GEO SMART ASIA 2016

Ground-based Imaging Radar for Landslide Monitoring

19th October 2016

Gs. Ir. Assoc. Prof. Dr. Chan Yee Kit

Associate Professor
Center for Remote Sensing and Surveillance Technologies
Multimedia University, Malaysia

Facts & Figures

China Banqiao dam's failure, killed > 171,000 people in 1975

Rana Plaza, Bangladesh, collapsed in 2013 (killed 1,129)

Highland Tower collapsed in 1993, Ulu Klang, Selangor, 48 killed

Landslides in KL, 2011, 12 people killed

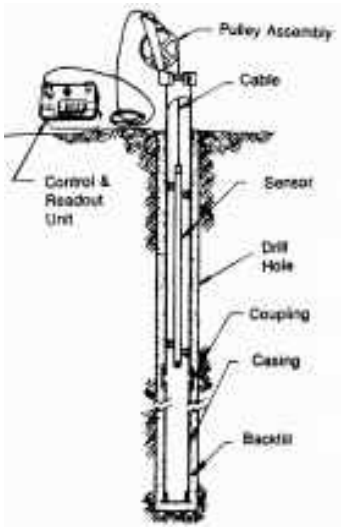
Bridge collapsed in Penang, 2013, 1 killed

> 1 mil people exposed to landslide hazards every year
> 21,000 landslide-prone areas in Malaysia (16,000 in Peninsular, 3,000 in Sabah, 2,000 in Sarawak)
> 120,000 high-rise buildings over 12 stories tall
> 48,000 dams over 15 m high
> 250 long bridges over 2 km long, hundreds of thousands of bridges, high risk mining sites, …

Existing Ground-Truth Monitoring Systems

3D Laser Scanner

Total Station



Inclinometer

Extensometer

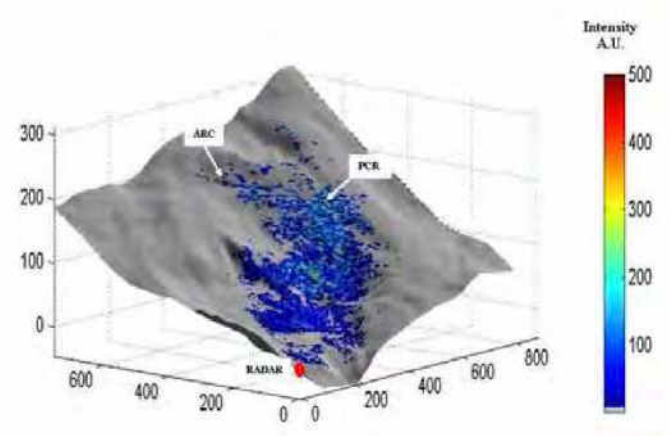
Tiltmeter

These are *ground-truth* measurement instruments:

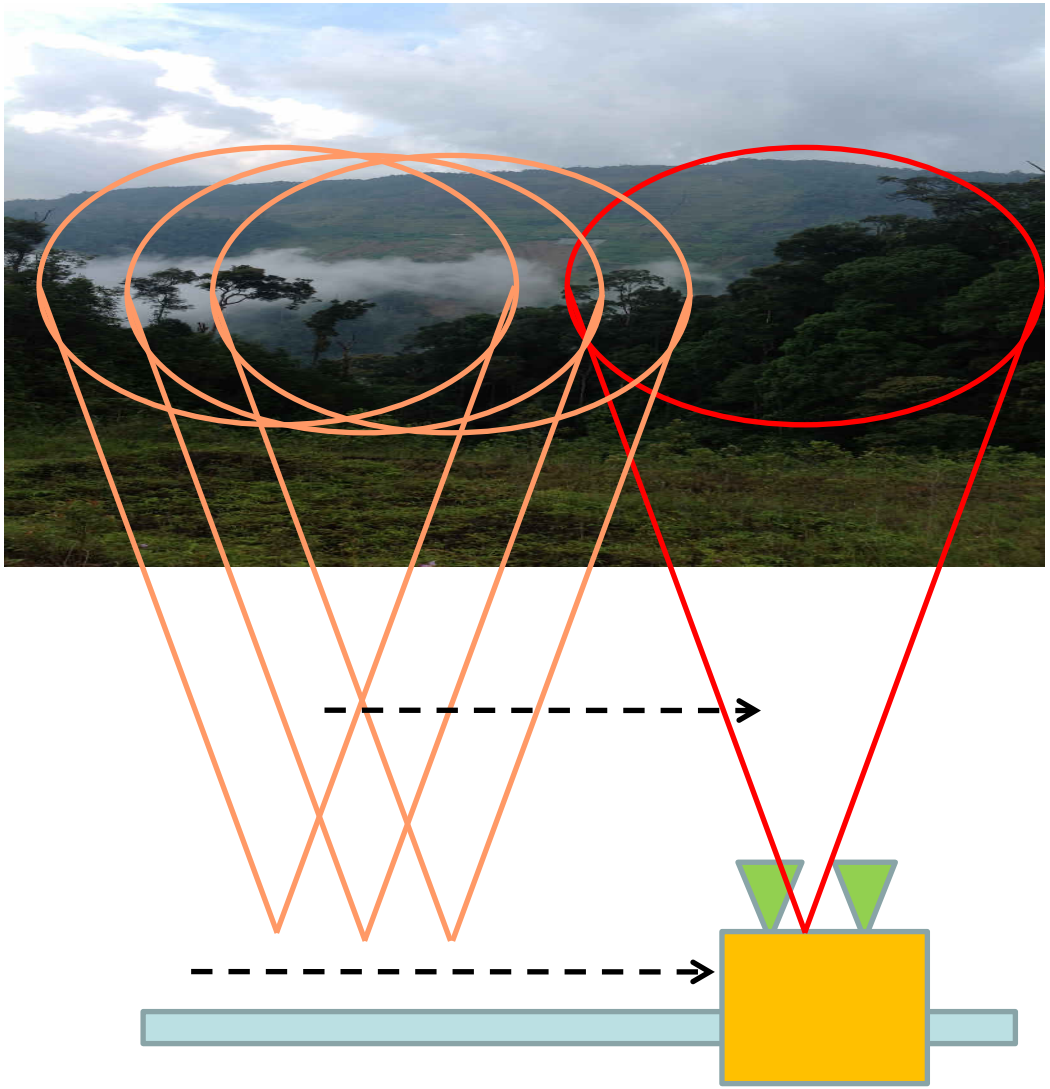
- ❑ Labor intensive
- ❑ Require maintenance on-site, thus increasing hazards to personnel re-entering potentially high risk areas

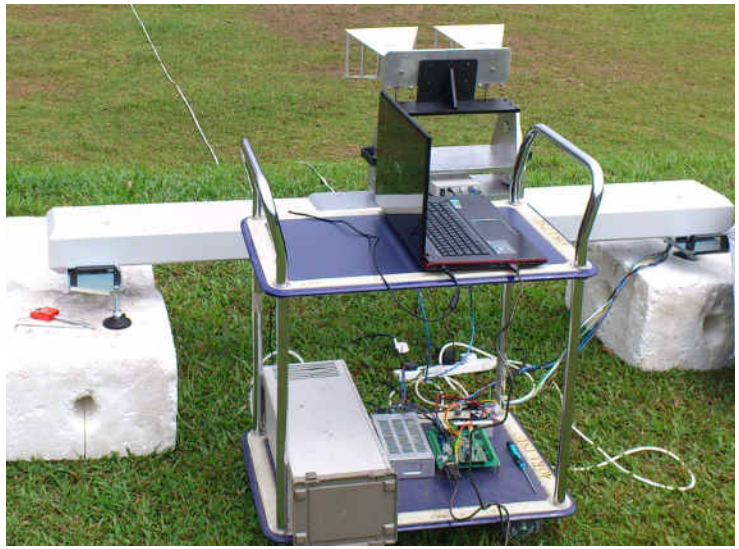
Urgent Need for Preventive Monitoring of Structural Health and Earth Environments

- ✓ Non-destructive – remote sensing
- ✓ High resolution – change detection in cm-mm
- ✓ Wide area coverage – complete 3D model
- ✓ All weather – 24/7 periodic monitoring
- ✓ Real-time online retrieval – early warning
- ✓ Low cost – affordable for developing countries

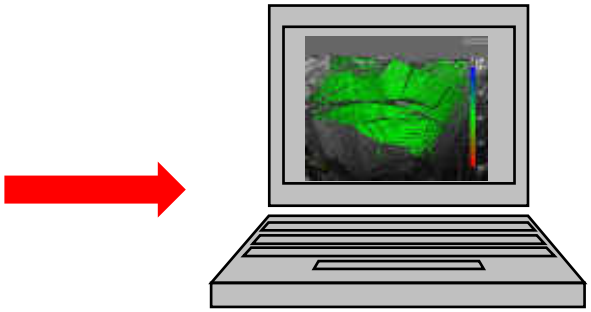


Remote Monitoring using GBSAR system





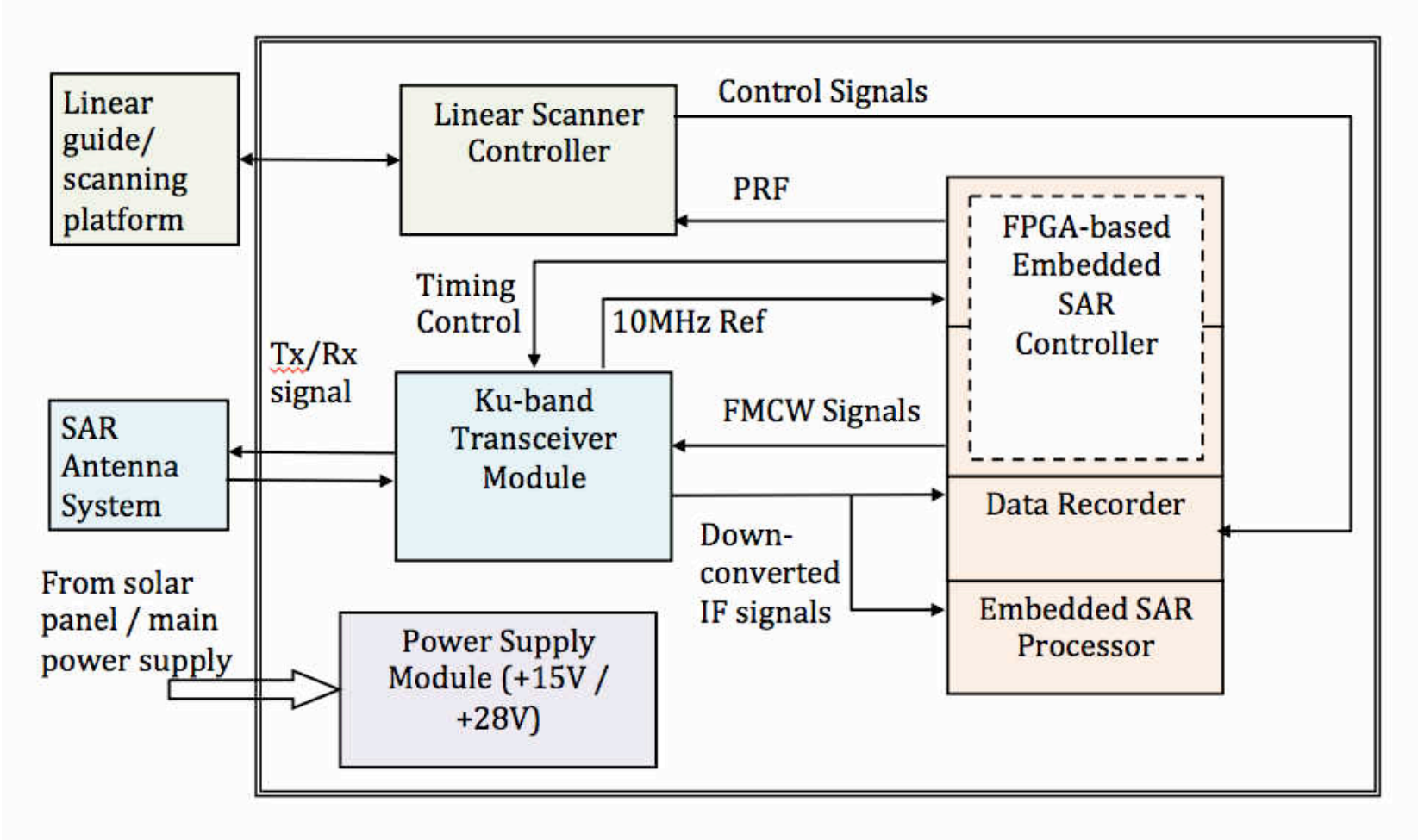
Use synthetic aperture processing technique to produce high resolution temporal InSAR images



GBSAR System Parameter

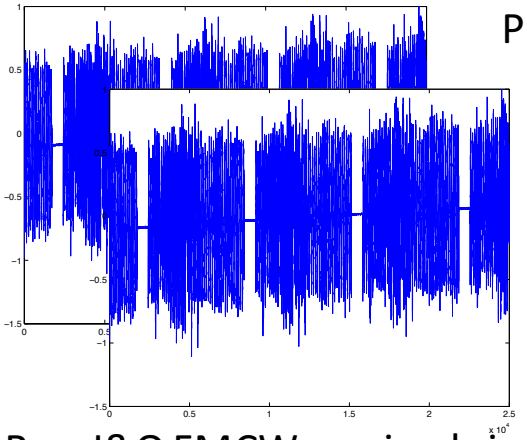
Design Parameter	Design Value
Operating Frequency	17.2 GHZ
Bandwidth	400 MHz
Waveform	FMCW
Polarization	single
Transmit Power	1 W
Antenna Gain	16 dBi
3dB beamwidth	10° (azimuth), 10° (elevation)
Synthetic Length	1.5 m
Range Resolution	0.5 m
Azimuth Resolution	5.8 mrad
Maximum Sensing Distance	2000 m
Sigma naught	−20 dB
SNR	> 10 dB

Functional Block Diagram of GBSAR



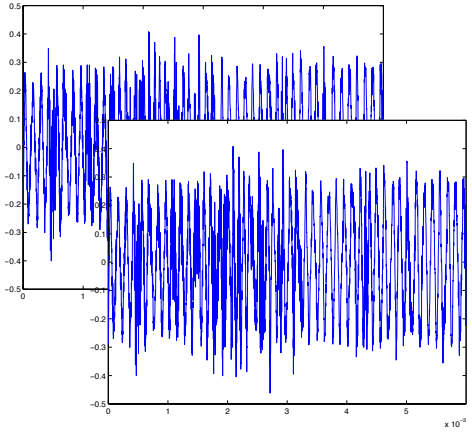
GBSAR Prototype

Raw SAR Signal Processing:

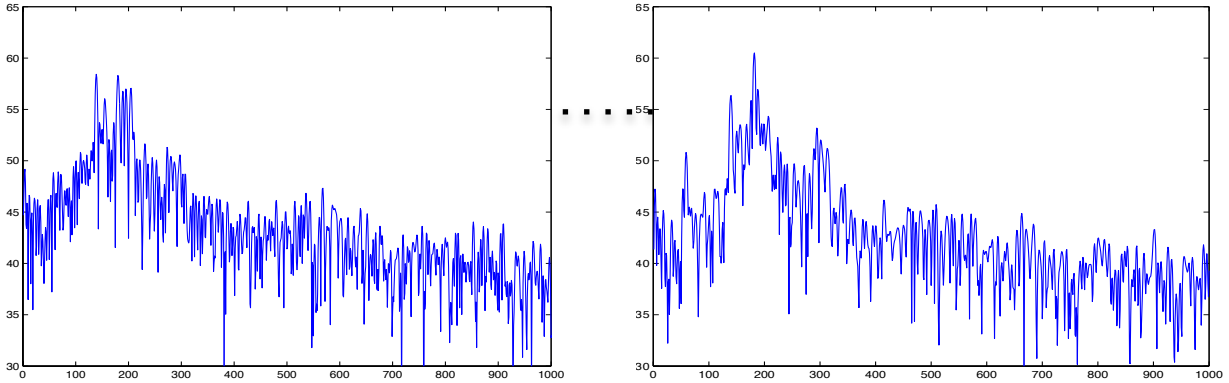


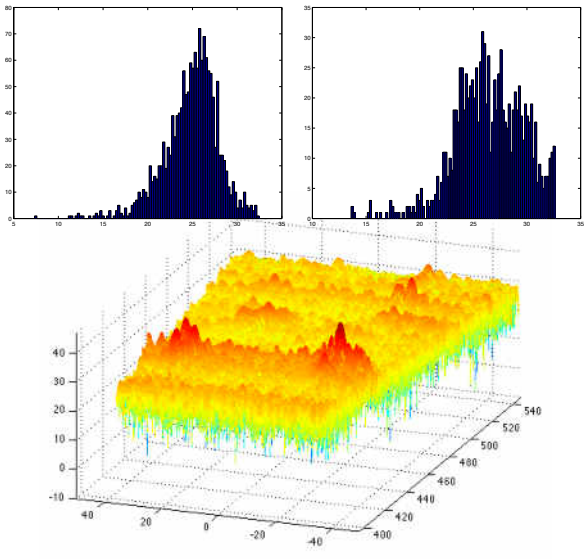
Raw I&Q FMCW received signals

Pre-sum filter



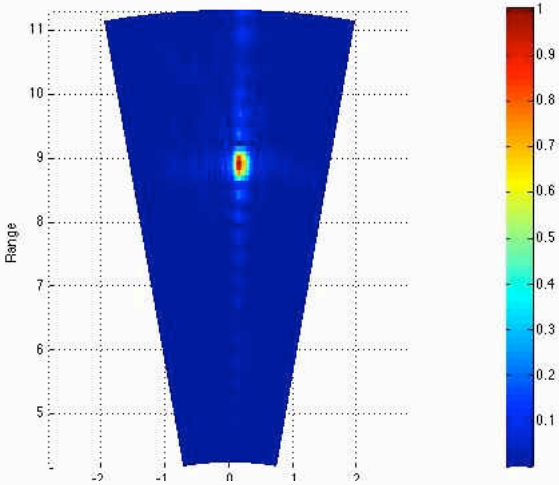
range compression

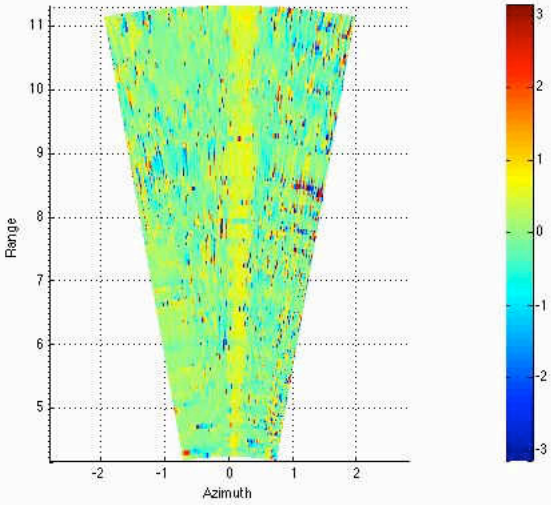




Combining multiple range lines and perform azimuth compression

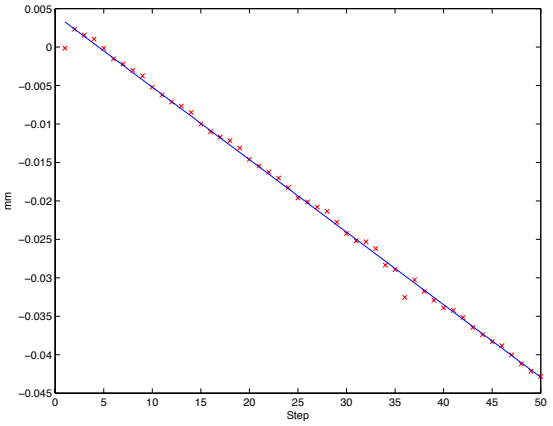
Preliminary Tests

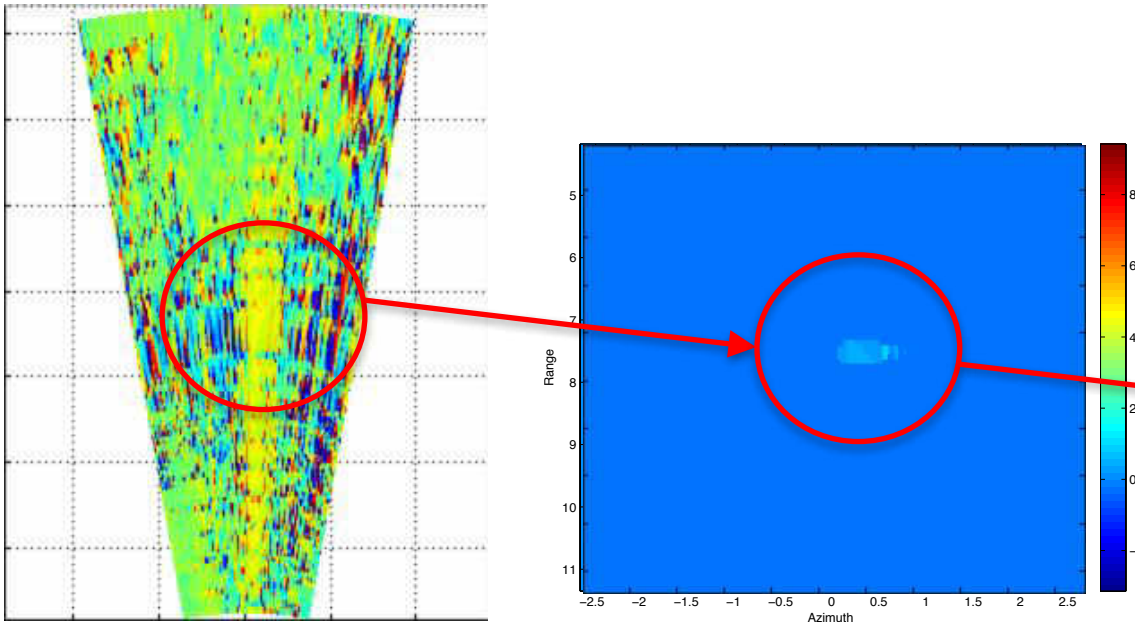


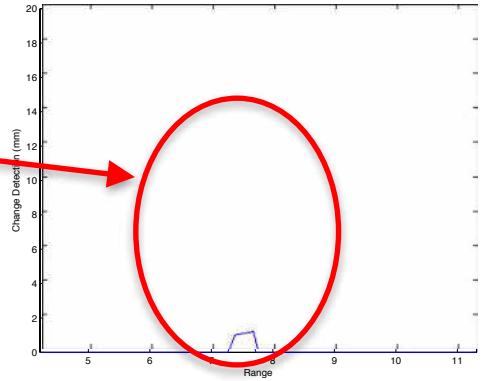


Change Detection in mm

Measured Accuracy < 5 mm



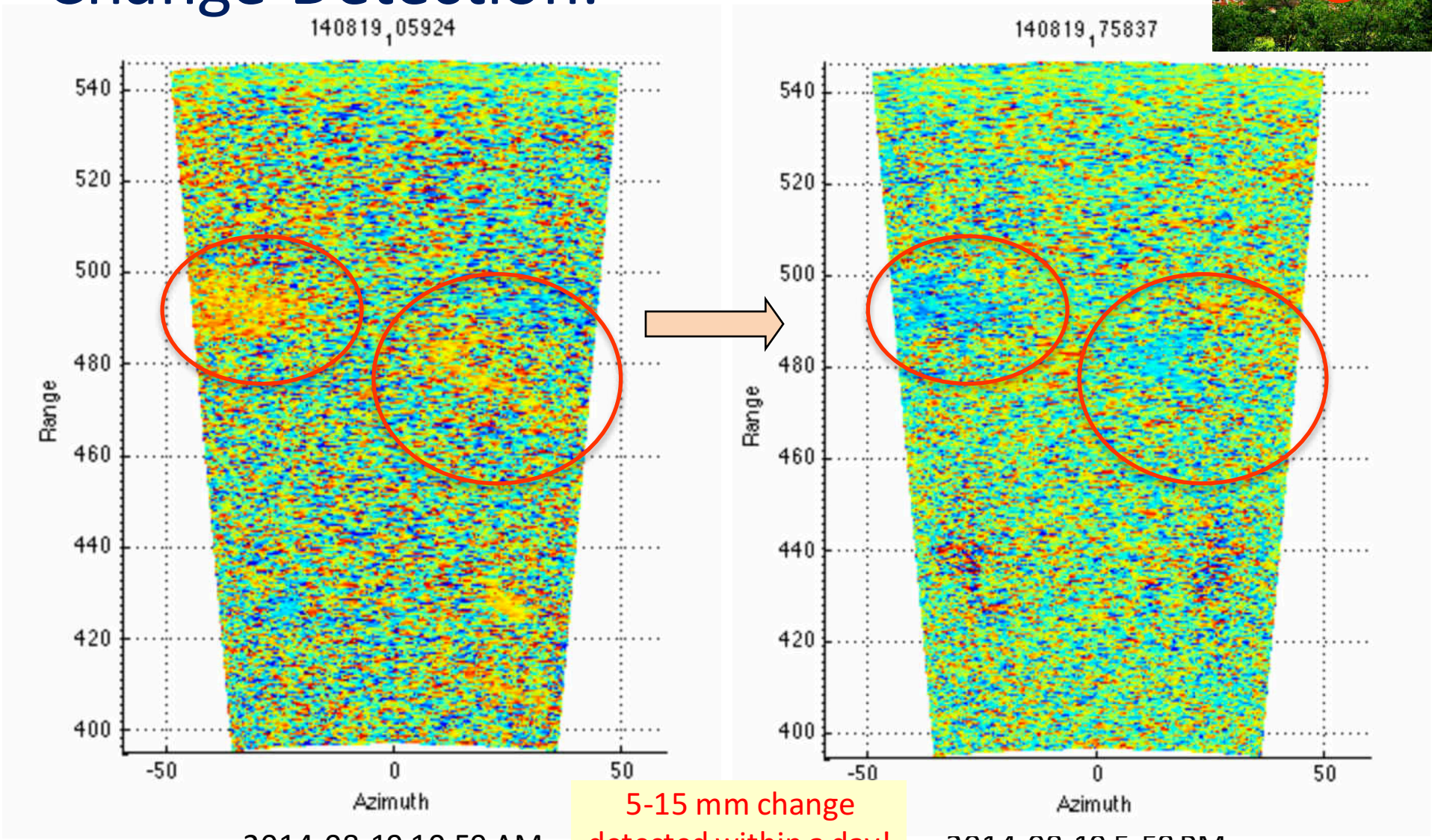




$$dR = \lambda \, d\phi / 4\pi$$

System Verification and Field Test

Change Detection:



2014-08-19 10:59 AM

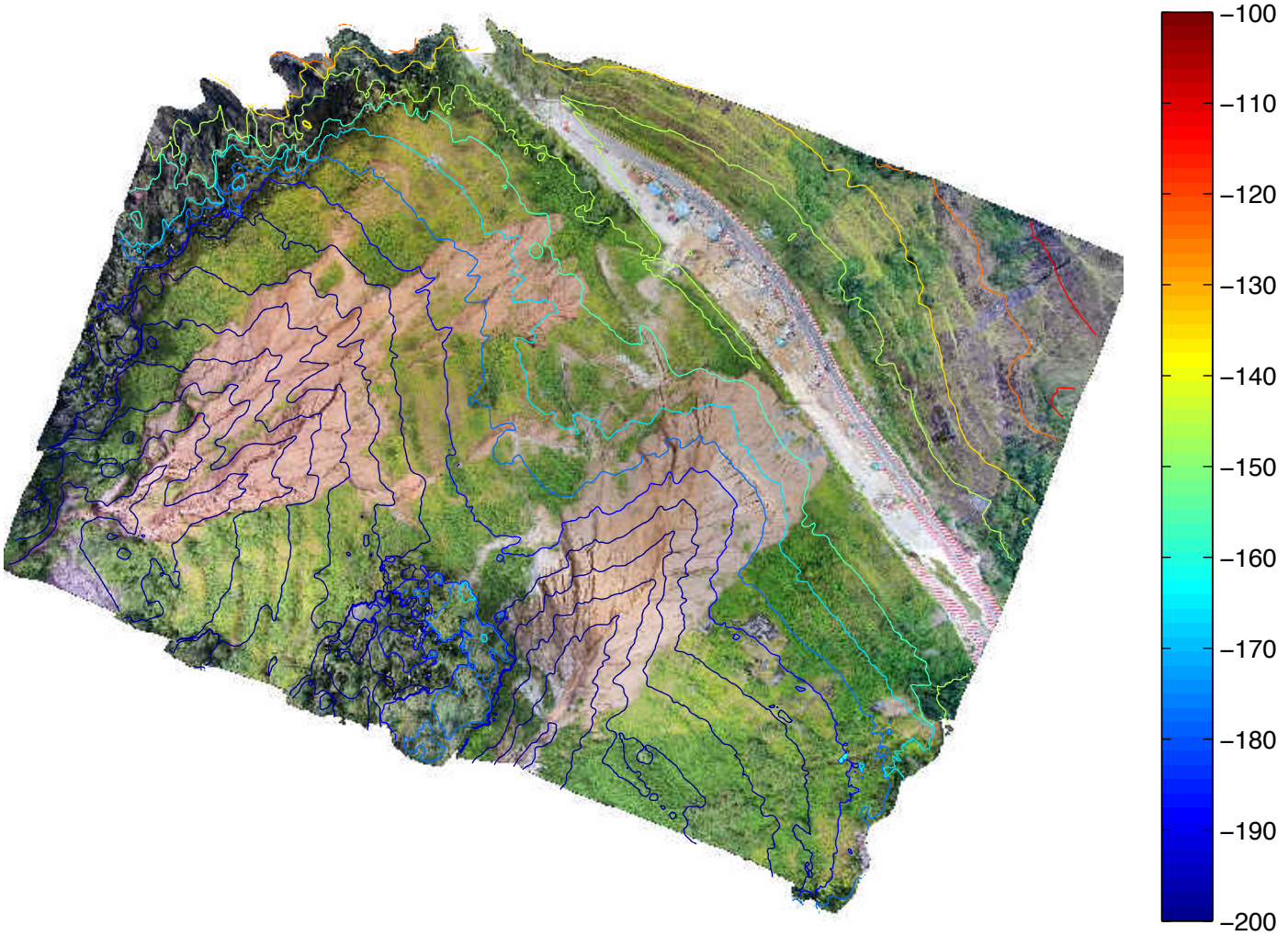
5-15 mm change detected within a day!

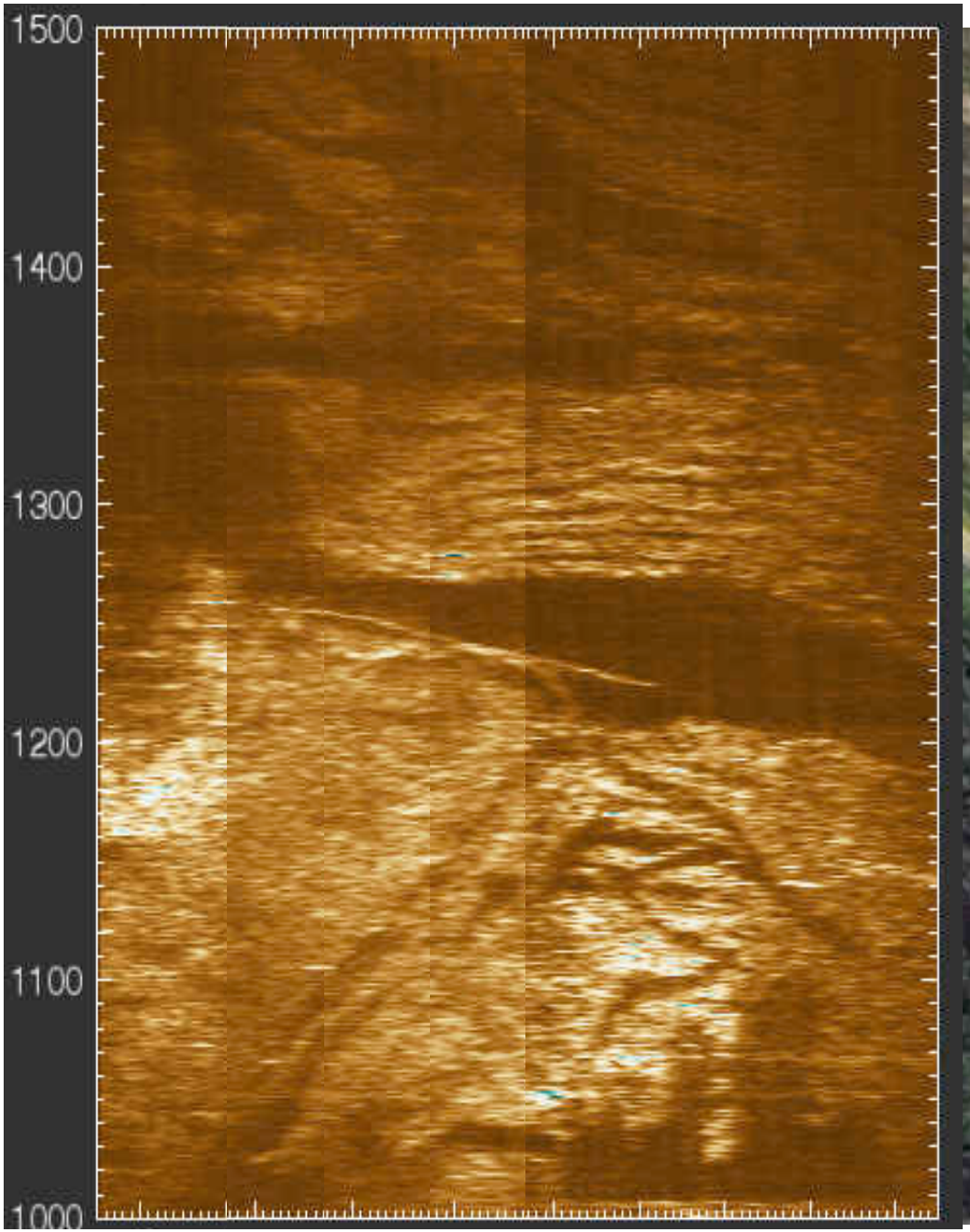
2014-08-19 5:58 PM

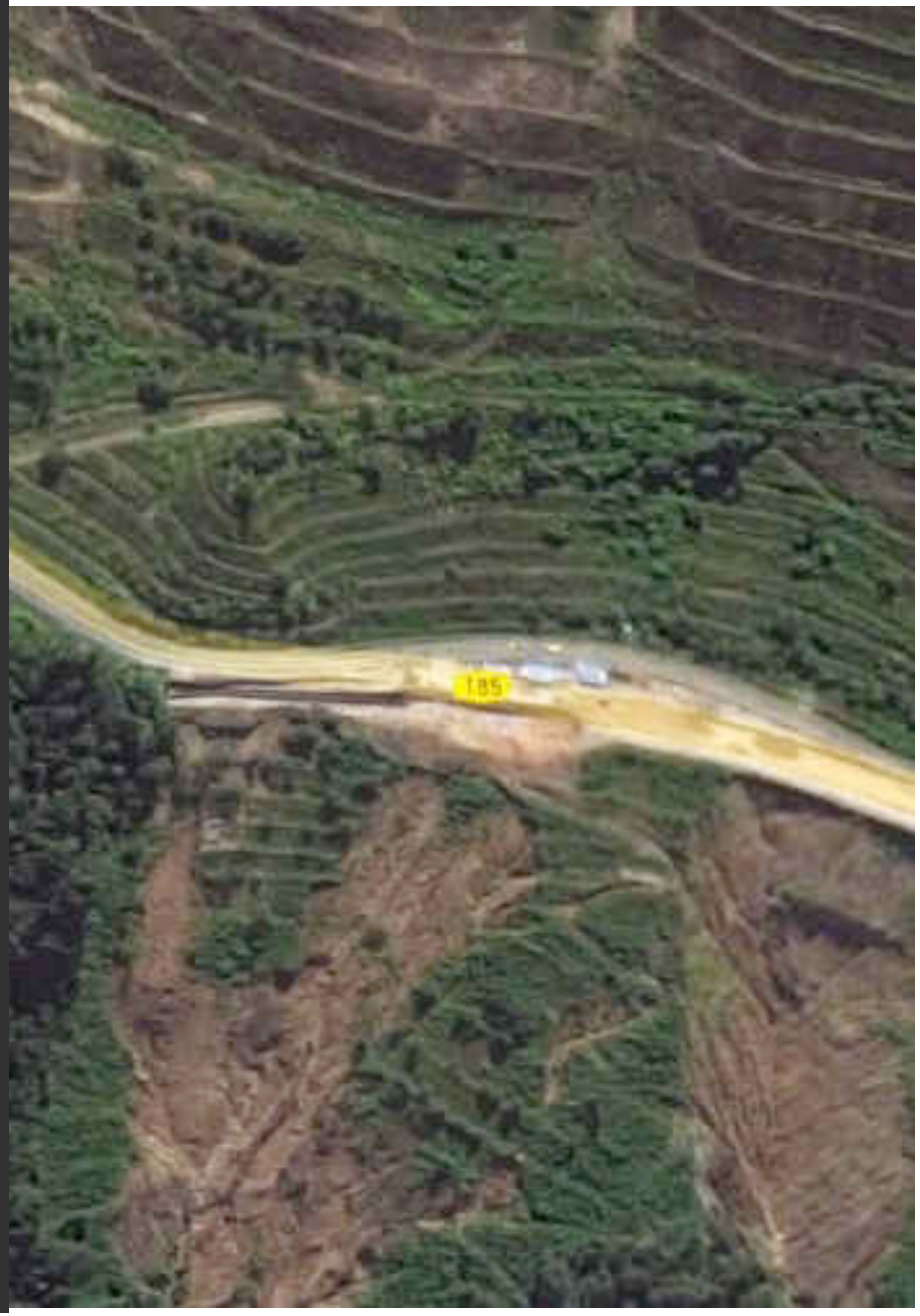
Actual Test Site (Gunung Pass, Cameron Highland)

Installation at Test Site

Test Site: TS001 Gunung Pass



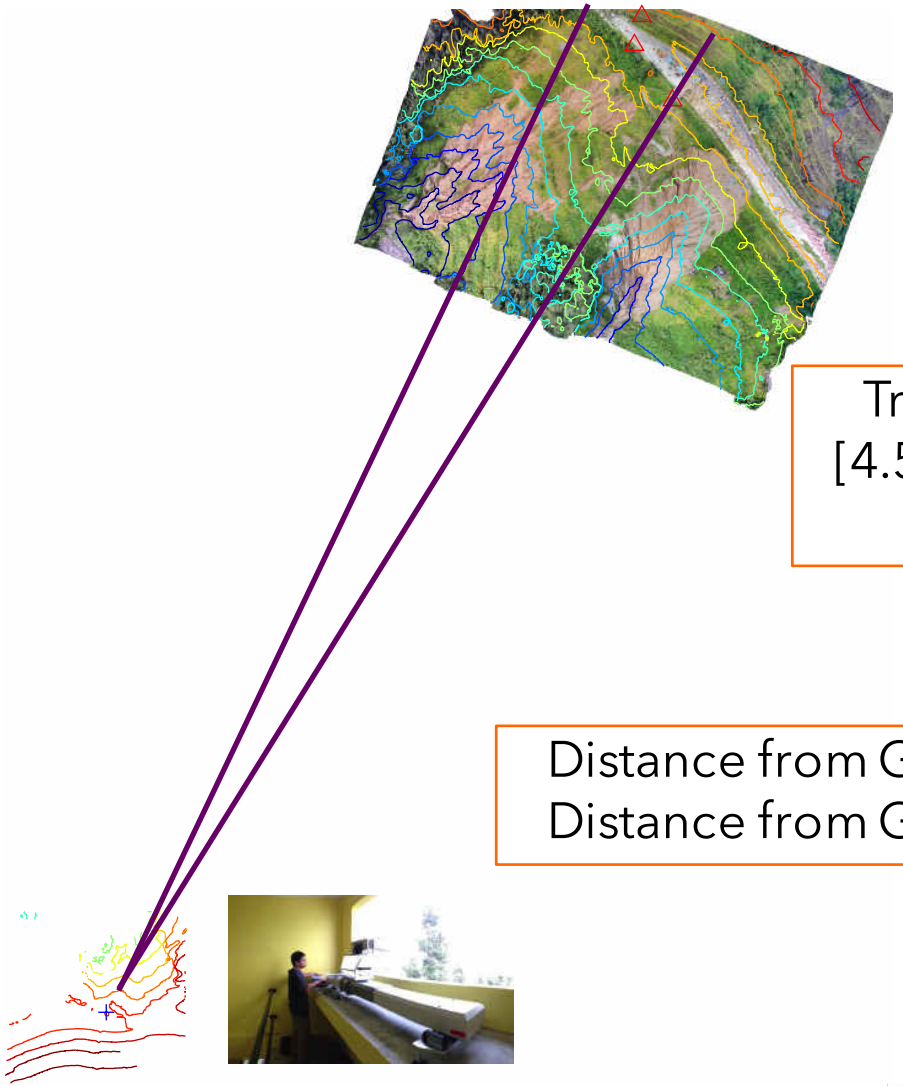




GBSAR Image

Satellite Image from Google

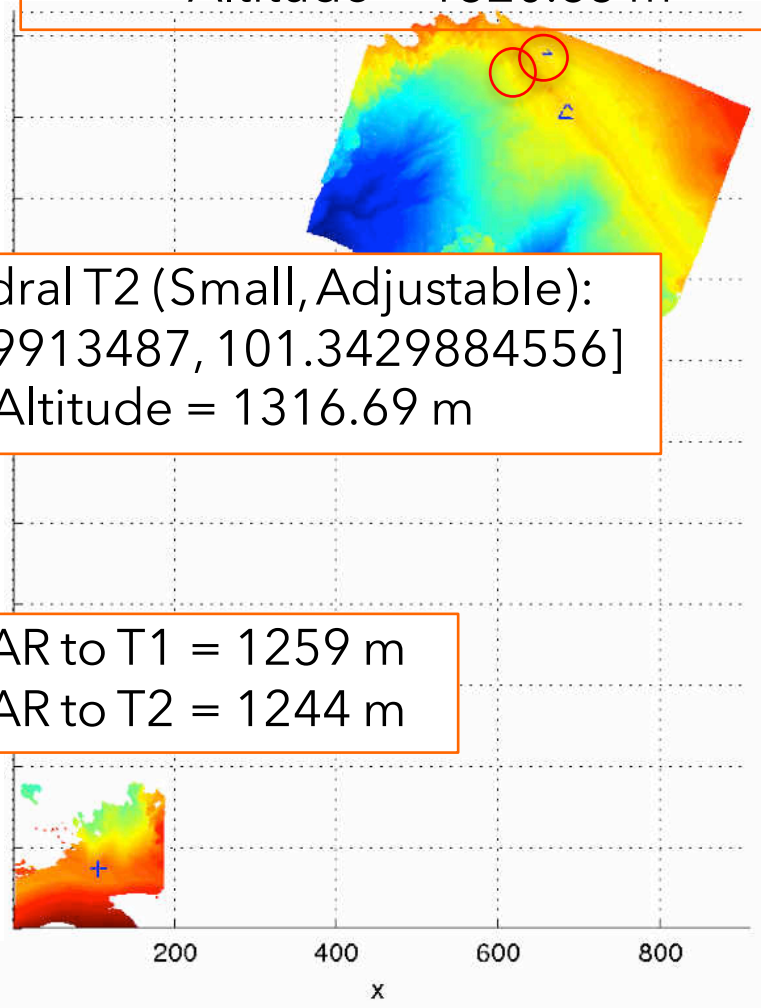
Trihedral Location



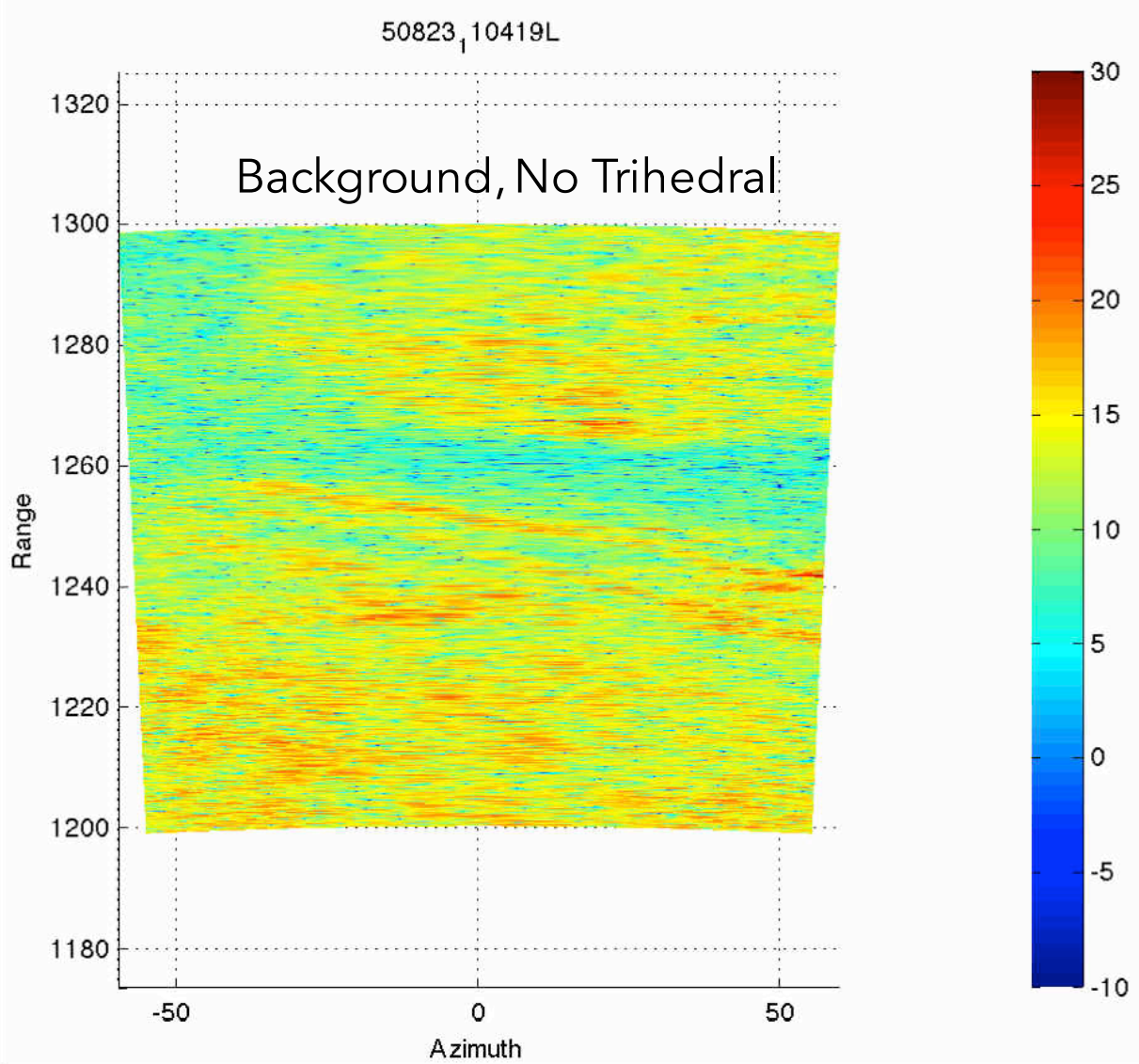
Trihedral T1(Large, Fixed):
[4.5919070143, 101.3433433900]
Altitude = 1320.83 m

Trihedral T2 (Small, Adjustable):
[4.5919913487, 101.3429884556]
Altitude = 1316.69 m

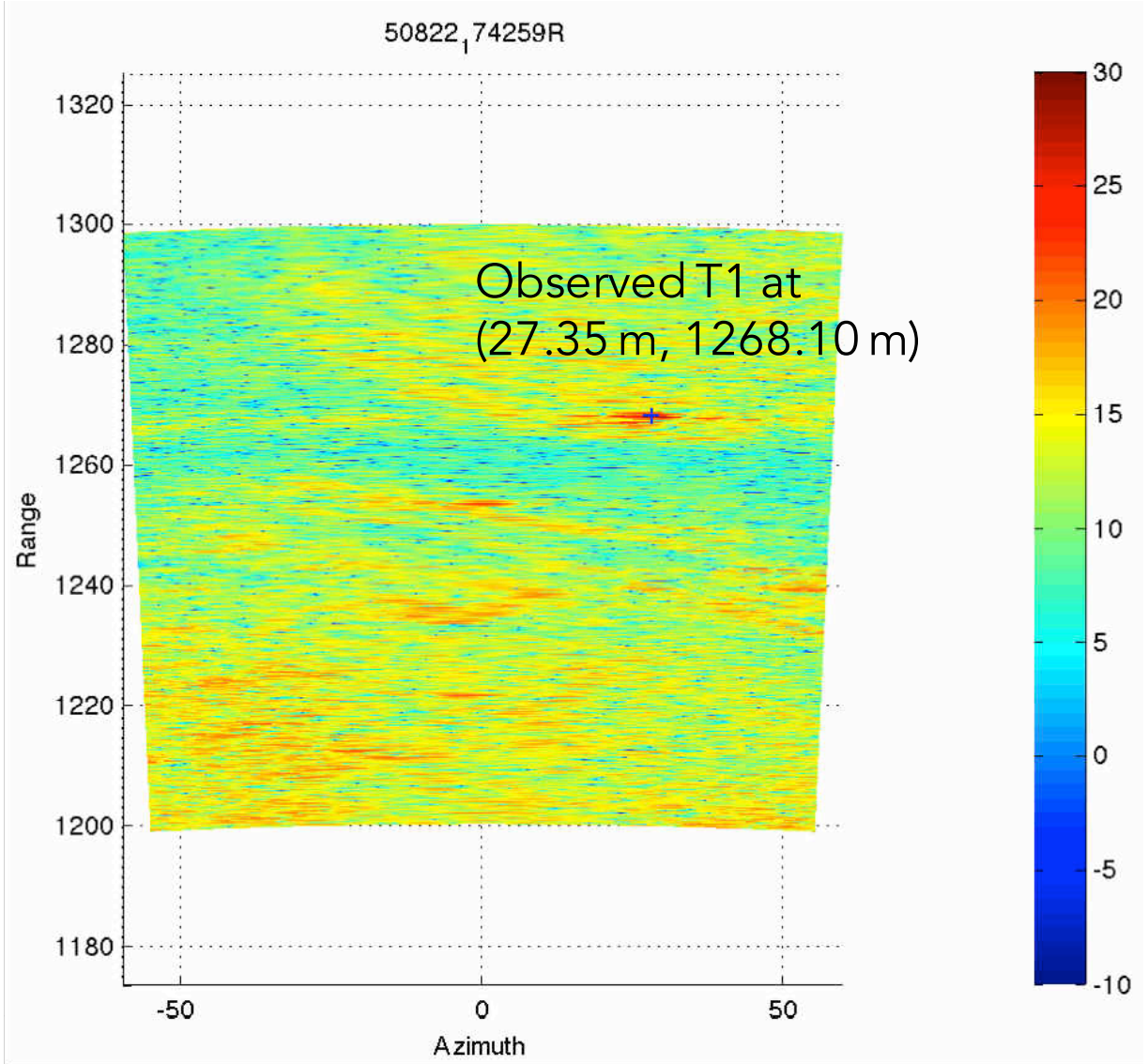
Distance from GBSAR to T1 = 1259 m
Distance from GBSAR to T2 = 1244 m



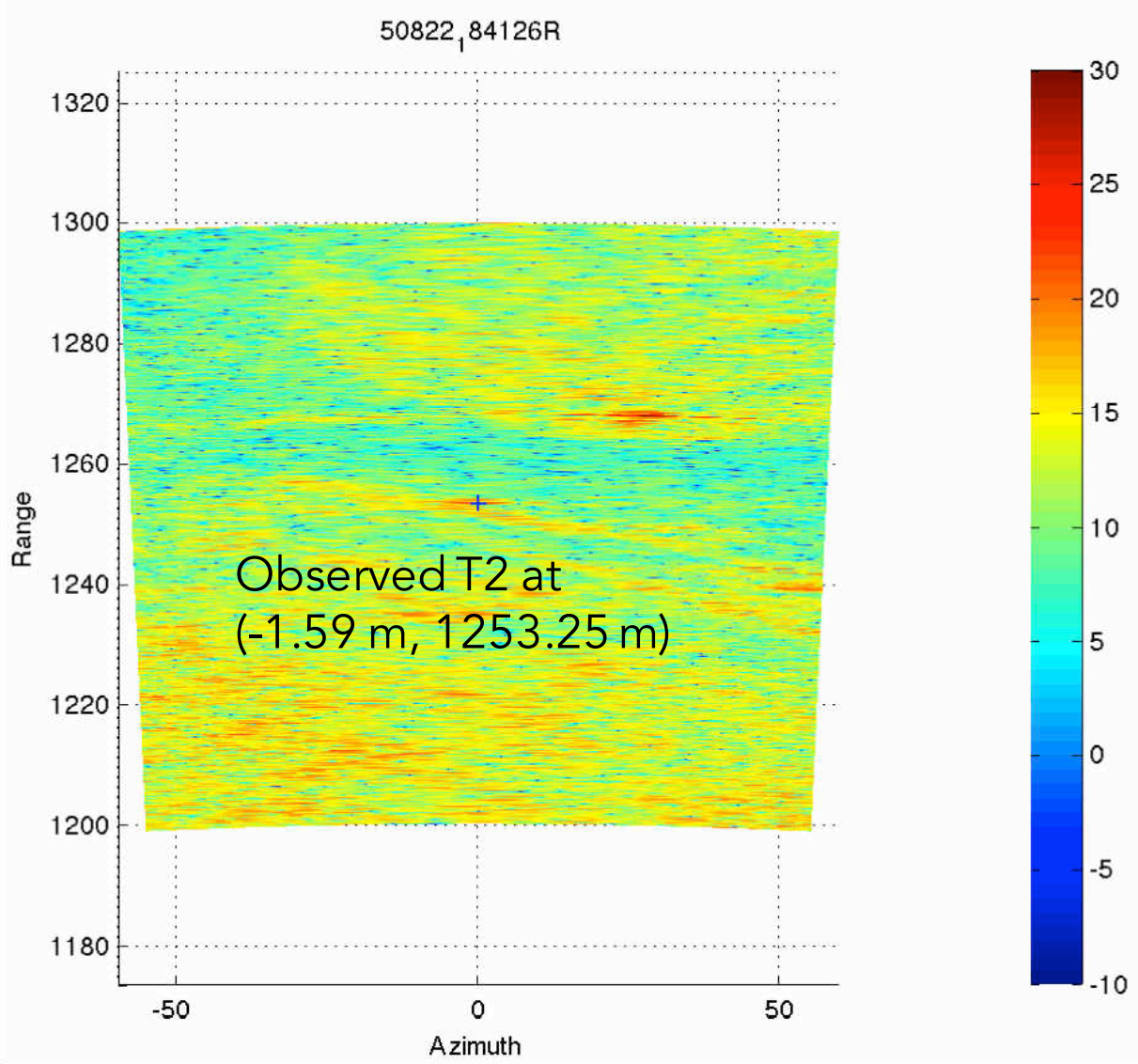
Sample data set: 150523-110419L



Sample data set: 150822-174259R

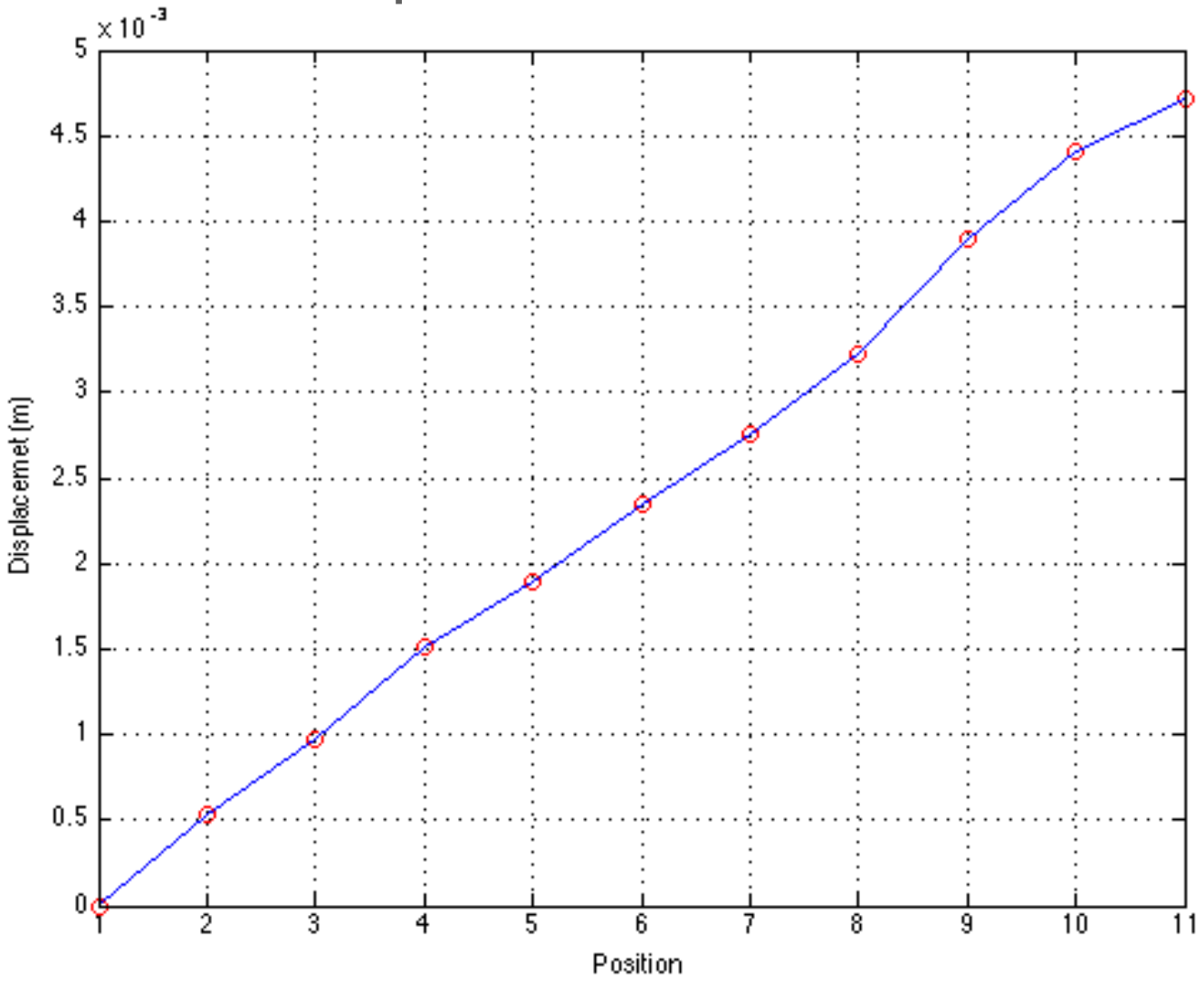


Sample data set: 150822-184126R

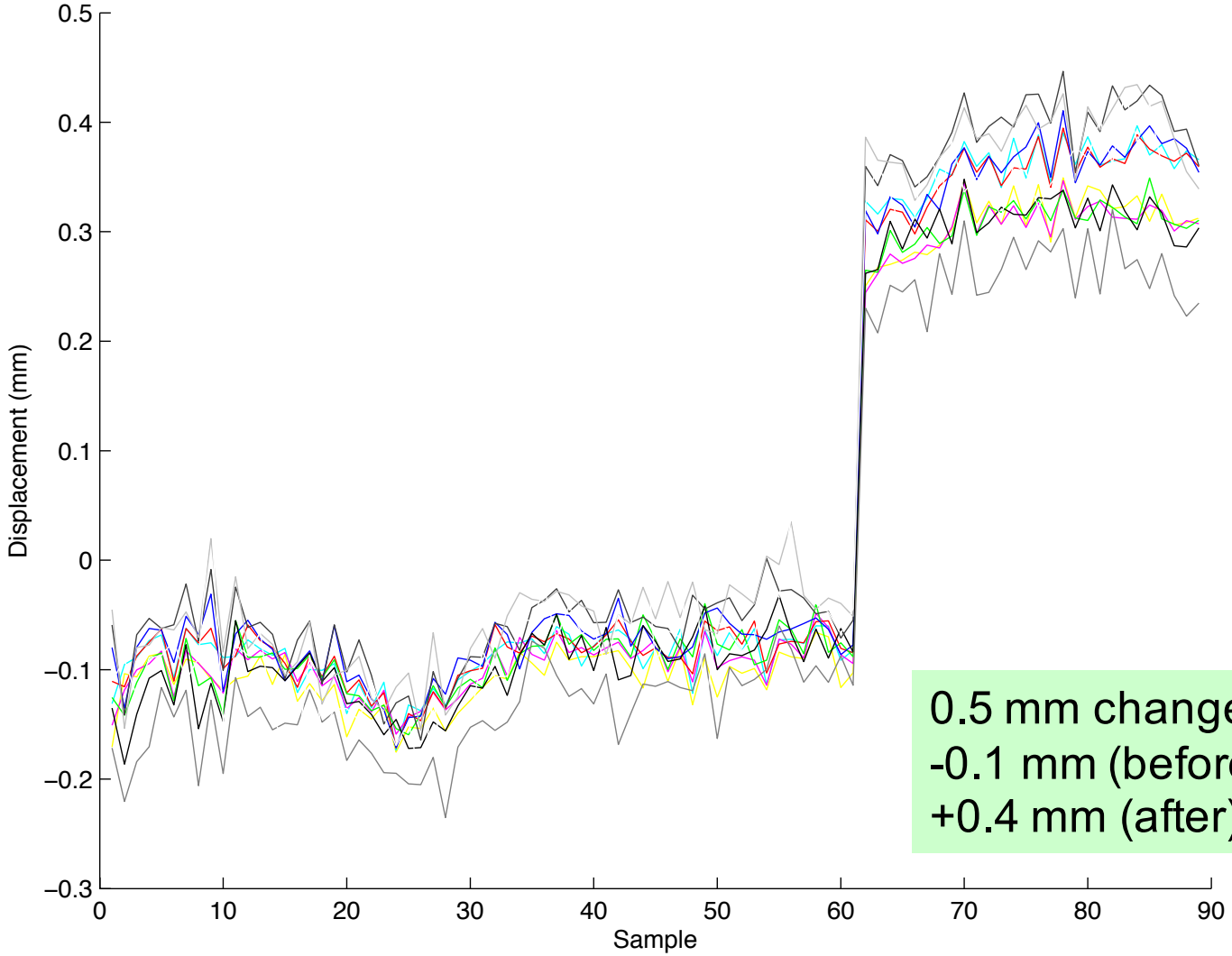



Fine adjustment of the trihedral T2 with 0.5 mm per step

Measured Displacement (0.5 mm/step)



0.5 mm change detection



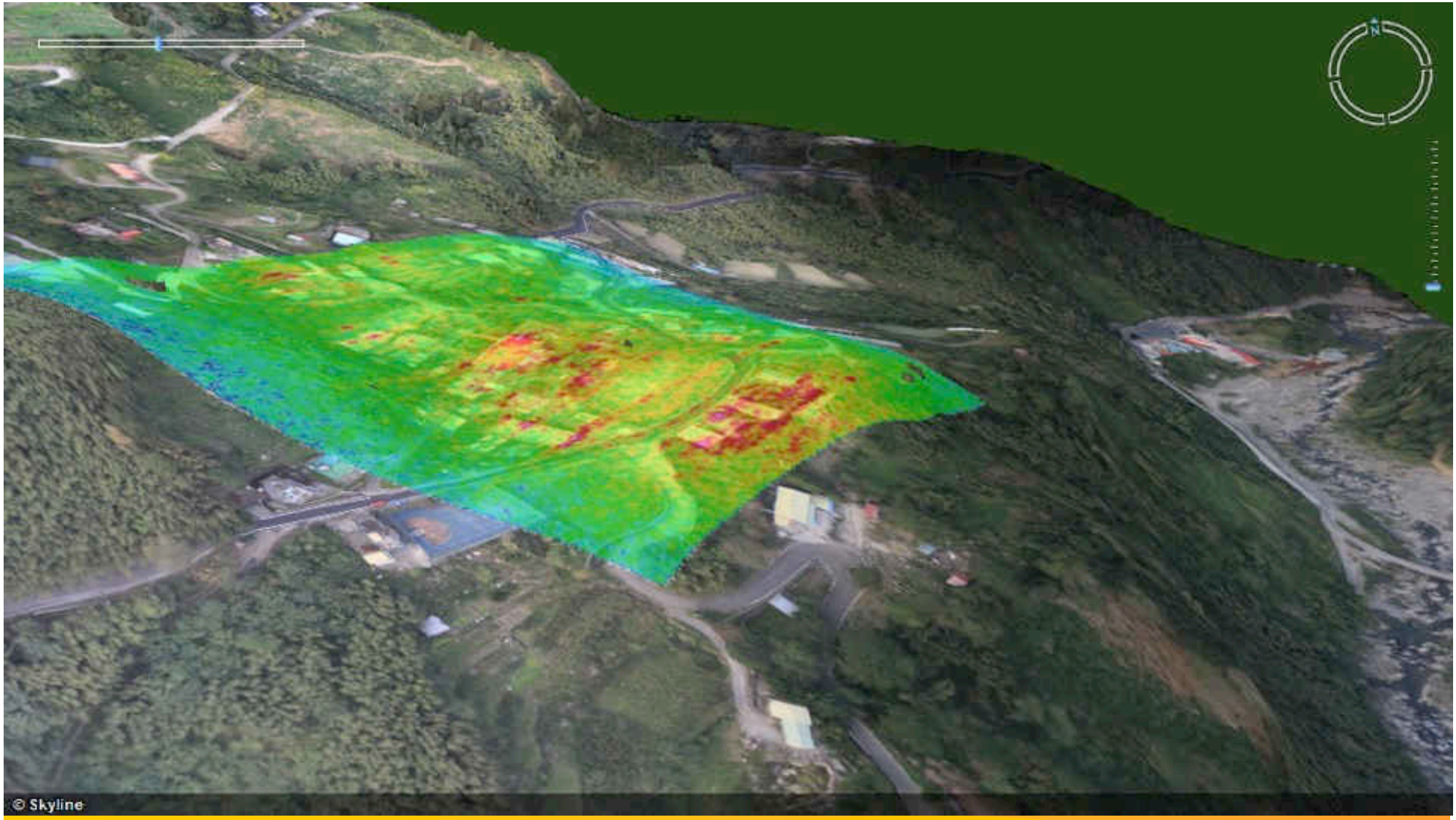
0.5 mm change
-0.1 mm (before)
+0.4 mm (after)

Study Area TS02: MeiHua School, TW

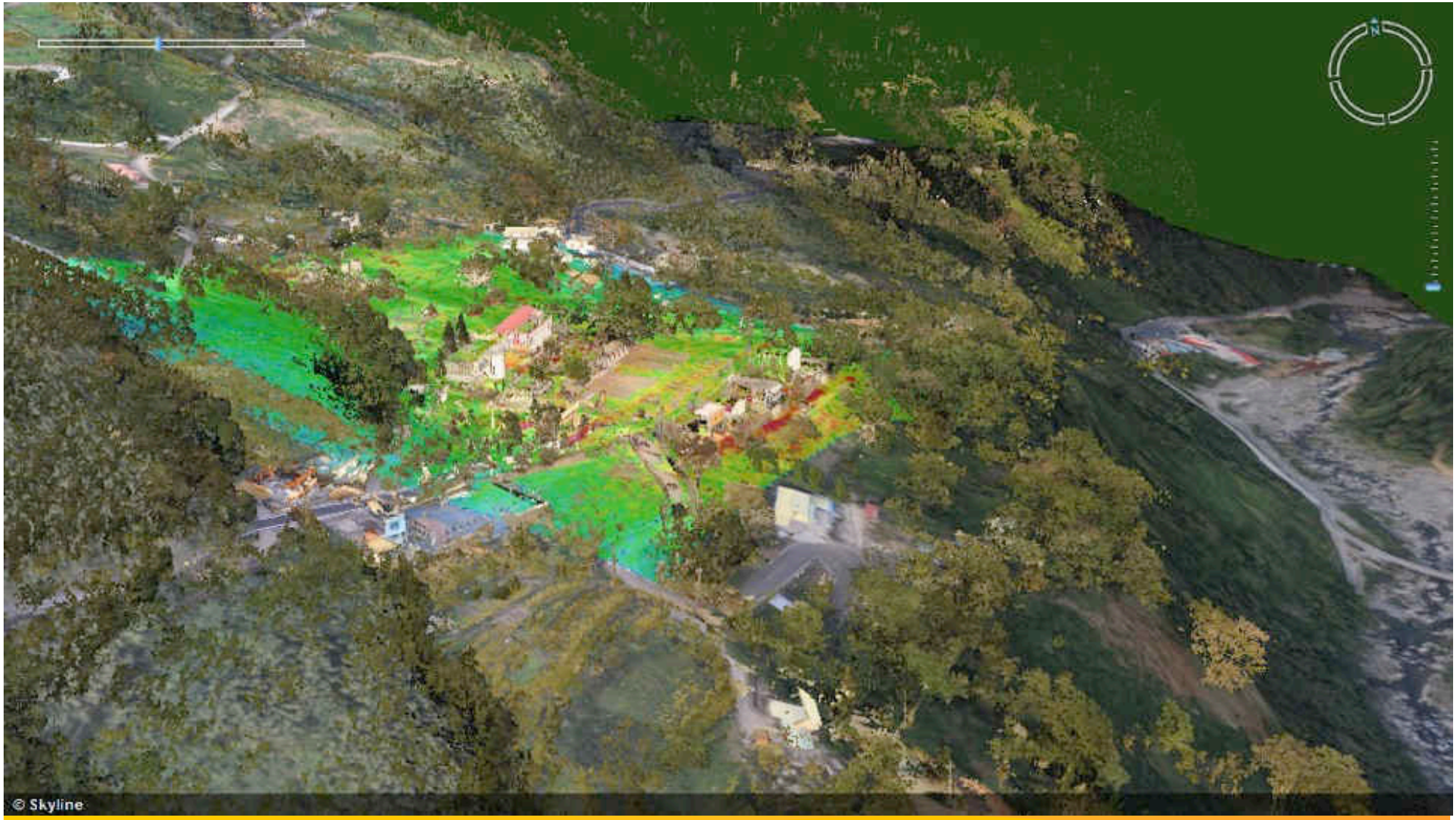
Sensing Distance: 500-1000 m
Swath Width: 150-200 m
Altitude: ~485-610 m

3D Optical View

3D Optical + GBSAR Image



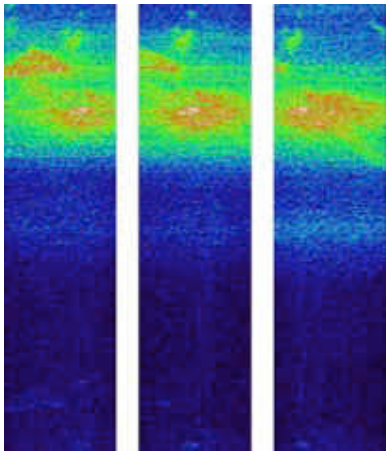
3D Optical + GBSAR + LiDAR Image

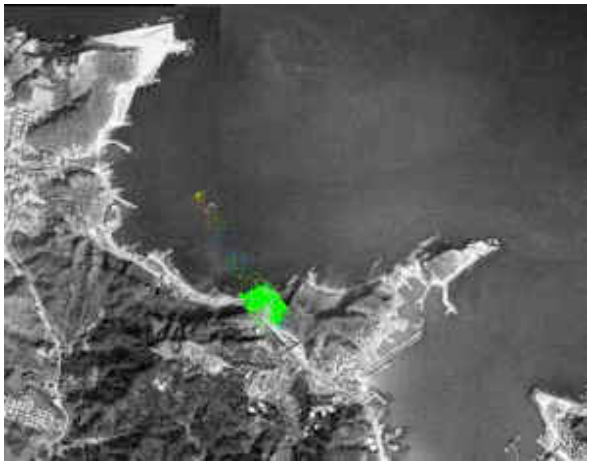


CRSST

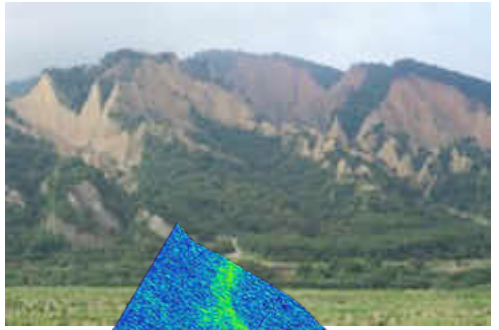
MMU
MULTIMEDIA UNIVERSITY

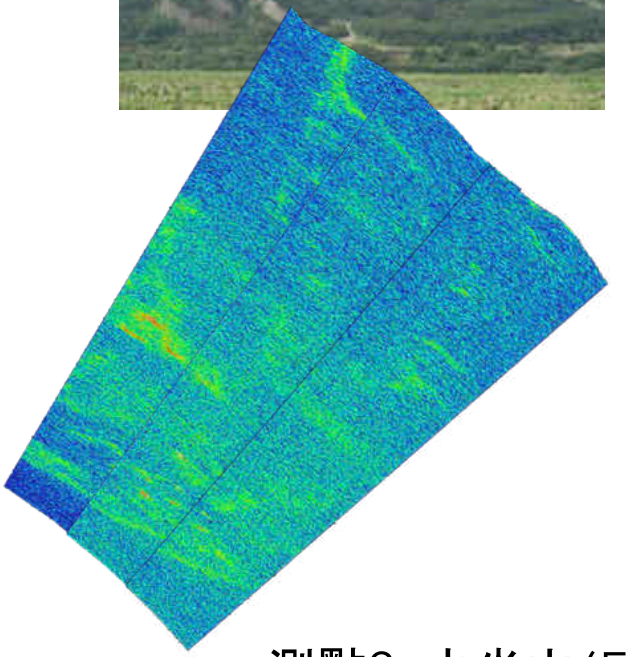
Taipei Measurement Campaign (02-08 June, 2016)



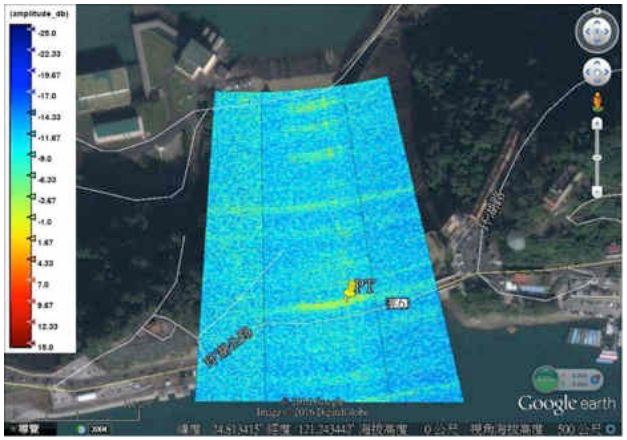


測點1 : 潮境中心 (KeeLong Test Site. 02-04 Jun)



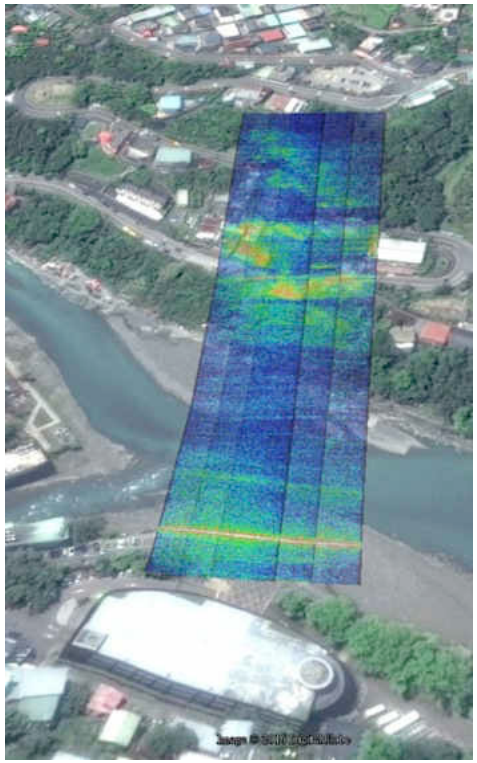


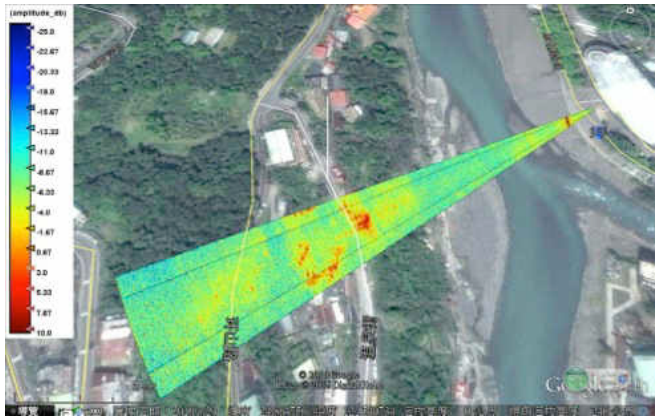
測點2 : 火炎山 (Fire Hill Test Site, 05 Jun)

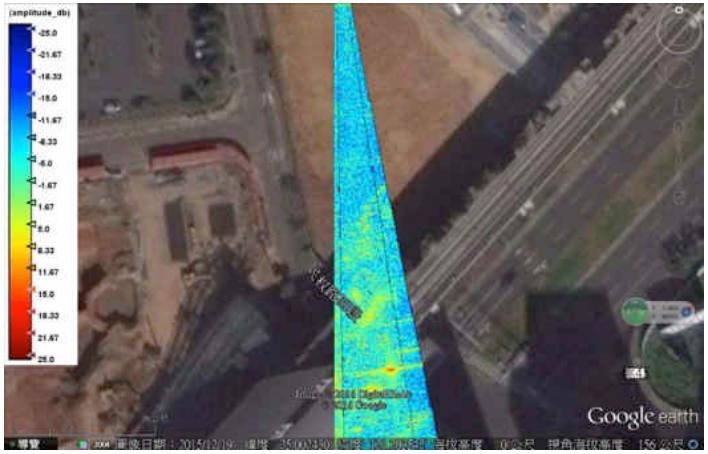


測點3 : 石門水庫大壩 (Simon Water Dam, 06 Jun)

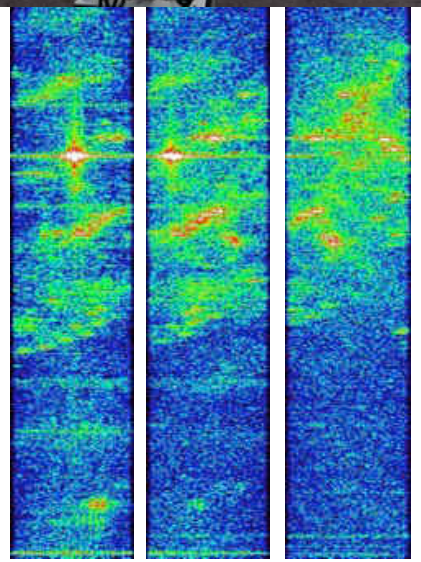
Taipei Measurement Campaign (02-08 June, 2016)





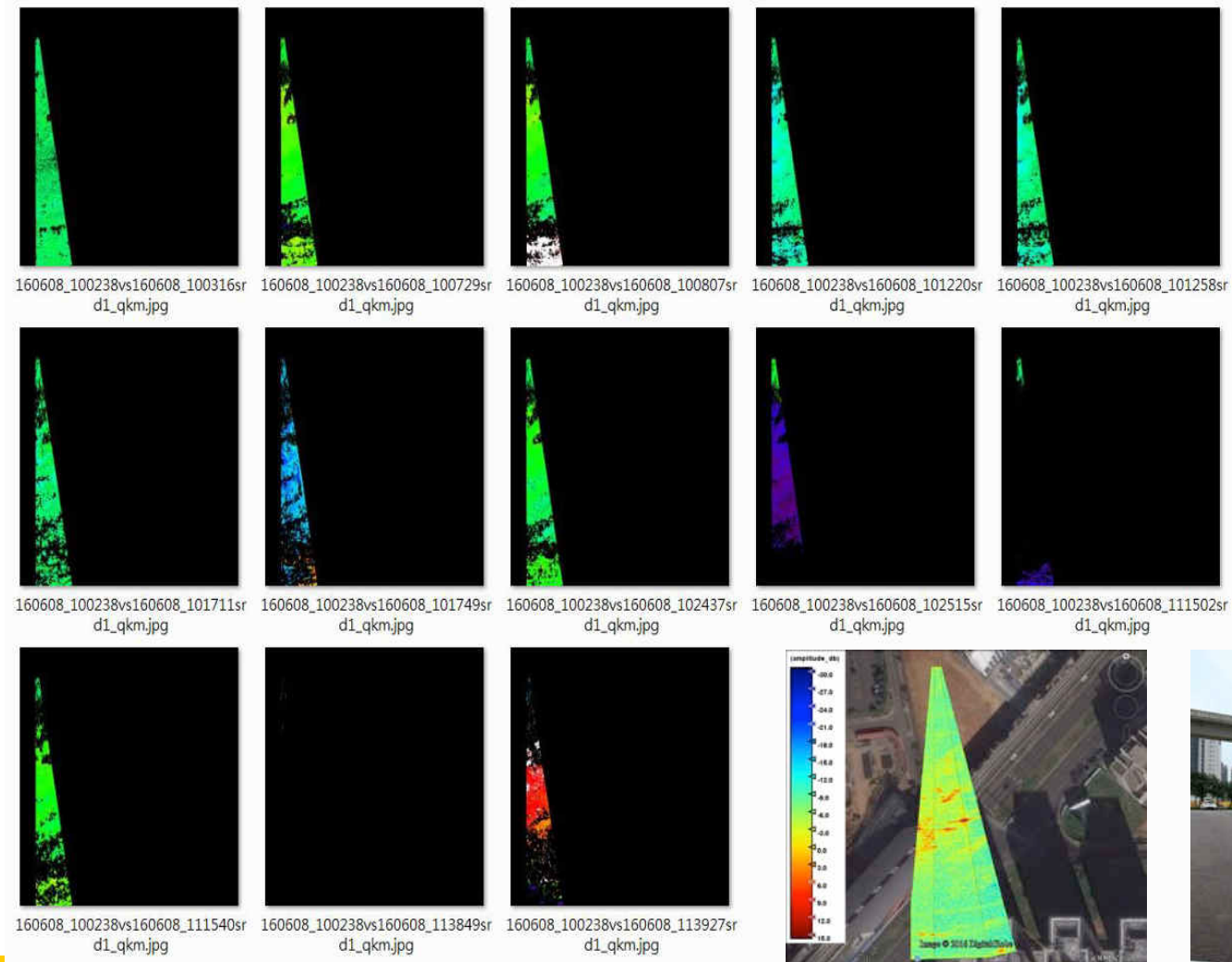


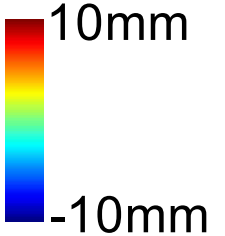
測點4 : 烏來 (WuLai Test Site, 07 Jun)



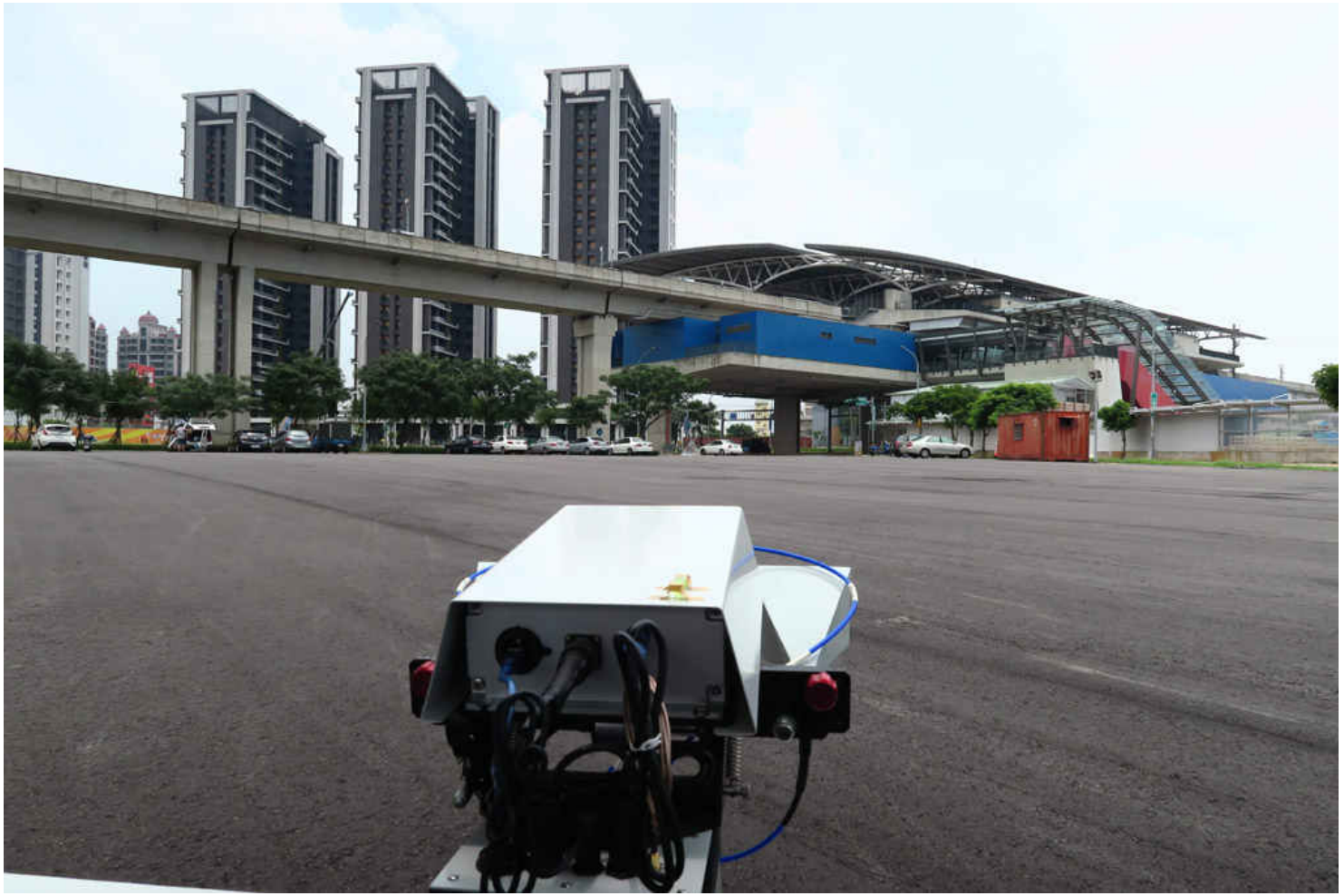
測點5 : 青埔捷運棒球場站 (CP LRT Station, 08 Jun)

Sample Results: Detection of Vibration at LRT Station

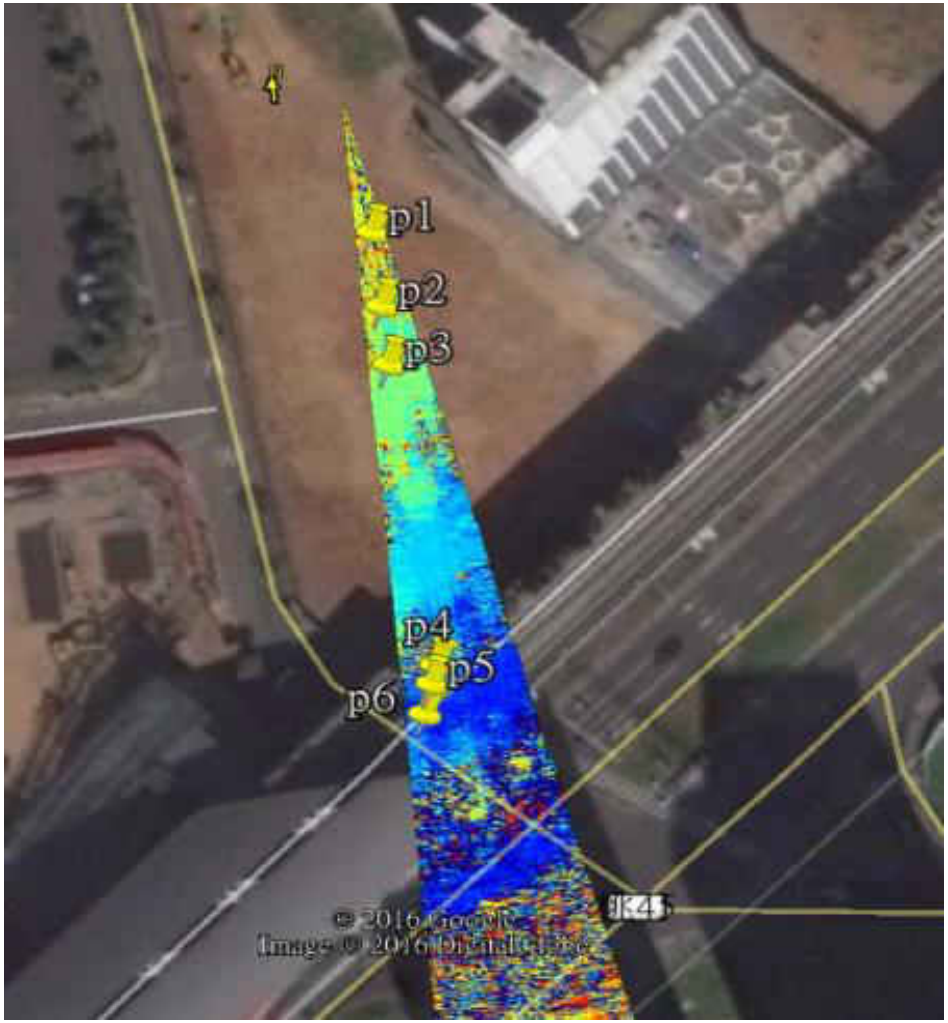




Taiwan Tao Yan Train Station



Changes Detection

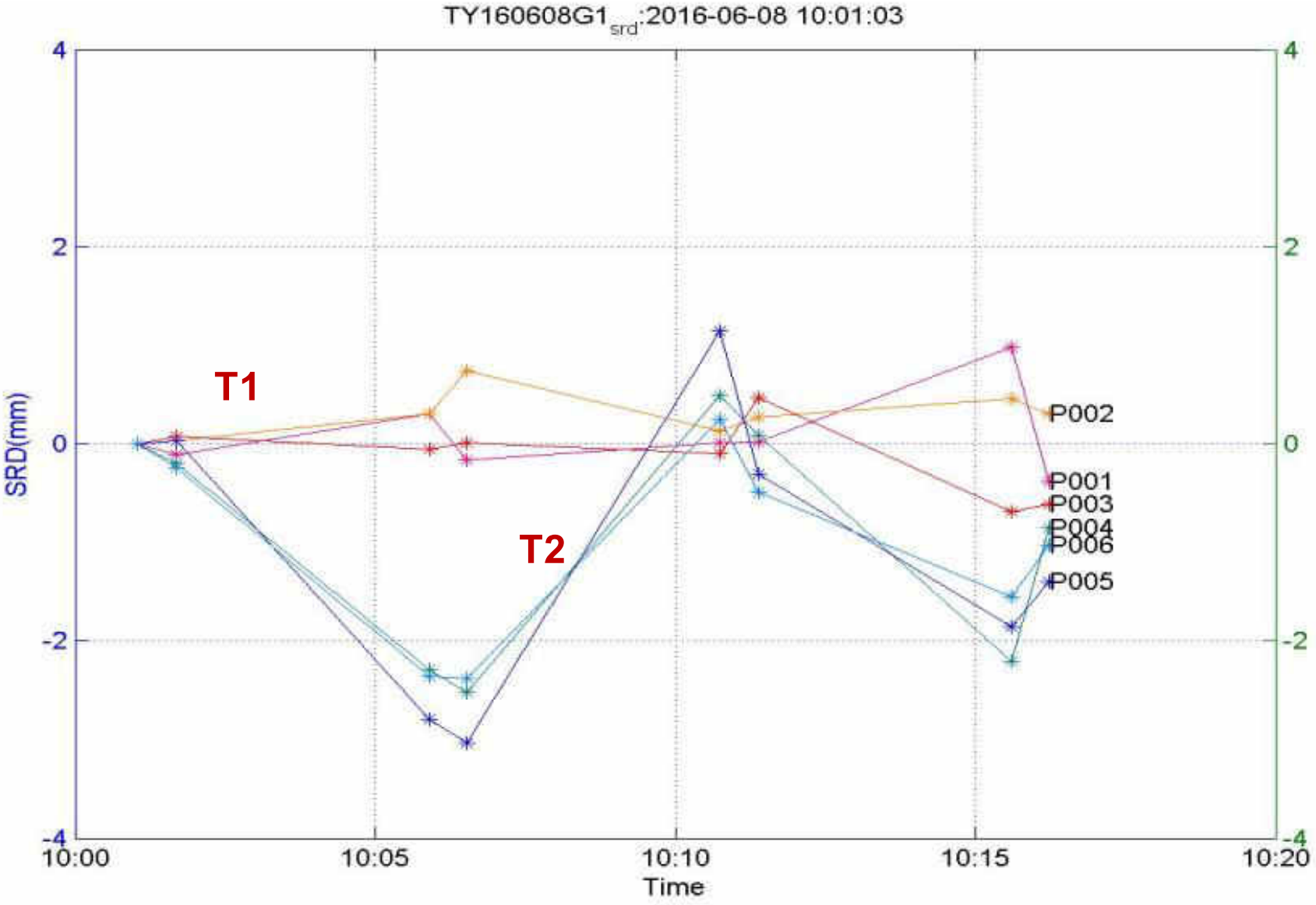


Observation Across Two Different Time

T1

T2

Observation Across Two Different Time Zone



Summary

- Ground movements and instabilities such as landslides, falling rocks can lead to considerable human and economic losses.
- Continuous monitoring on high risk area is important to give insight into the mechanisms of land deformation.
- In Malaysia, there are 21,000+ landslide-prone areas to be monitored.
- A mmW GBSAR has been developed. It has 0.5 m × 5.8 mrad spatial resolutions, and change detection capabilities up to 5 mm.
- The GBSAR is suitable tool for the land deformation detection, landslide monitoring as well as man made structure monitoring.

THANK YOU