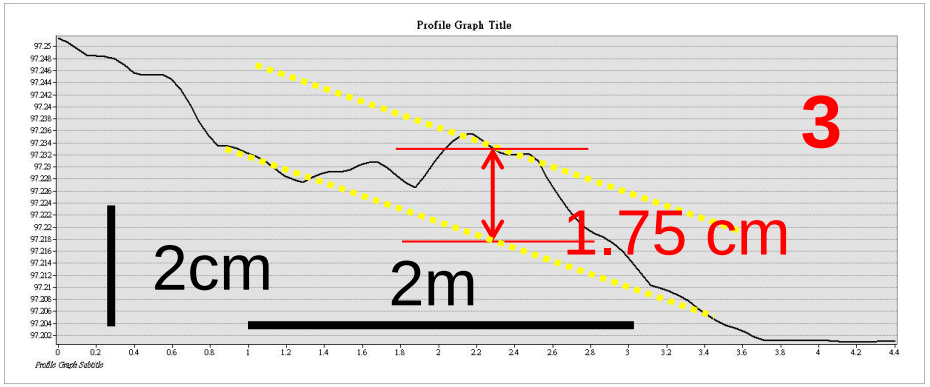


航帶平差後誤差

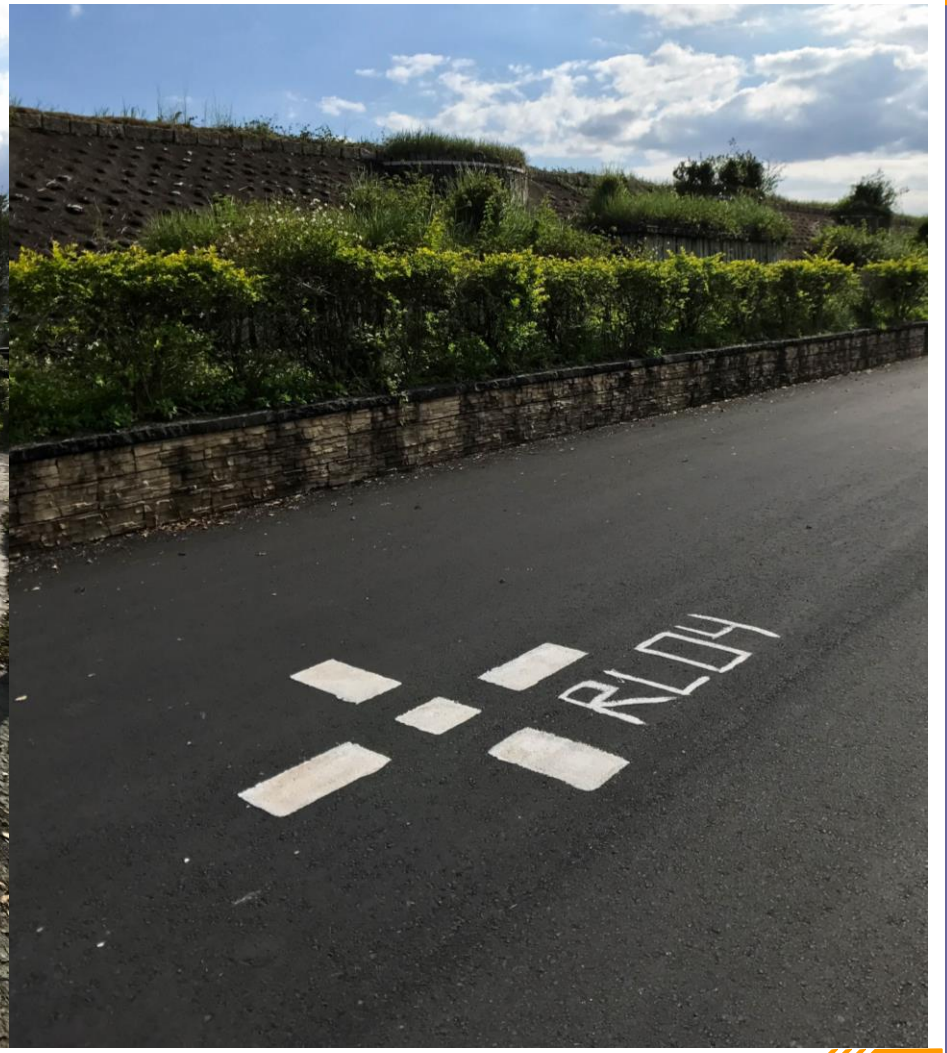

3
2
1


Profile Graph Title
1.25 cm
1
2cm
2m

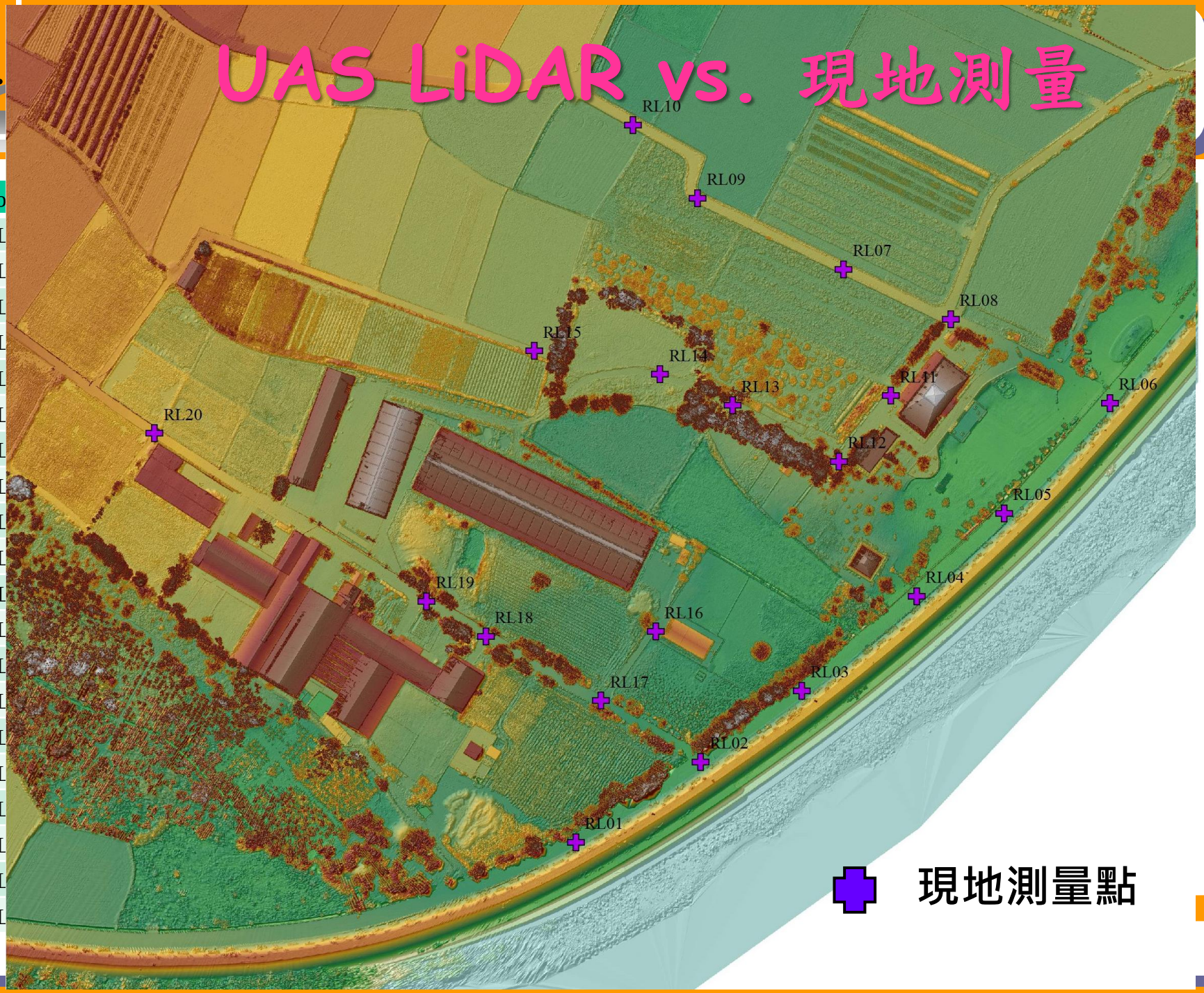

Profile Graph Title
3.5 cm
2
2cm
2m


Profile Graph Title
3
1.75 cm
2cm
2m

現地檢核點布設及量測

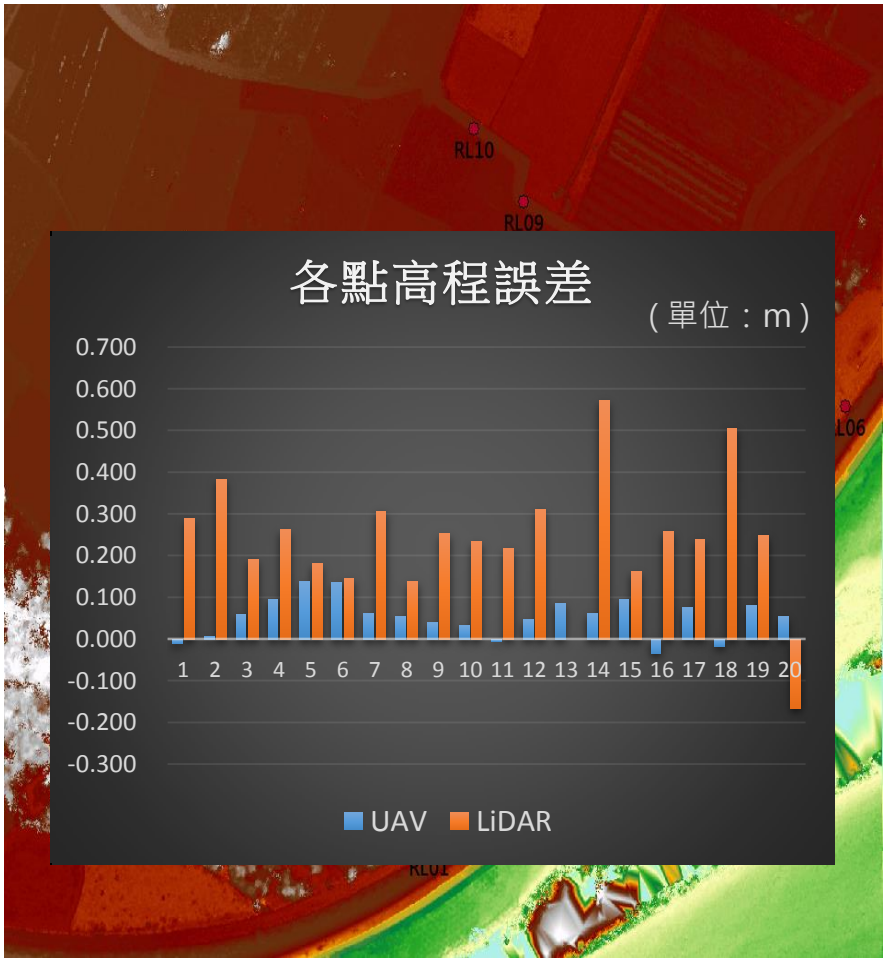


UAS LiDAR vs. 現地測量

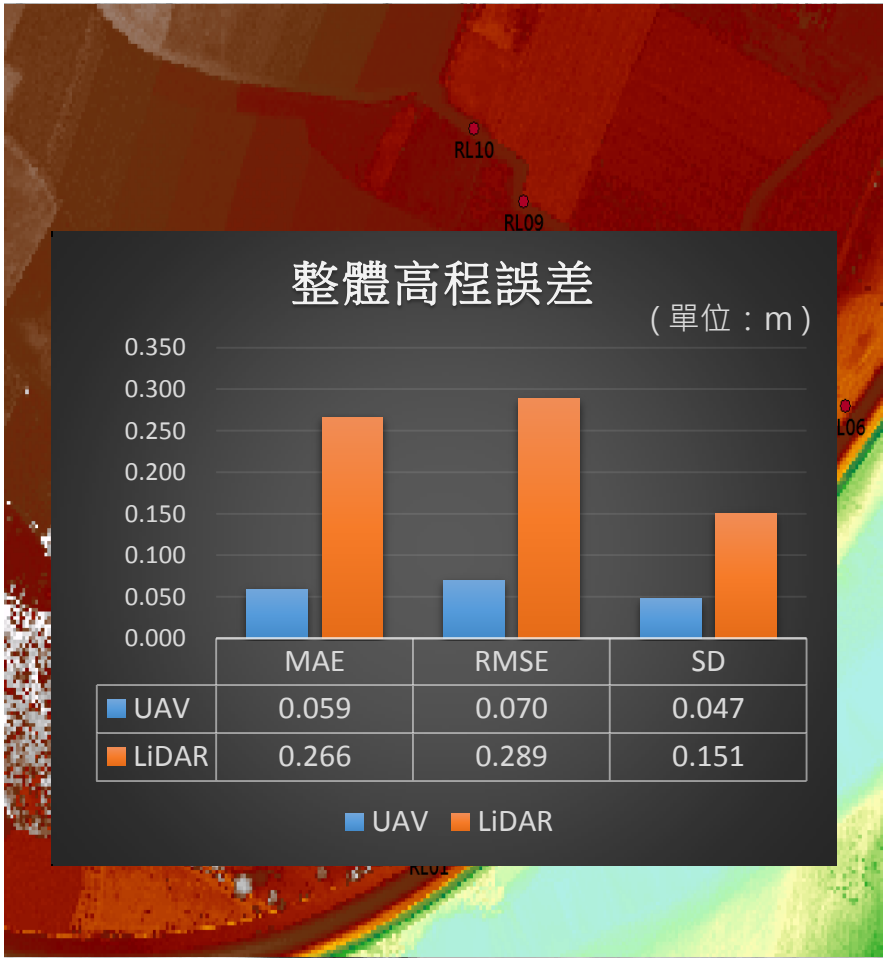


UAS cam. vs. Airborne LiDAR

UAS_DSM 0.22m*



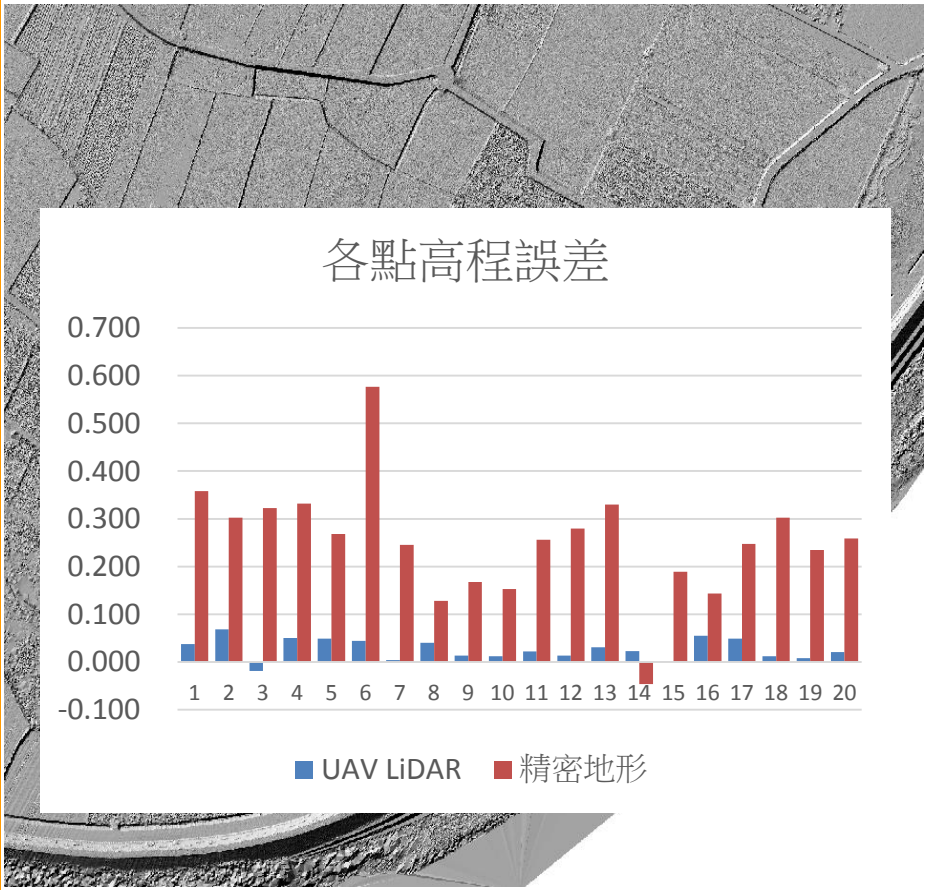
LiDAR_DSM 2m



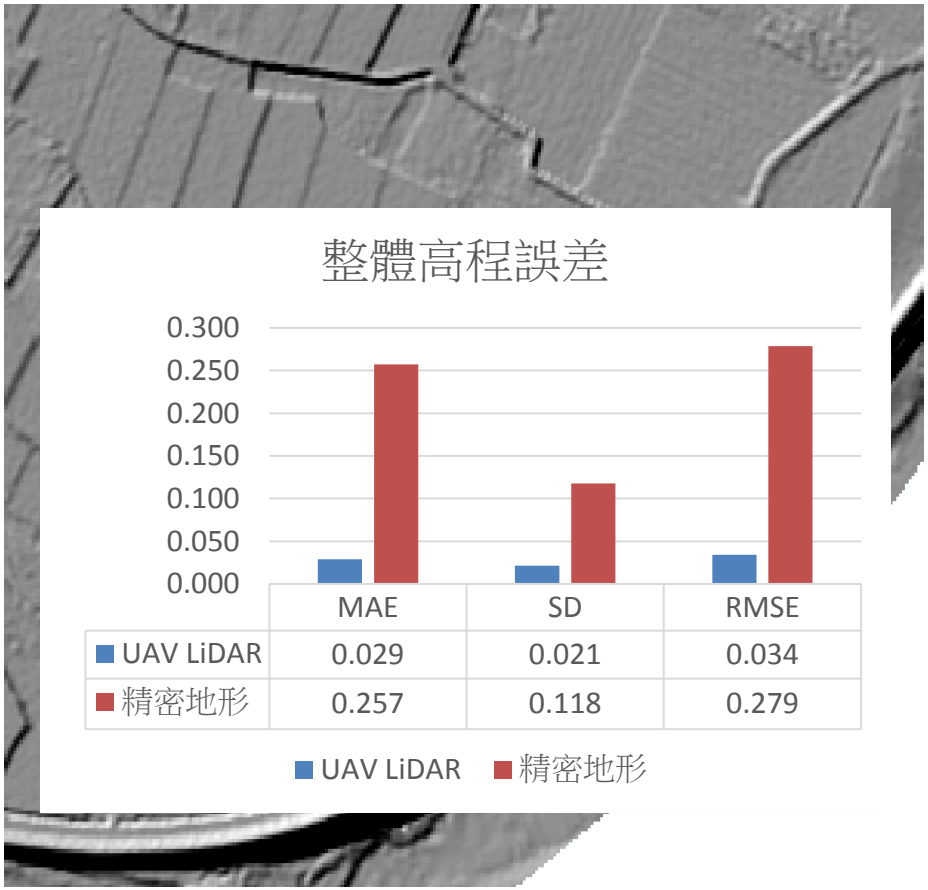
*: UAV 影像匹配密點雲解析度，影像原始解析度 GSD 5 cm

UAS LDAR vs. Airborne LiDAR

UAS LiDAR 0.05m



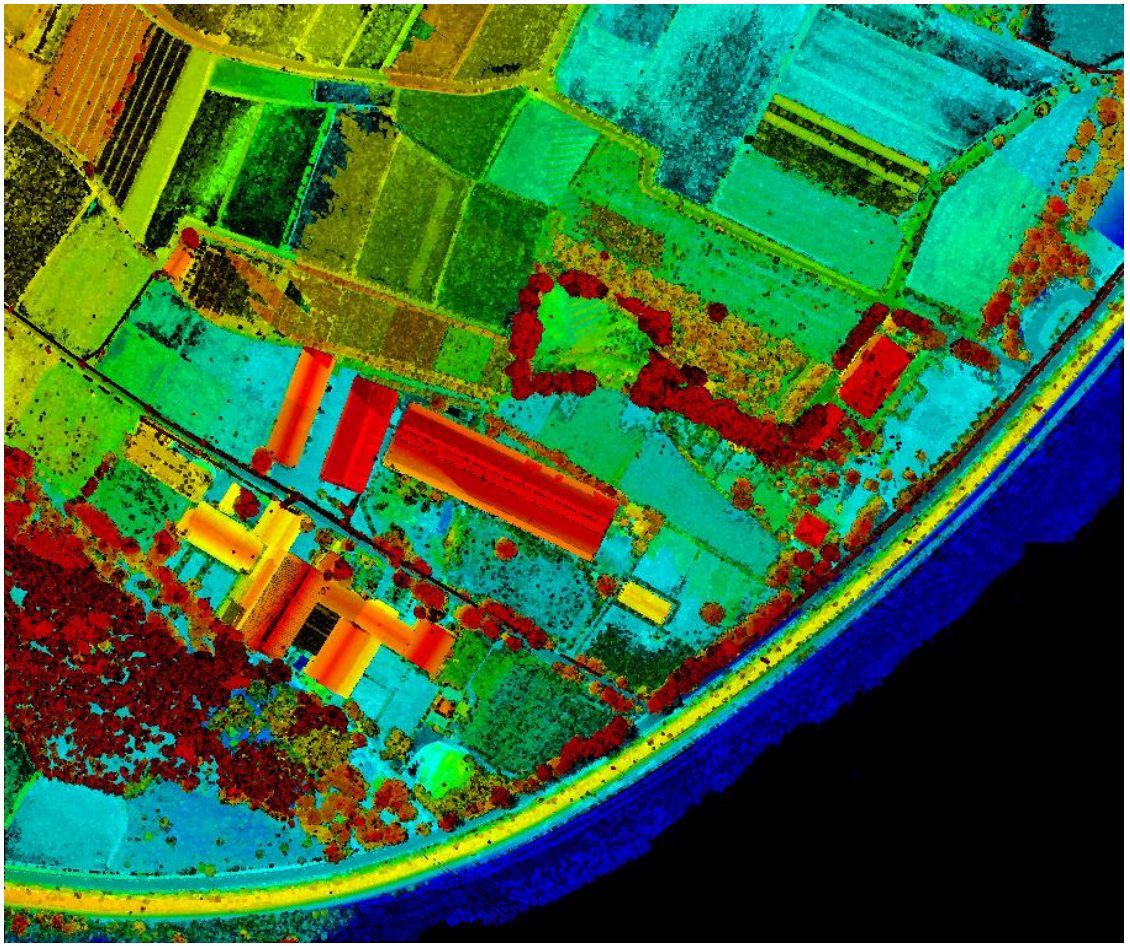
Airborne LiDAR 2m




Thanks for your attention

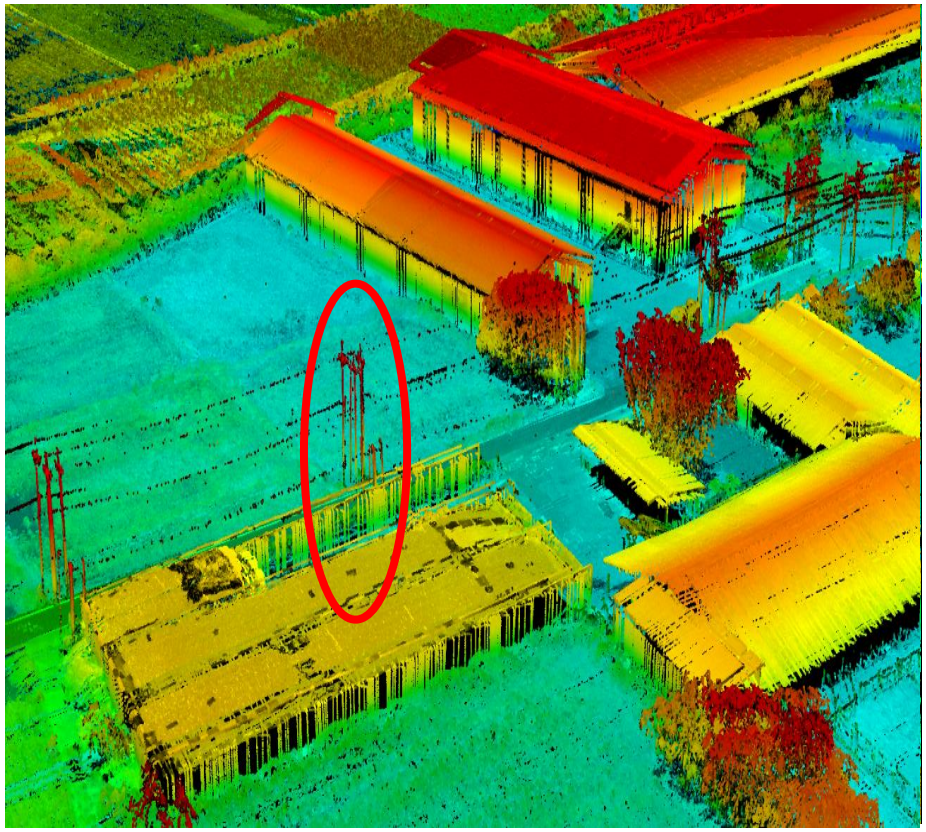
無人機光達點雲

無人飛行載具	Vapor 55
光達	VUX-1 UAV
飛航高度	150 m
飛航速度	2 m/s
掃瞄角度	120°
掃瞄頻率	20 Hz
脈衝頻率	300 kHz
點雲密度	200 (110) pts/m²

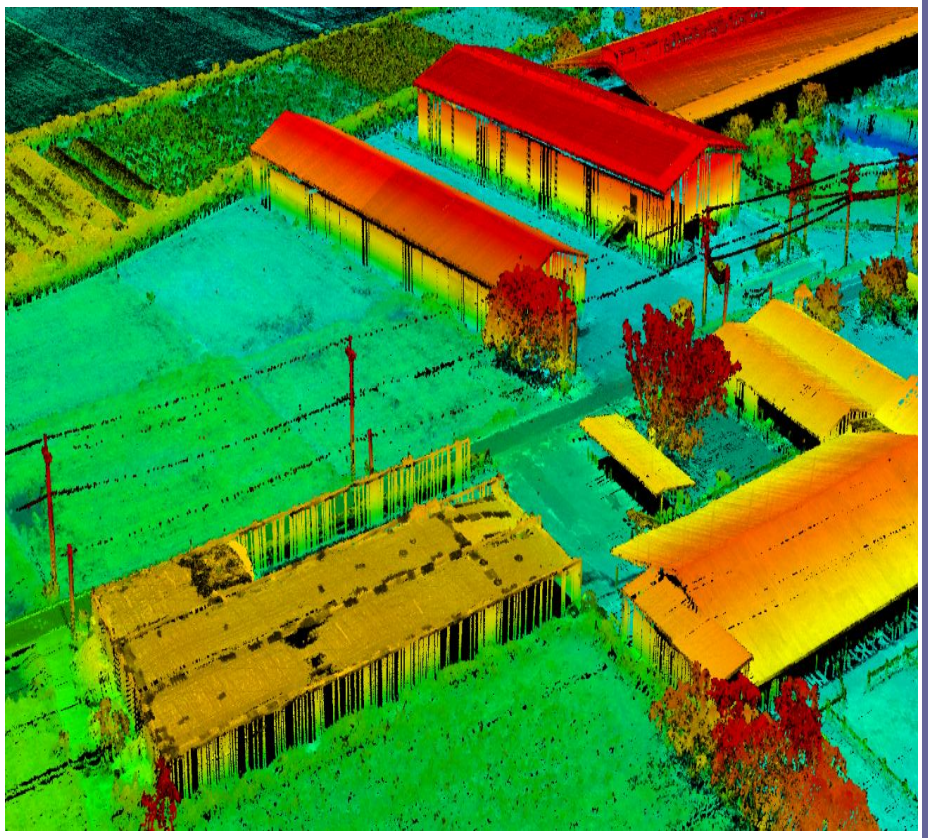


航帶率定平差比較

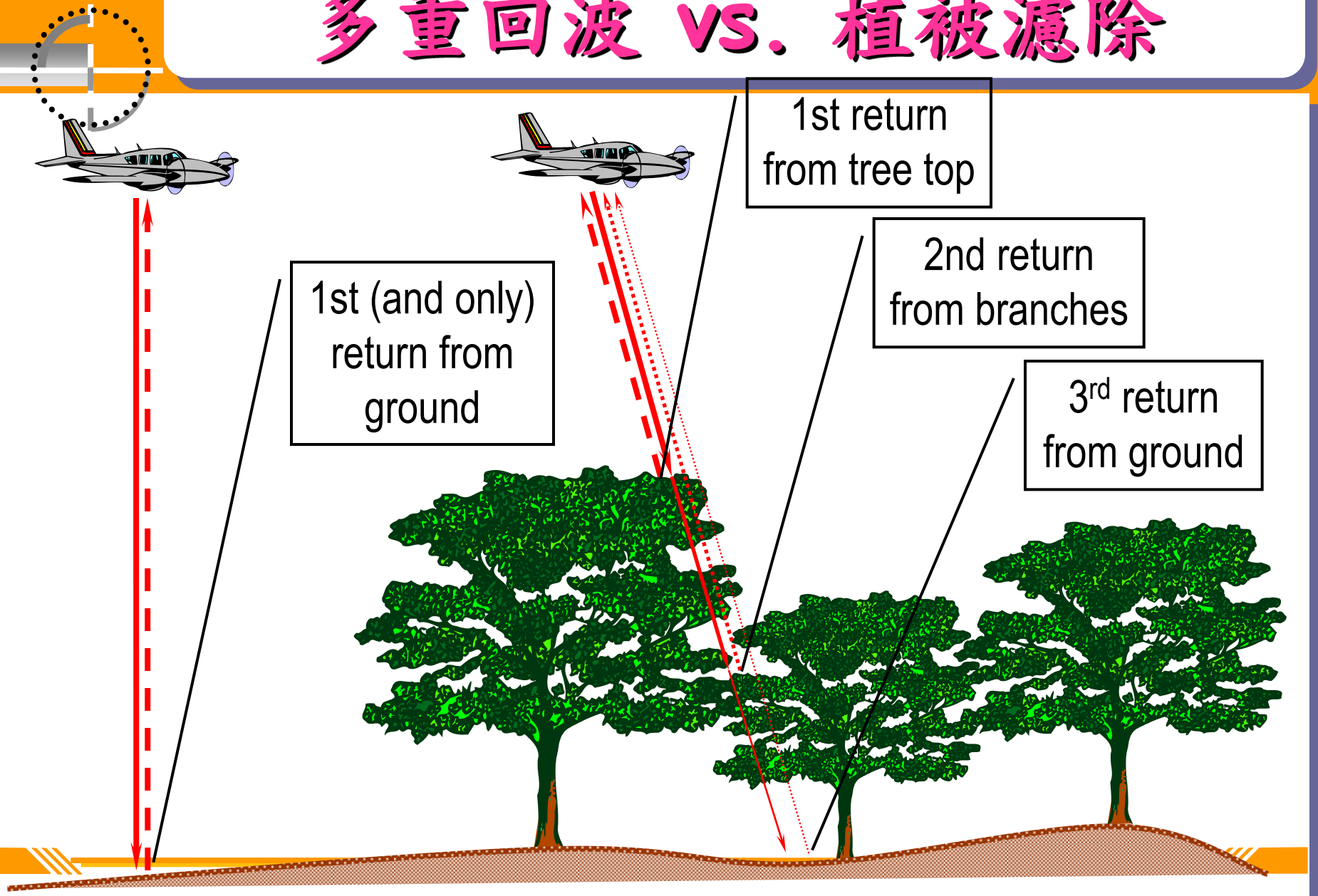
原始資料



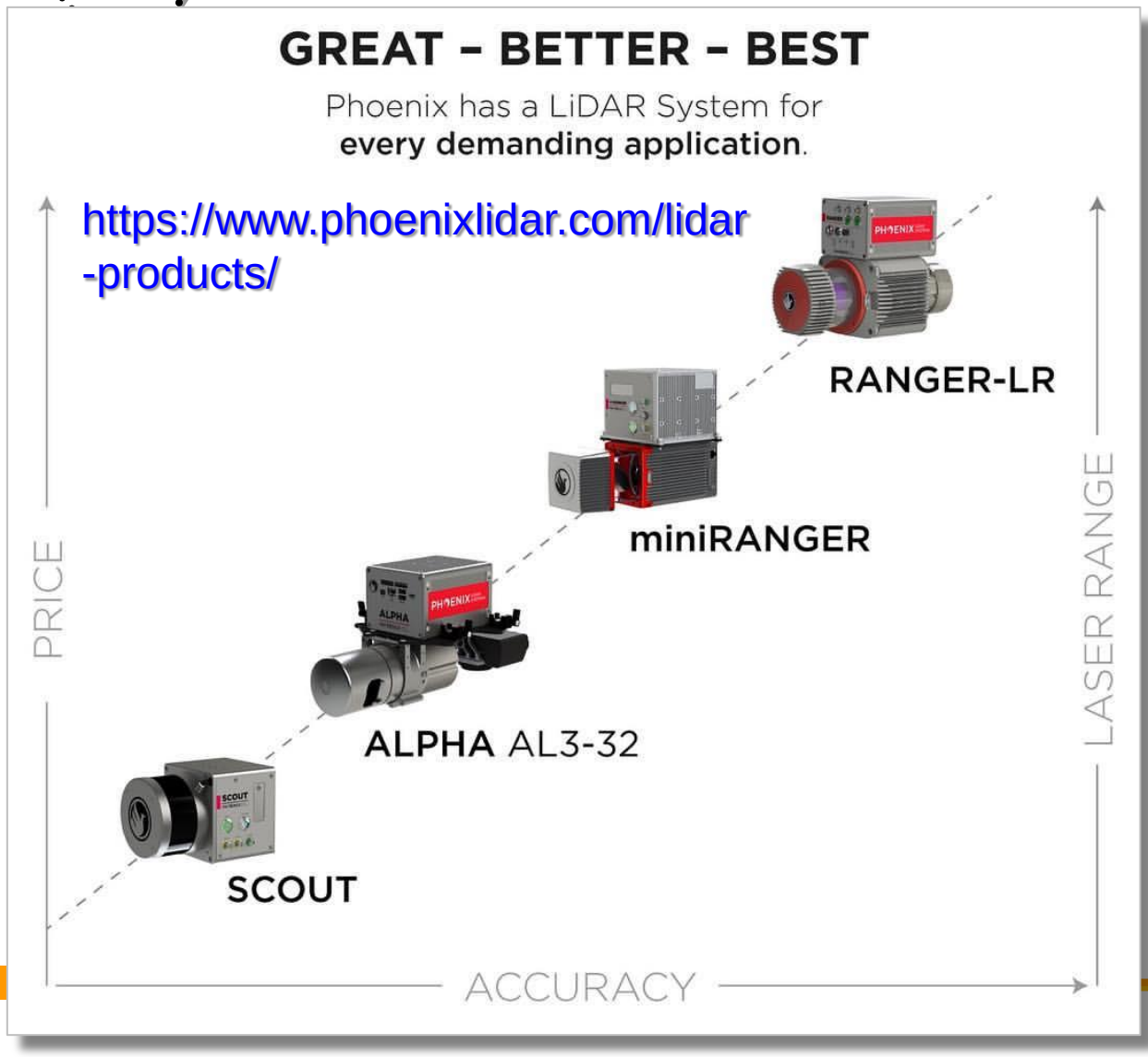
平差後

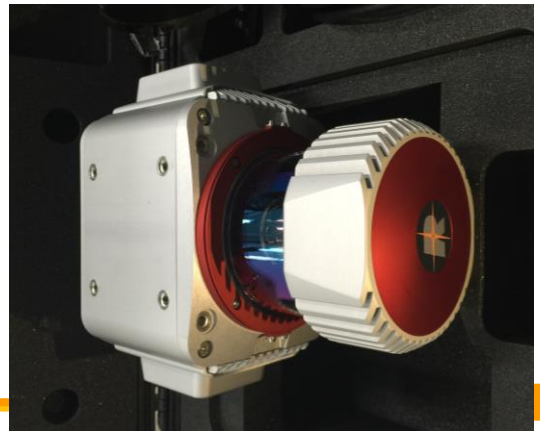


多重回波 vs. 植被濾除


1st return
from tree top
2nd return
from branches
1st (and only)
return from
ground
3rd return
from ground

Comparison of LiDAR system

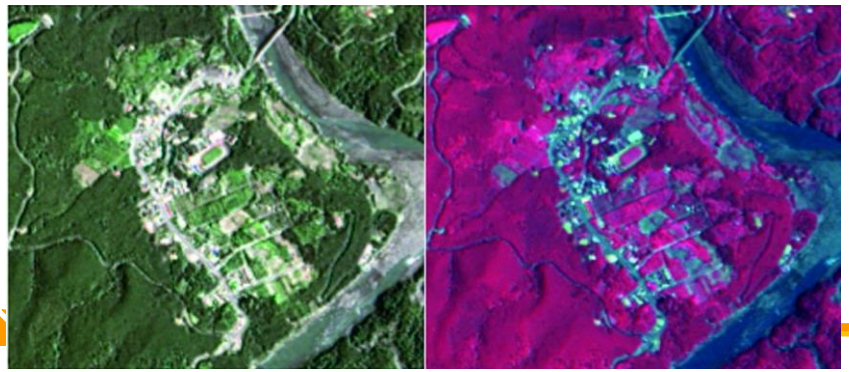




Multispectral Image

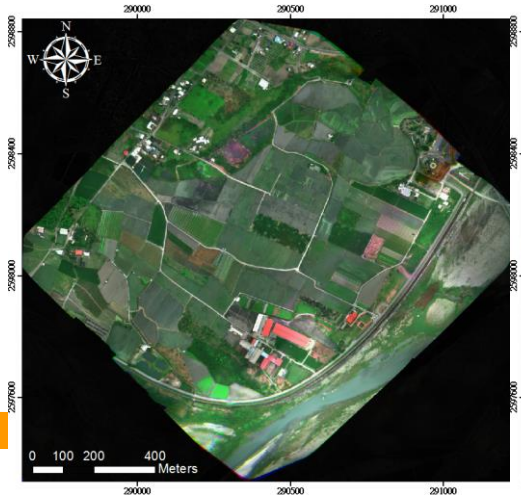
- 6 bands multispectral camera (1280x1024, 1.3 megapixel)
- 10bit radiometric resolution
- Focal length of lenses 8.3 mm
- Size 115 mm x 78 mm x 80 mm
- Weighs appr. 700 g

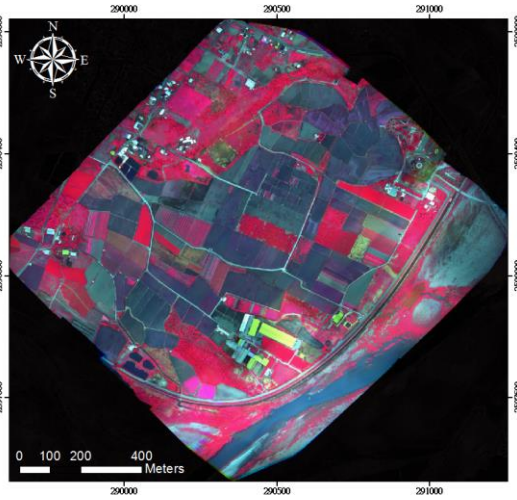
Tetracam mini-MCA



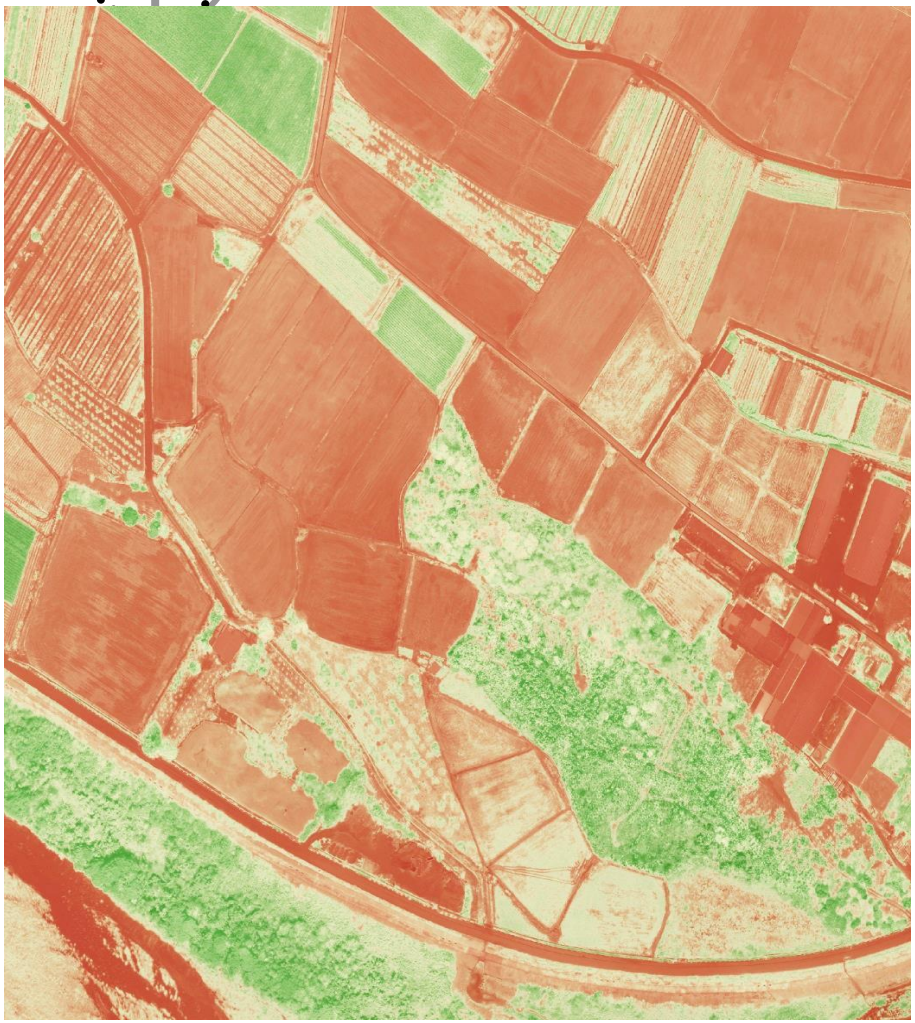
多光譜相機及研發

- 6 bands multispectral camera (1280x1024, 1.3 megapixel)
- 10bit radiometric resolution
- Focal length of lenses 8.3 mm
- Size 115 mm x 78 mm x 80 mm
- Weighs appr. 700 g

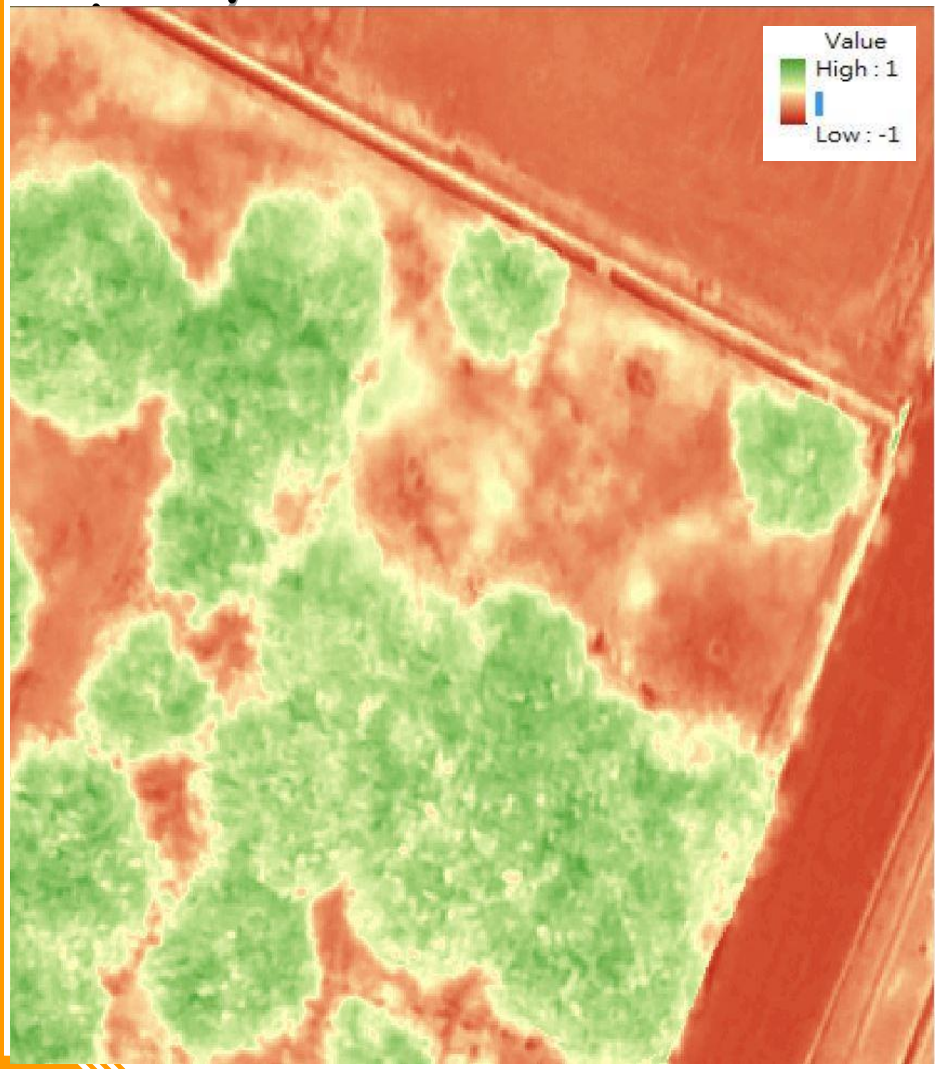


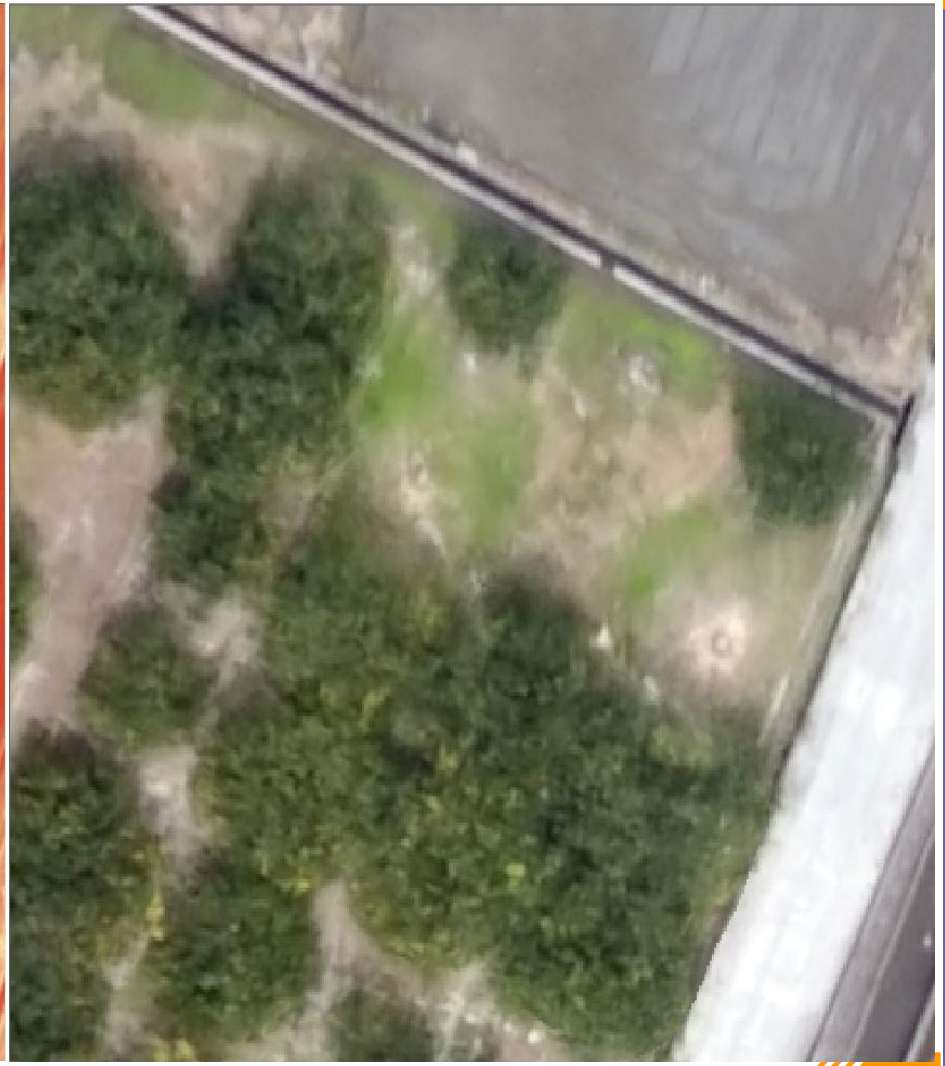


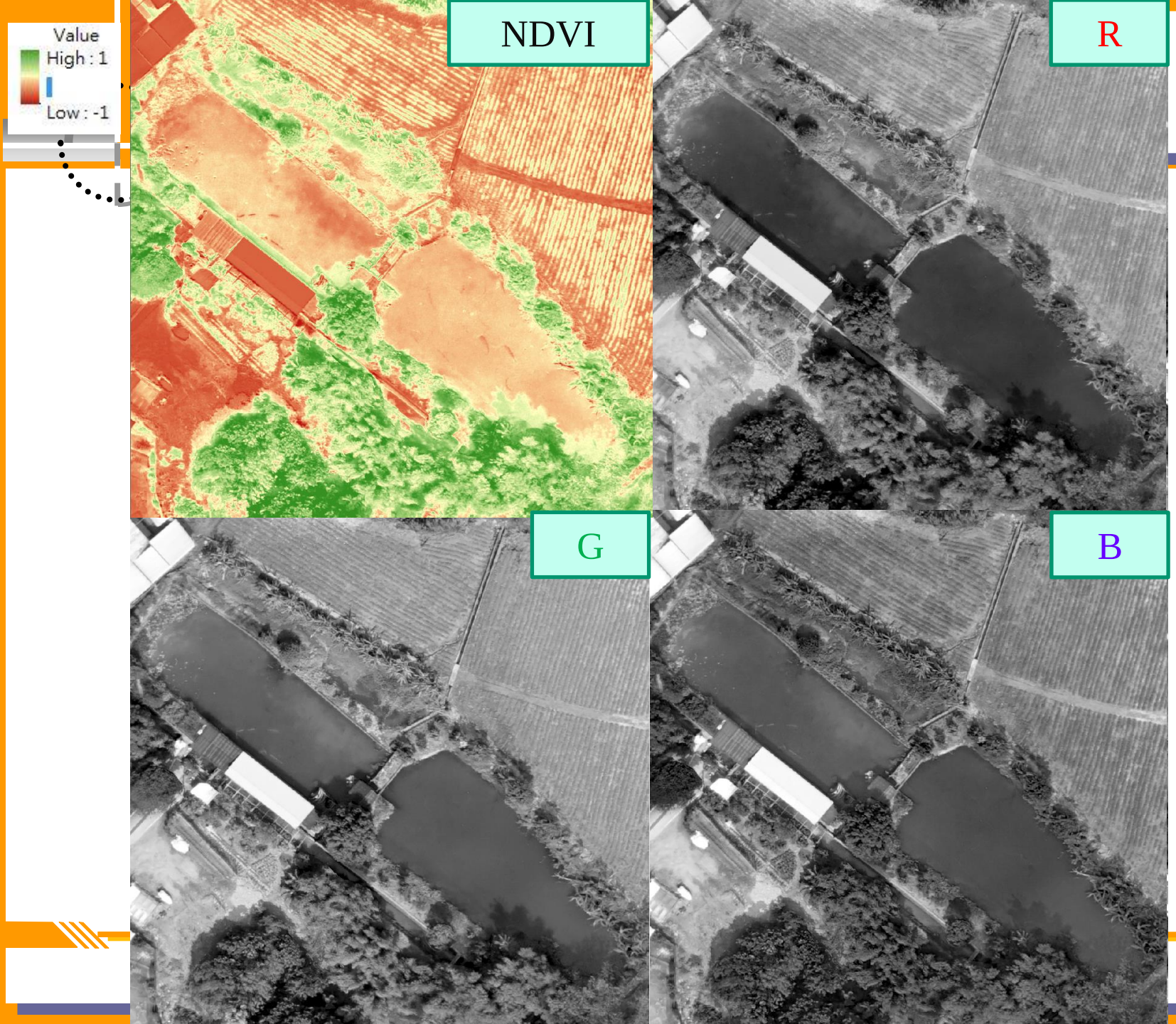
NDVI vs. RGB



NDVI vs. RGB

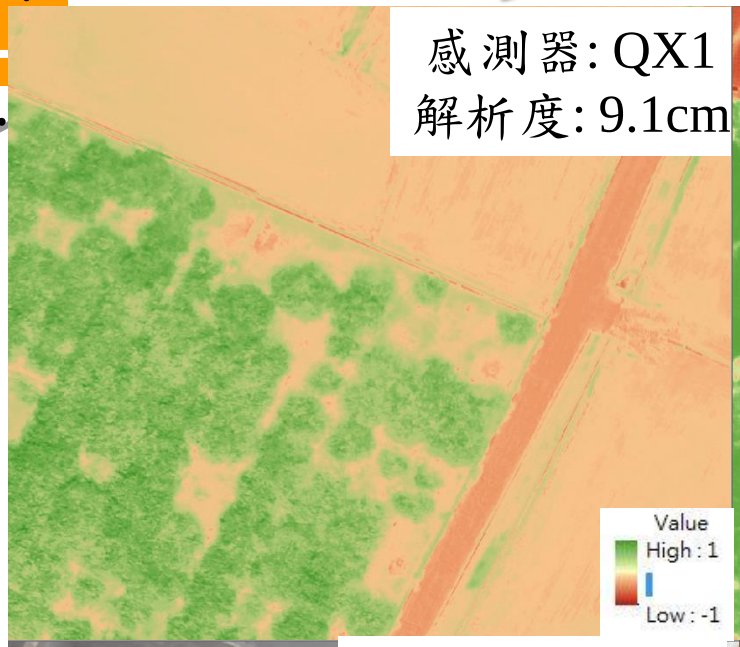




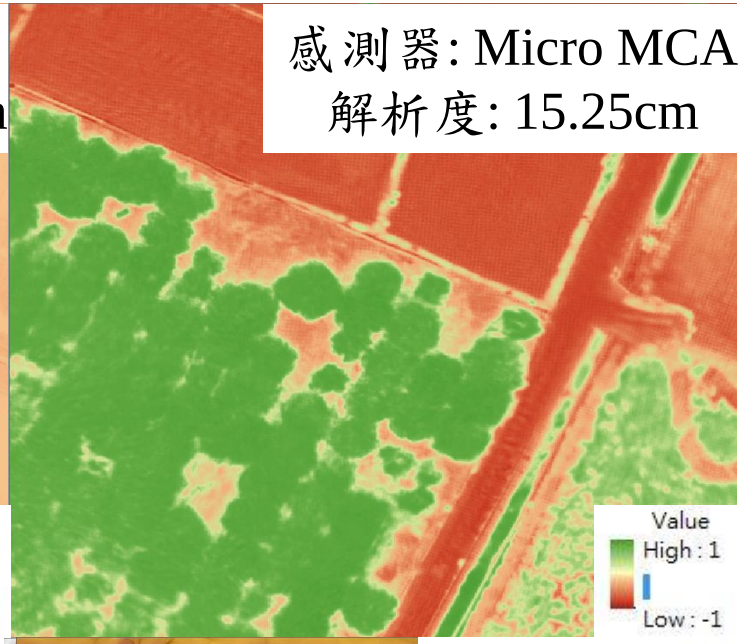

Value
High : 1
Low : -1
NDVI
R
G
B

多光譜相機比較

感測器: QX1
解析度: 9.1cm

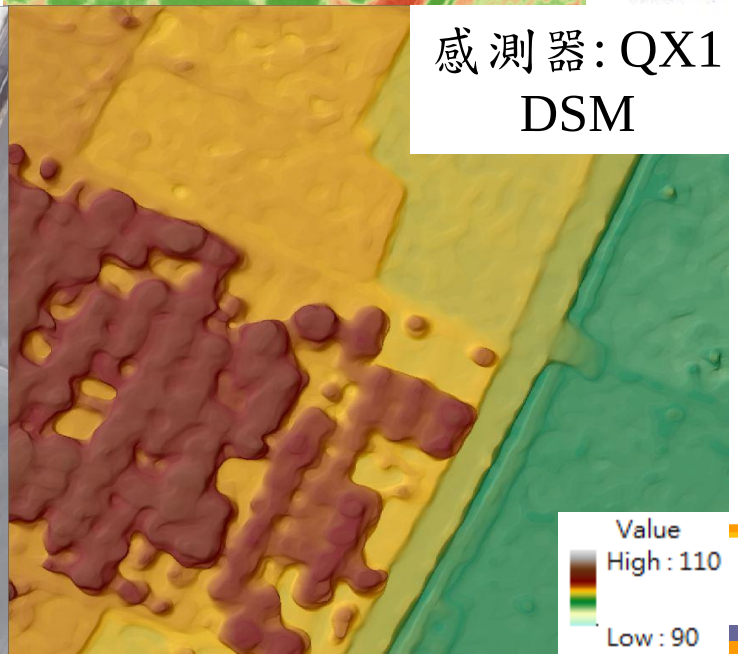


感測器: Micro MCA
解析度: 15.25cm



感測器: QX1
解析度: 5.07cm

感測器: QX1
DSM



Microdrones MD4-1000

- Climb rate: 7.5m/s
- Cruising speed: 15m/s
- Propulsion: 1000W
- Net weight: 2650g
- Payload: 0.8 Kg (recom.)
- Payload: 1.2Kg (max)
- Max take-off weight: 5550g
- Dimensions: 1030cm (rotor shaft to rotor shaft)
- Endurance: up to 88 min
- Temperature Range: -10 ~ 50℃
- Humidity: < 90%
- Wind tolerance: < 6m/s (steady pictures); < 12m/s (cruising)
- RC distance: 1000m
- Ceiling altitude: <1000m
- Take-off altitude: < 4000m

Homemade Fixed-Wing Drones

Oblique Photogrammetry Drone

- Wing span： 1.5~2.2 m
- Fly height：> 4000m
- Speed： 10-20m/s
- Power：LiPo
- Payload: <1000g
- Endurance： 40~120 mins
- Net weight： 1500~4500g
- Camera： Sony QX100, QX-1, A7R... etc.