THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Project 32278_3:
Towards Near-Real Time InSAR Deformation Estimation

X.L. Ding

The Hong Kong Polytechnic University

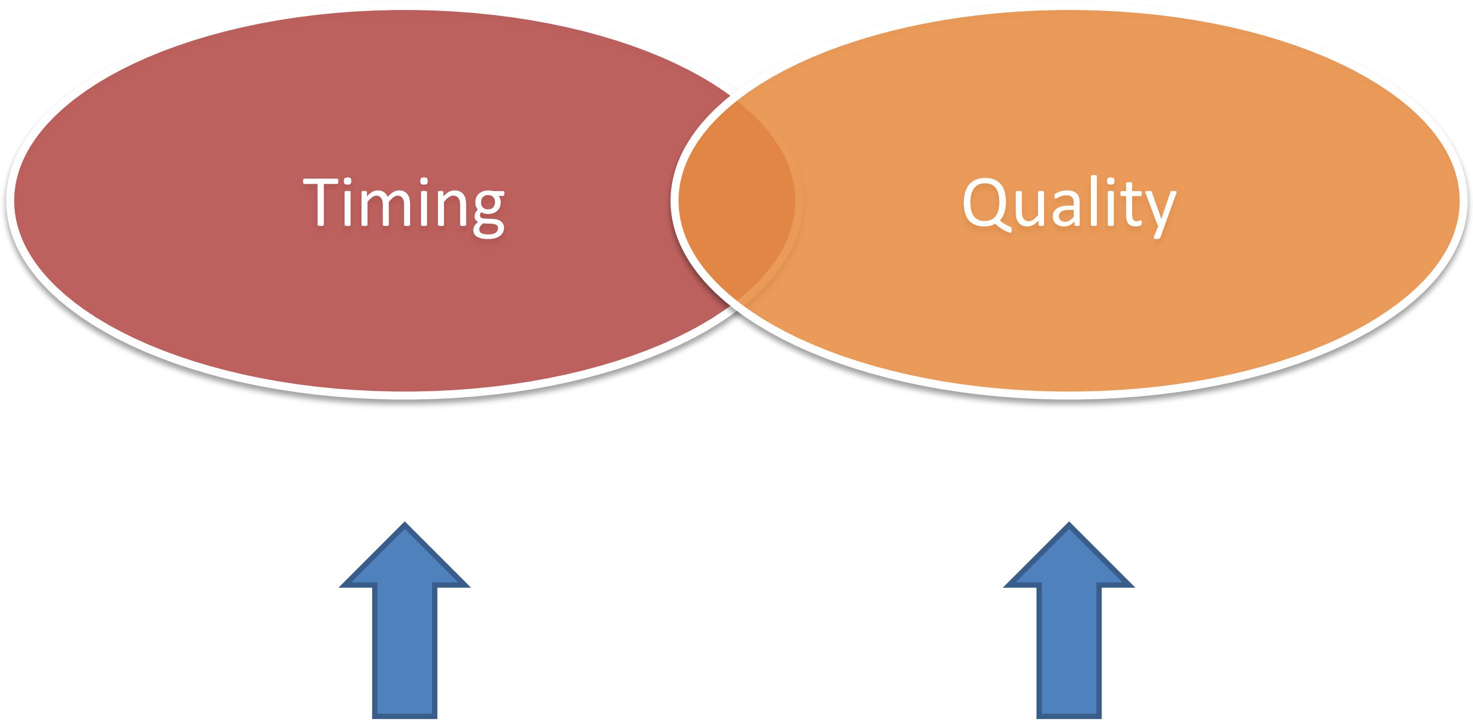
THREE- AND FOUR-DIMENSIONAL TOPOGRAPHIC MEASUREMENT AND VALIDATION

European Leader Investigator Prof. Rocca Fabio Dipartimento di Elettronica ed Informazione Politecnico di Milano, ITALY	***Chinese Leader Investigator*** Prof. Deren Li State Key Lab. of Info. Eng. in Surveying, Mapping and Remote Sensing, CHINA

List of Principal Investigators (PIs)

Topic Nr.	**PIs**	**Title**
32278_1	*Prof. Norbert Haala,* *Prof. Timo Balz*	***Topographic Mapping - Validation; TMV***
32278_2	*Prof. Stefano Tebaldini,* *Prof. Mingsheng Liao*	***Multi-baseline SAR processing for 3D/4D reconstruction; MBSAR***
32278_3	*Prof. Ramon Hanssen,* *Prof. Xiaoli Ding*	***Towards Near-Real Time InSAR Deformation estimation; NRT***

Towards Near-Real Time InSAR Deformation Estimation ?



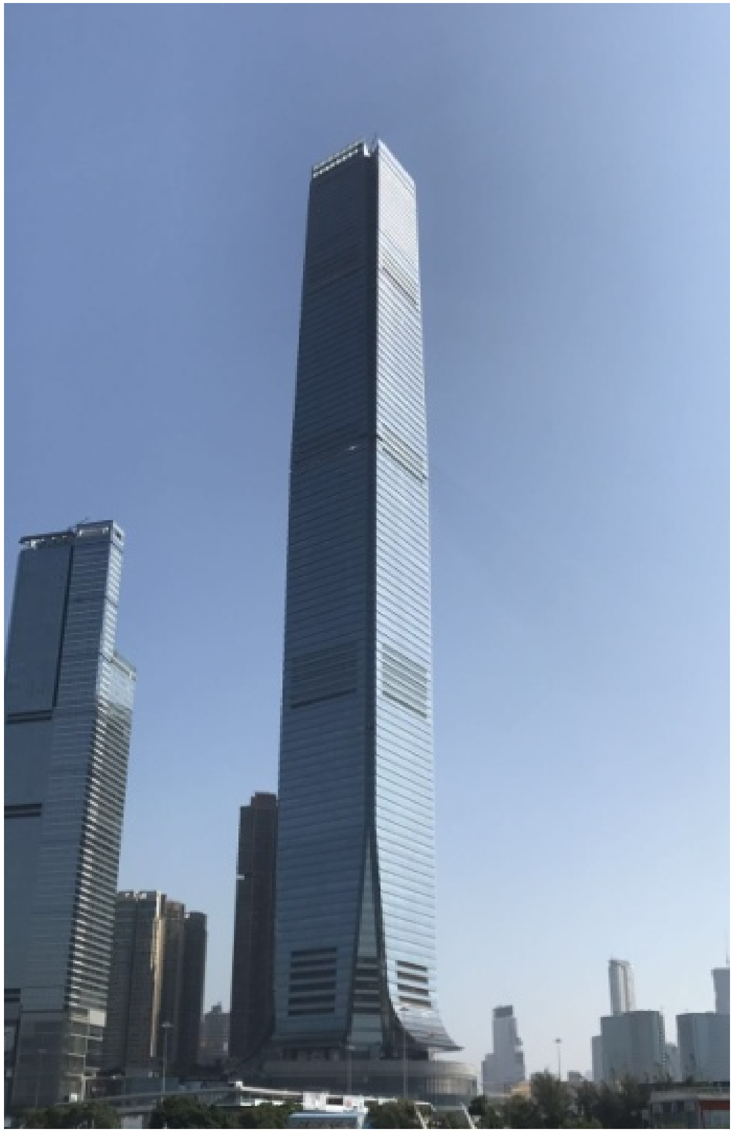
Data processing efficiency

Knowing the quality
Enhancing the quality

Towards Near-Real Time InSAR Deformation Estimation

- Structural dynamics from ground based radar system
- TCP multi-temporal InSAR model

How much cn these structures move ?



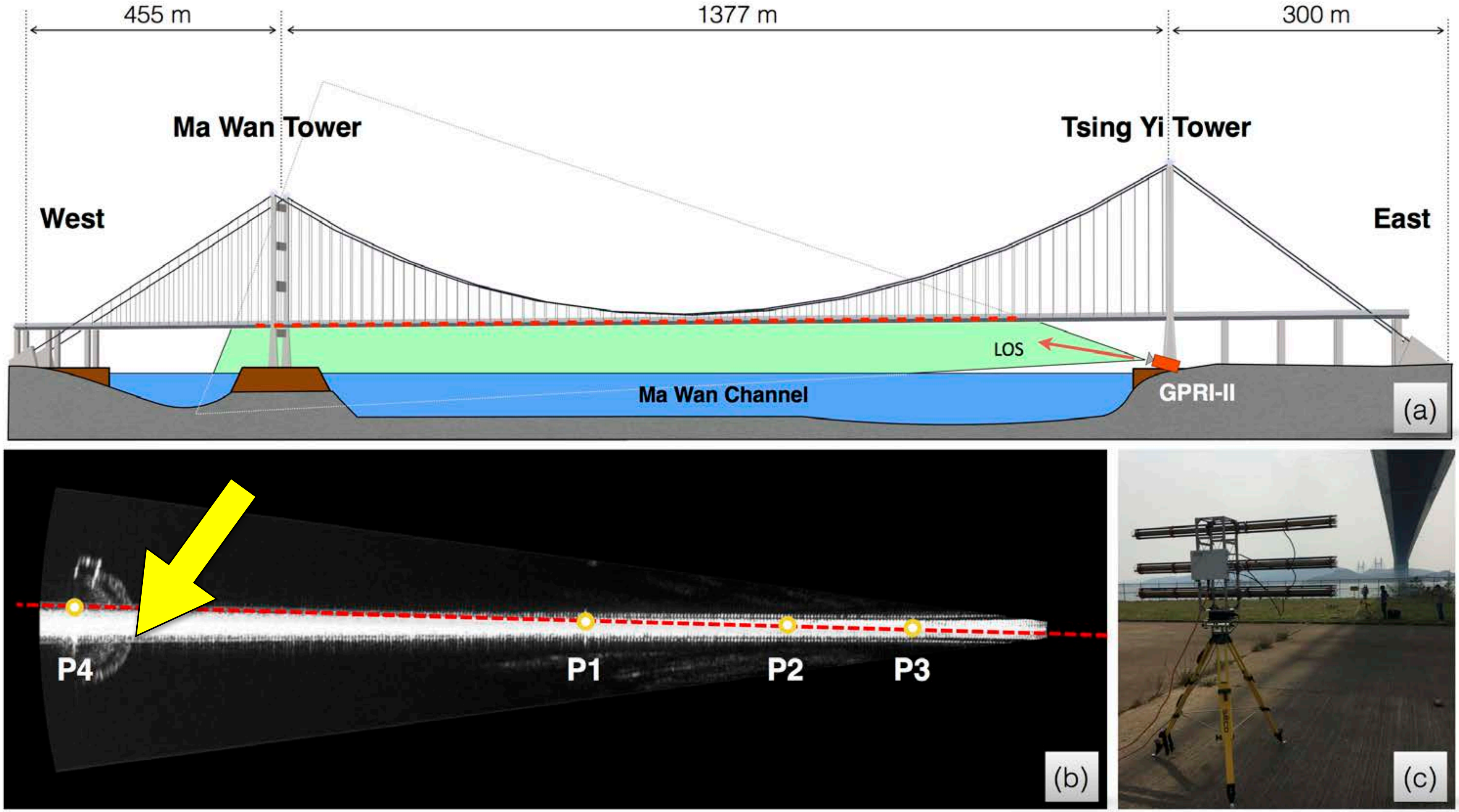
It is the world's ninth-longest span suspension bridge, and was the second longest at time of completion.

The span is the longest carrying rail traffic.

Tsing Ma Bridge

Tsing Ma Bridge

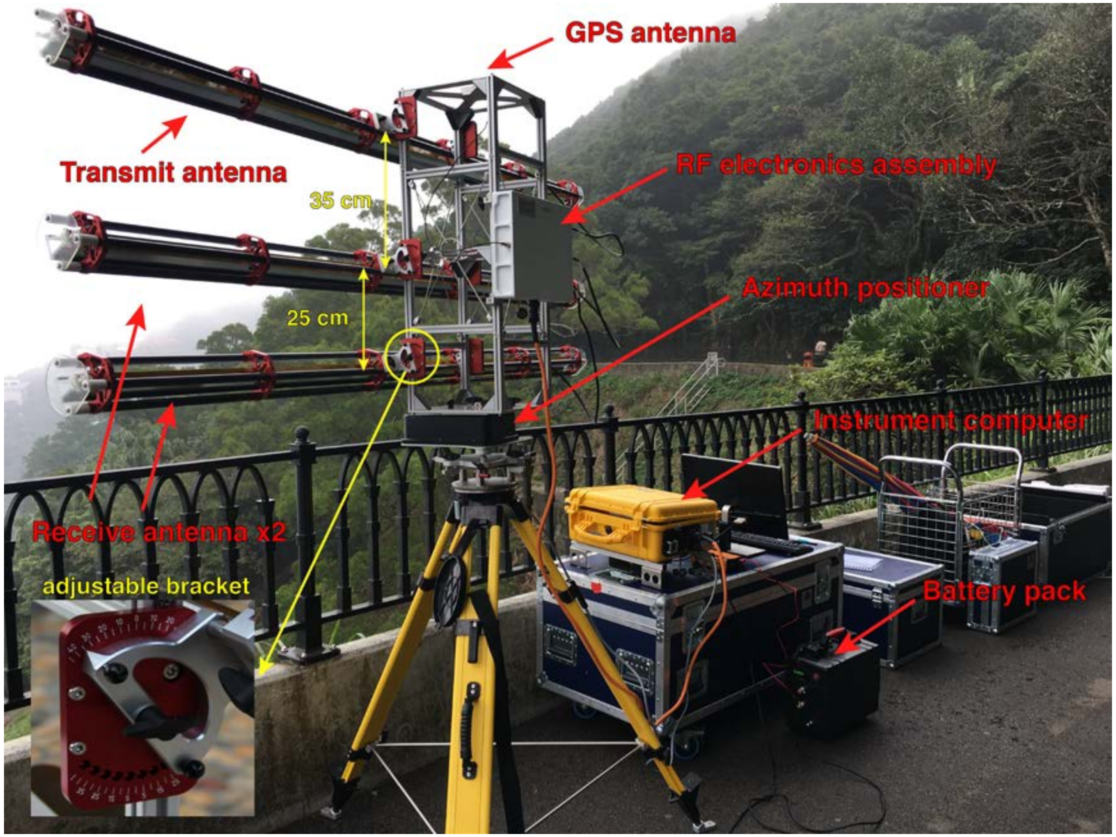
Coordinates	22°21′05″N 114°04′27″E
Carries	6 lanes of roadway (upper) 2 MTR rail tracks, 2 lanes of roadway (lower)
Crosses	Ma Wan Channel
Locale	Ma Wan Island and Tsing Yi Island
Official name	Tsing Ma Bridge
Characteristics	
Design	Double-decked suspension bridge
Width	41 metres (135 ft)
Longest span	1,377 metres (4,518 ft)
Clearance below	62 metres (203 ft)
History	
Opened	22 May 1997; 19 years ago
Statistics	
Daily traffic	trains and cars
Toll	HK$30 (cars, combined with Kap Shui Mun Bridge)



Date: 28th, Mar. 2016
Distance: 80 ~ 1500 m
Elevation: 10 deg.
Temperature: 20°

GPRI Instrument

❖ GAMMA Portable Radar Interferometer (GPRI)



① Antennas

(slotted-waveguide antennas)

② Antennas tower (GPS)

③ RF electronic assembly

④ Azimuth scanner (panoramic)

⑤ Instrument controller

⑥ Battery pack

Frequency Range	17.1 to 17.3 GHz 200 MHz BW	Wavelength	17.4 mm	Measurement Range	50 m ~ 10 km

Resolution of GPRI

❖ Slant Range Resolution

(Werner et. al, 2008)

$$\Delta R_{sr} = \frac{c \cdot \tau_p}{2} = \frac{c}{2 \cdot B_w}$$

(200 MHz, 0.75 m)

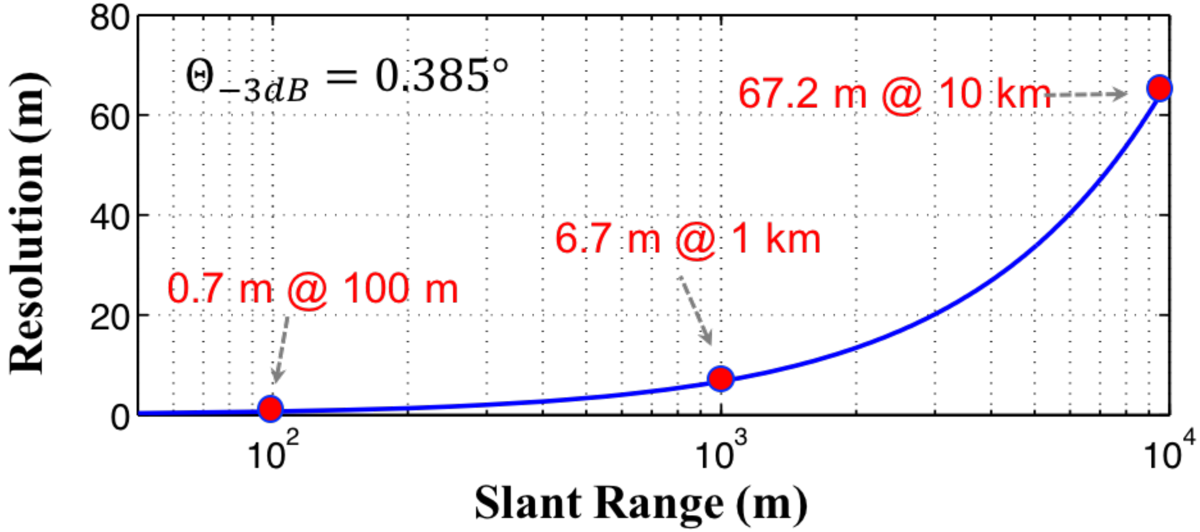
Bandwidth

❖ Azimuth Resolution

Azimuth beamwidth

$$\Delta R_{az} = \sin(\Theta_{-3dB}) \cdot r$$

Slant range



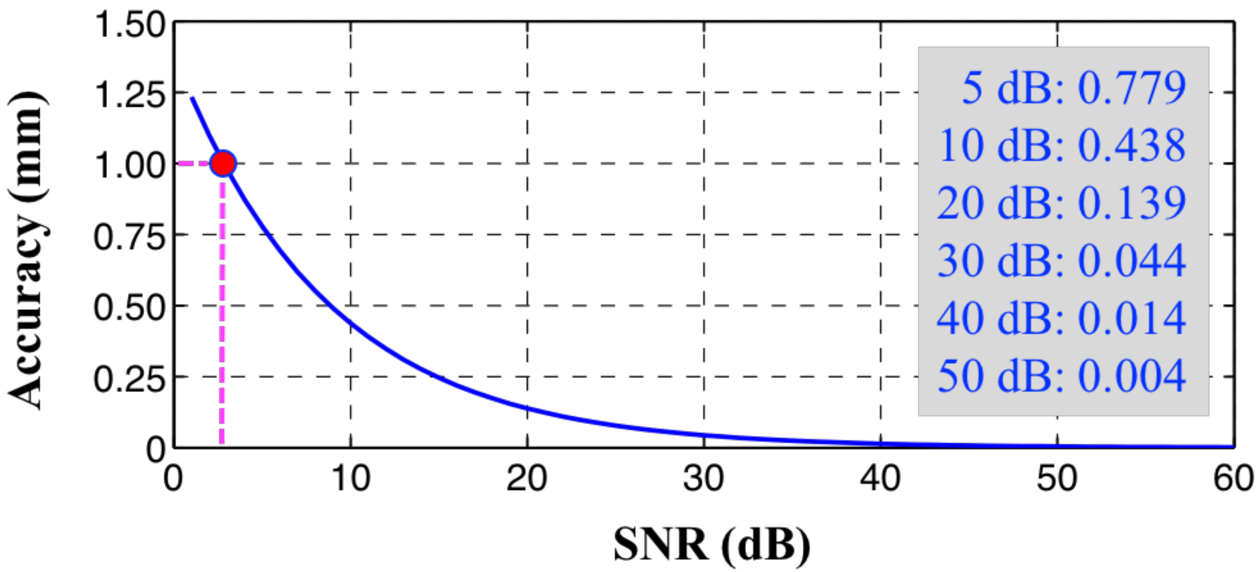
Relationship between azimuth resolution and slant range (azimuth beamwidth = 0.385 deg)

Accuracy of GPRI

❖ Accuracy of Deformation Measurement (ideal condition)

$$\hat{\sigma}_{d_{LOS}} = \frac{\lambda}{4\pi} \cdot \sigma_{\varphi} \approx \frac{\lambda}{4\pi} \cdot \frac{1}{\sqrt{SNR}}$$

(Werner et. al, 2012)



❖ Accuracy of Deformation Measurement

Normally: $\sigma_{d_{LOS}} < 1$ mm (1 km distance)

(*dependent on the atmospheric phase screen along LOS*)

Types of Data Acquisition – FAS

- Fixed azimuth scanning – FAS (1D)

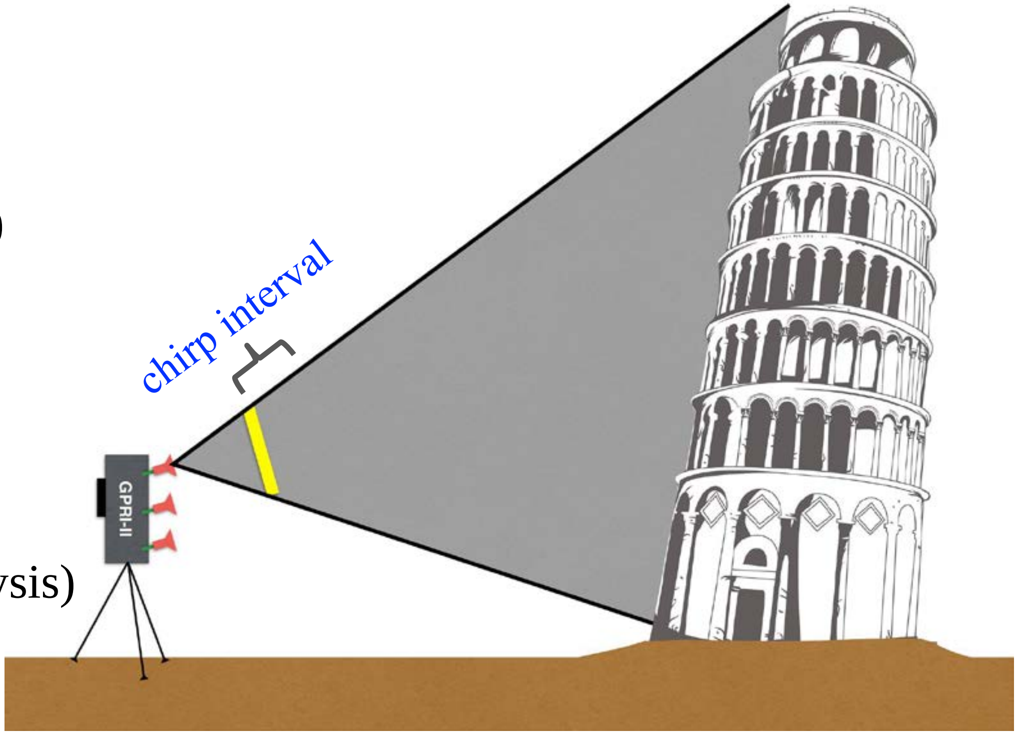
Radar signals are transmitted and received along constant directions.

- ✓ 1D map

  (only a range plot in fixed direction)
- ✓ High sampling rate

  (up to 4kHz, 250 µs per sample)
- ✓ Dynamic monitoring

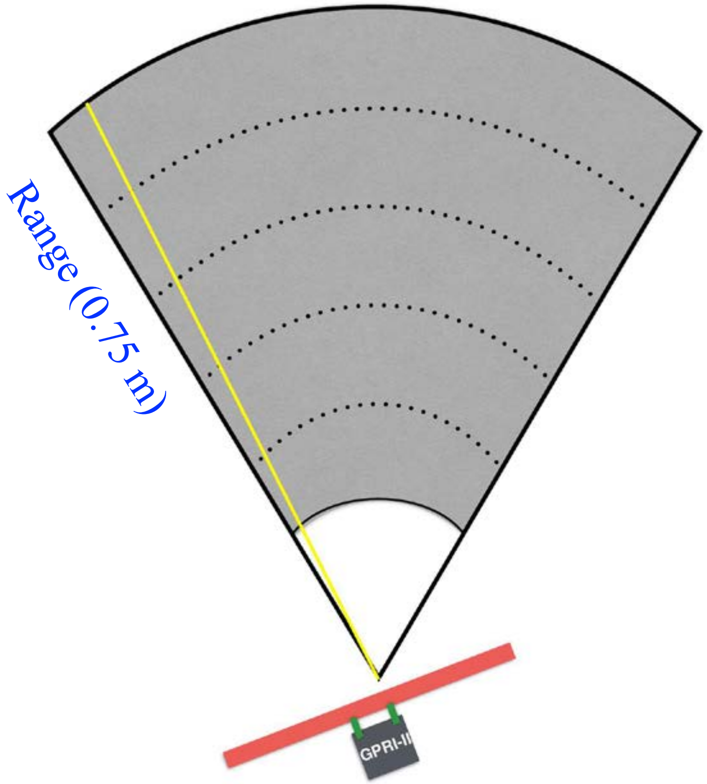
  (rapid deformation & transient analysis)



Types of Data Acquisition – RAS

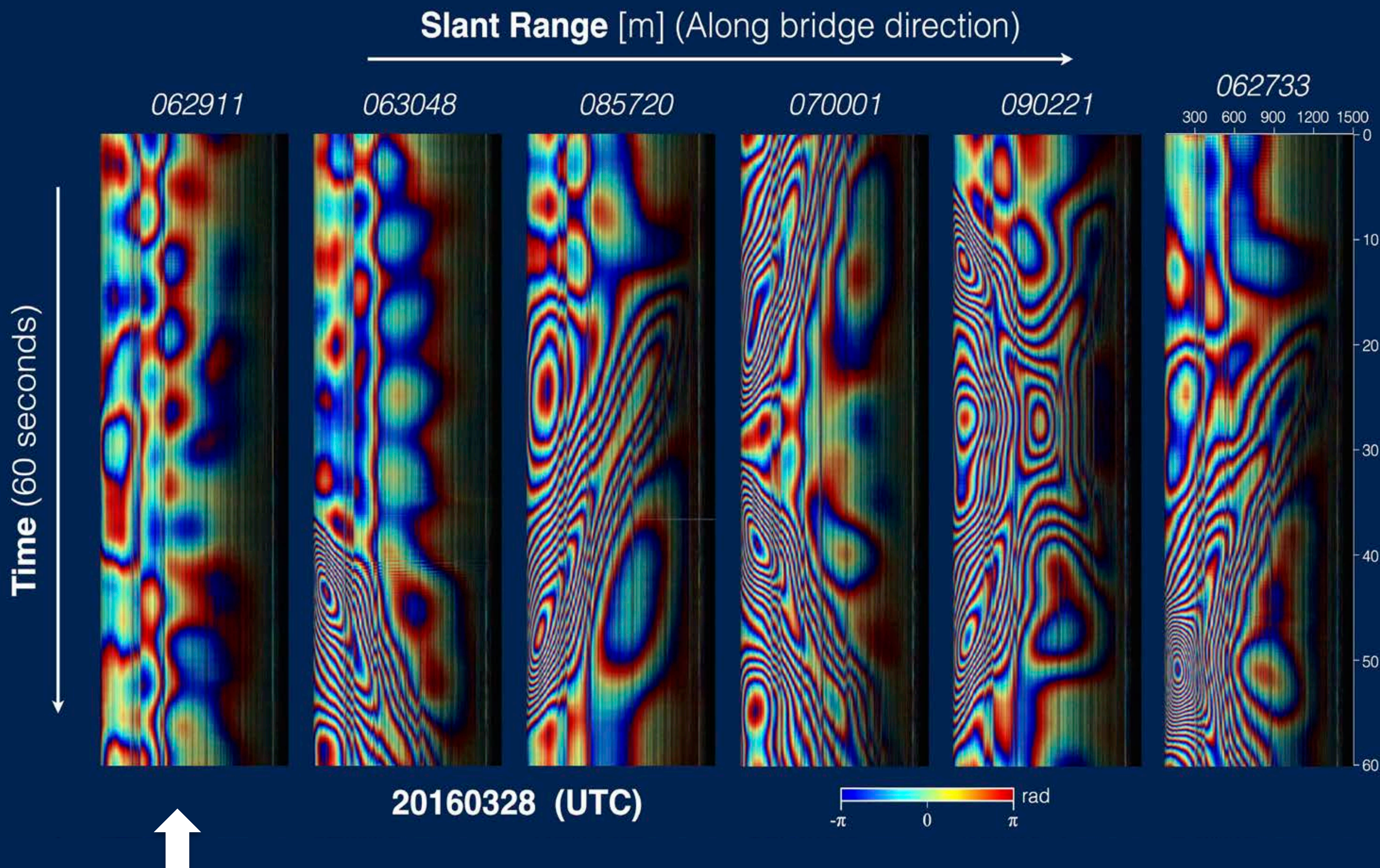
- Rotating azimuth scanning – RAS (2D)

Radar images are constructed by rotating the antennas in azimuth around the central axis of the tower.

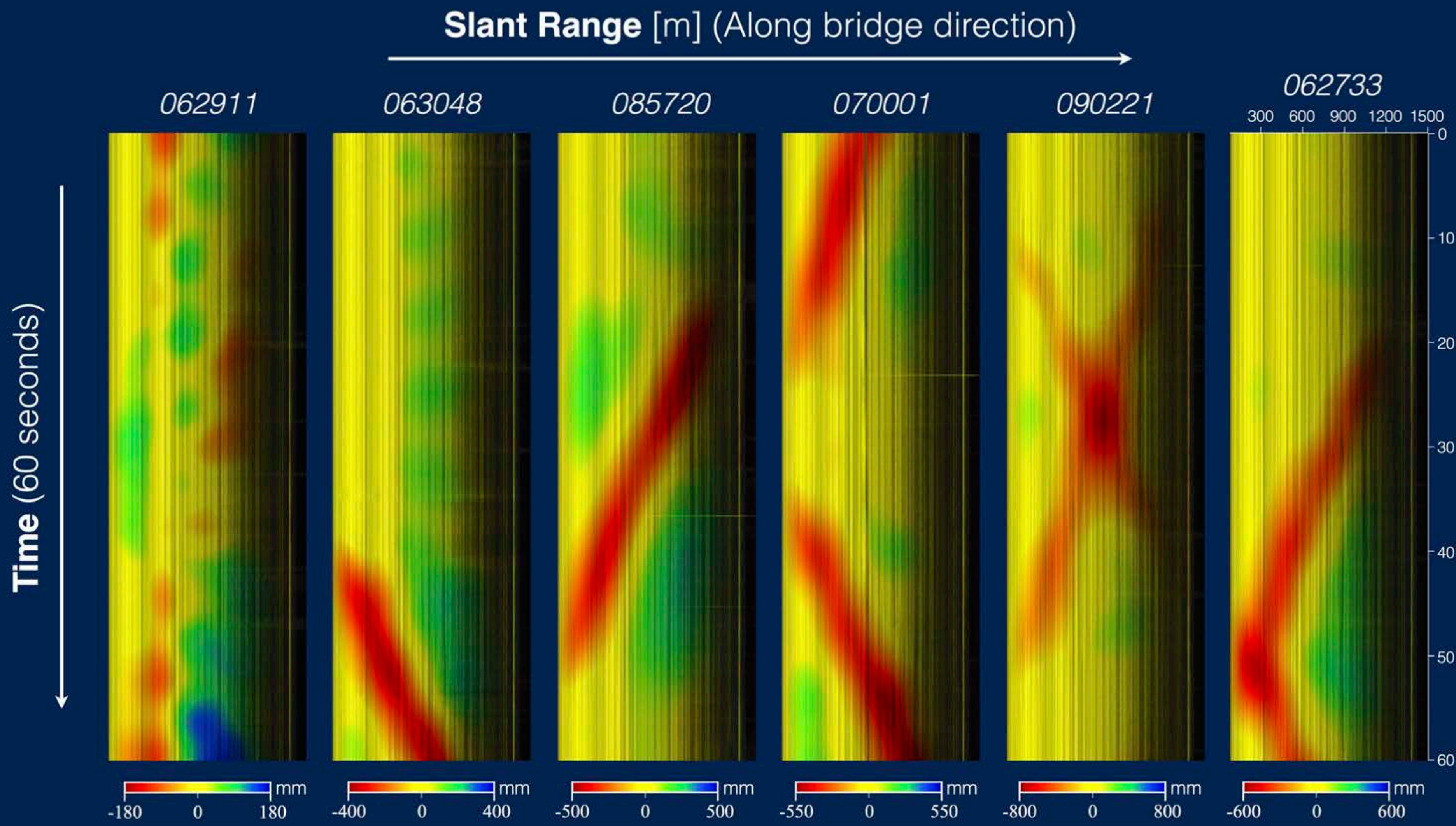


- ✓ 2D map (range & azimuth)
- ✓ 360º with steps of approximately 0.1º
- ✓ Static monitoring

  (large area & long-term deformation)

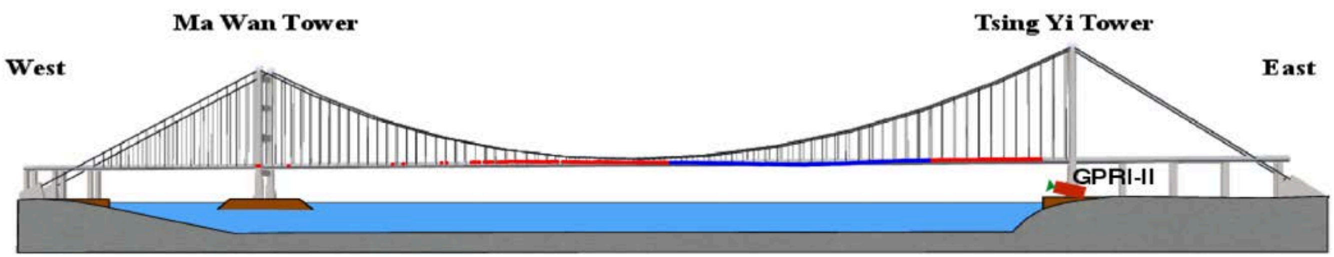


no train passing **One MTR passing** **Two MTRs passing**

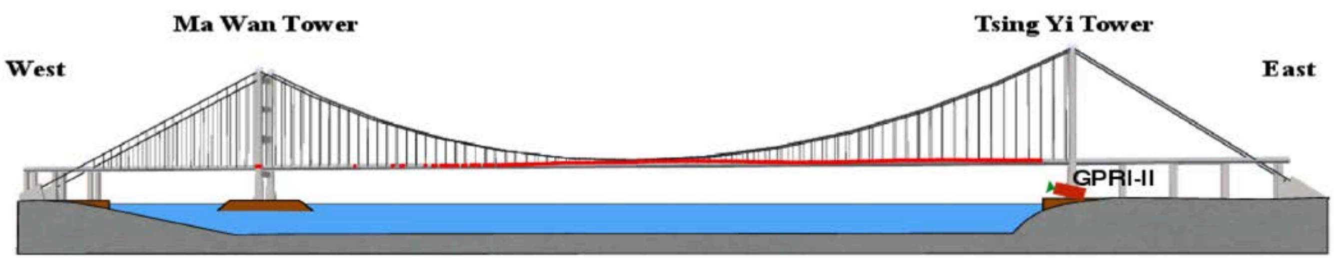


Vertical Displacement maps

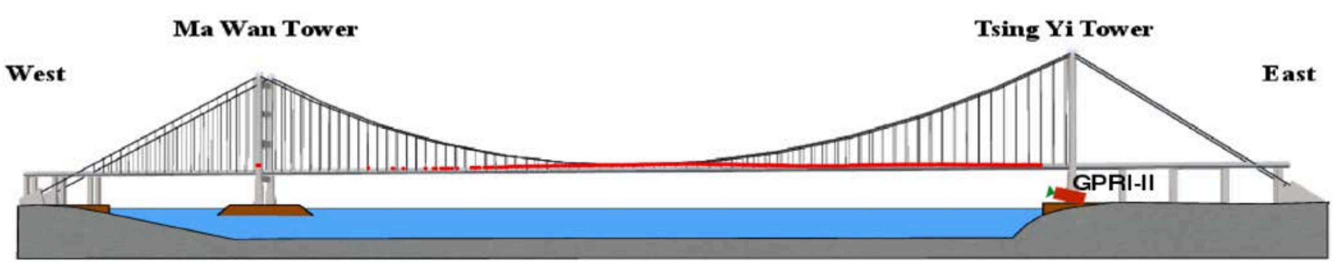
● Red (upward) ● Blue (downward)



2016–03–28 06:29:1.9



2016–03–28 08:57:1.9

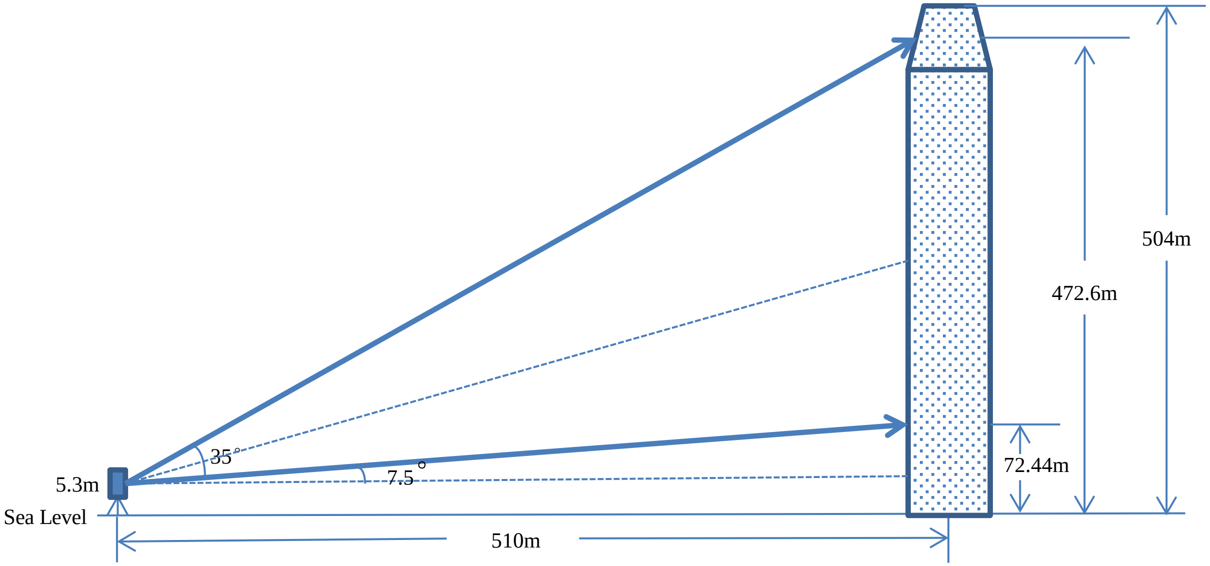


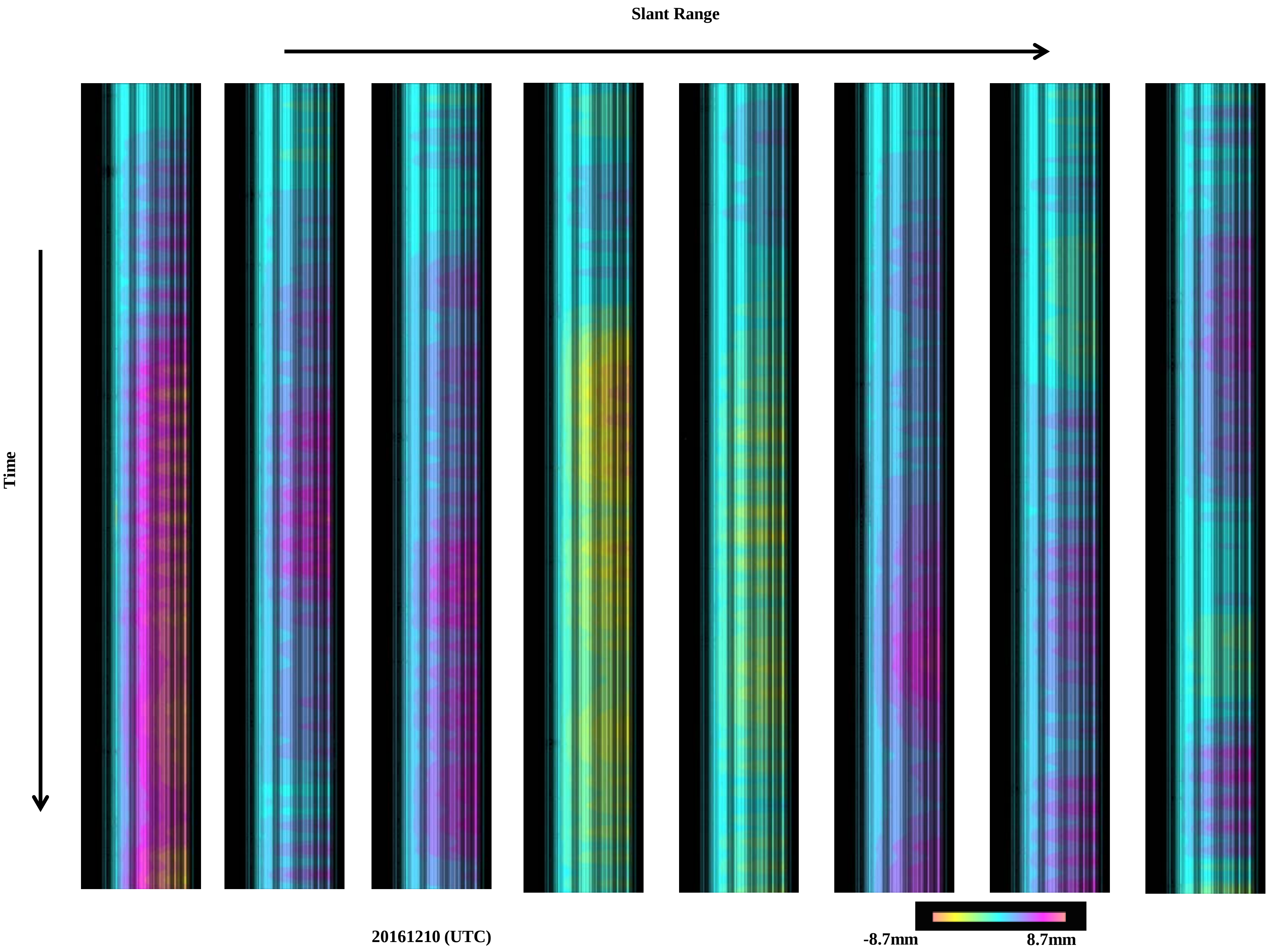
2016–03–28 09:02:1.9

Hong Kong ICC Building

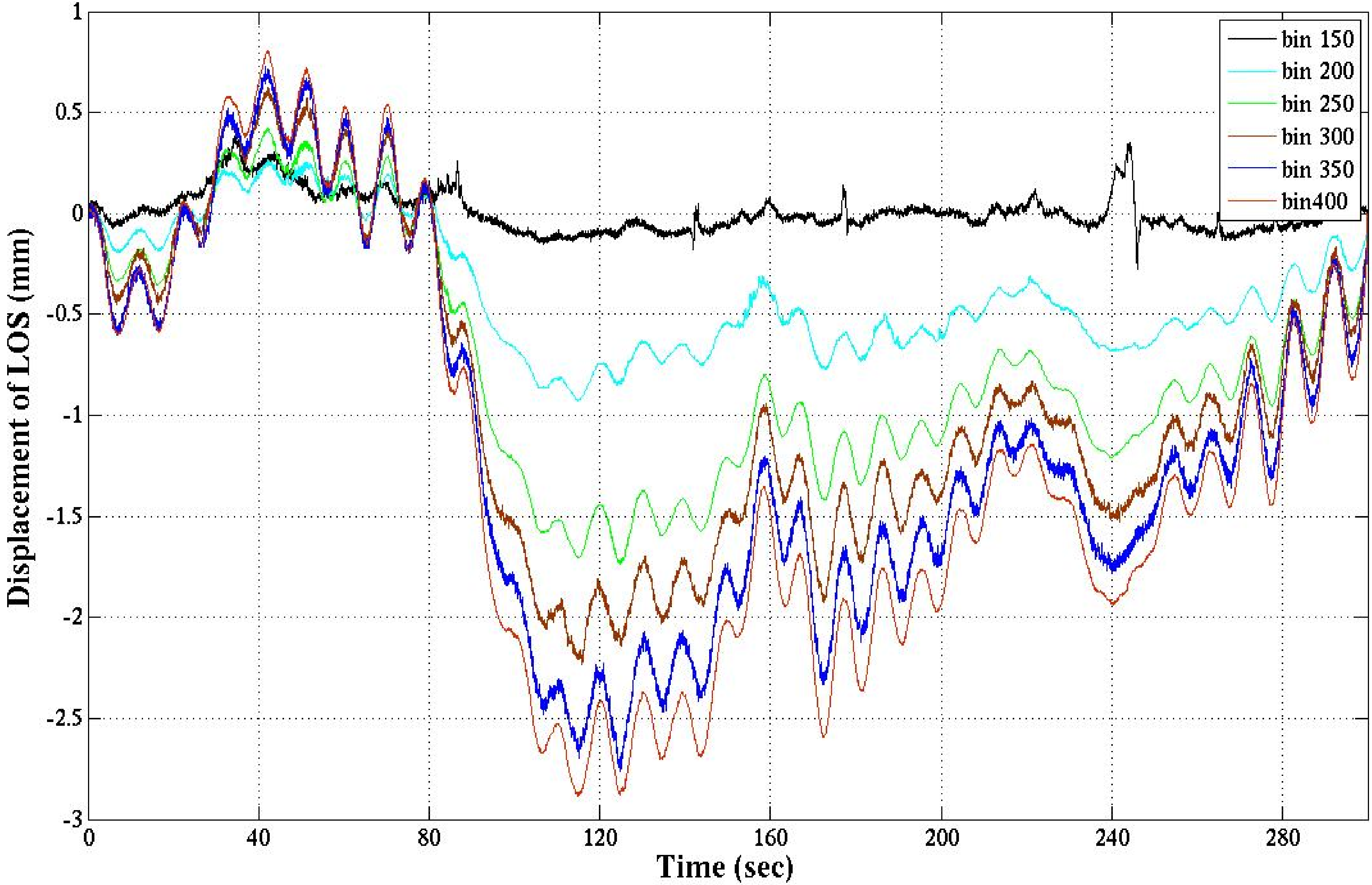
Hong Kong ICC Building

Observation date: 2016-12-10
Distance: 300-750m
Observation duration: 300 秒
Samples: 12500
Antenna angle: 25°

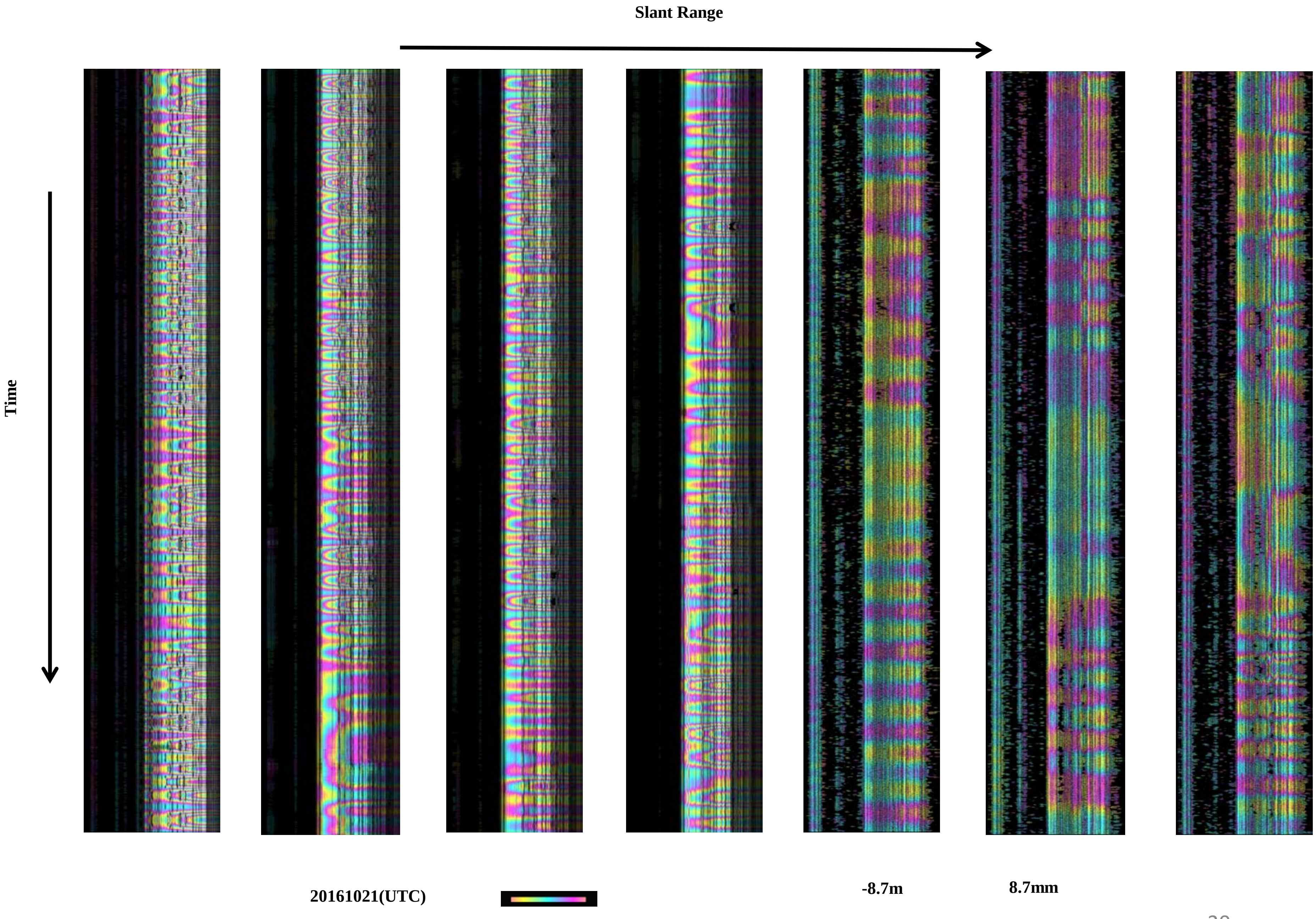


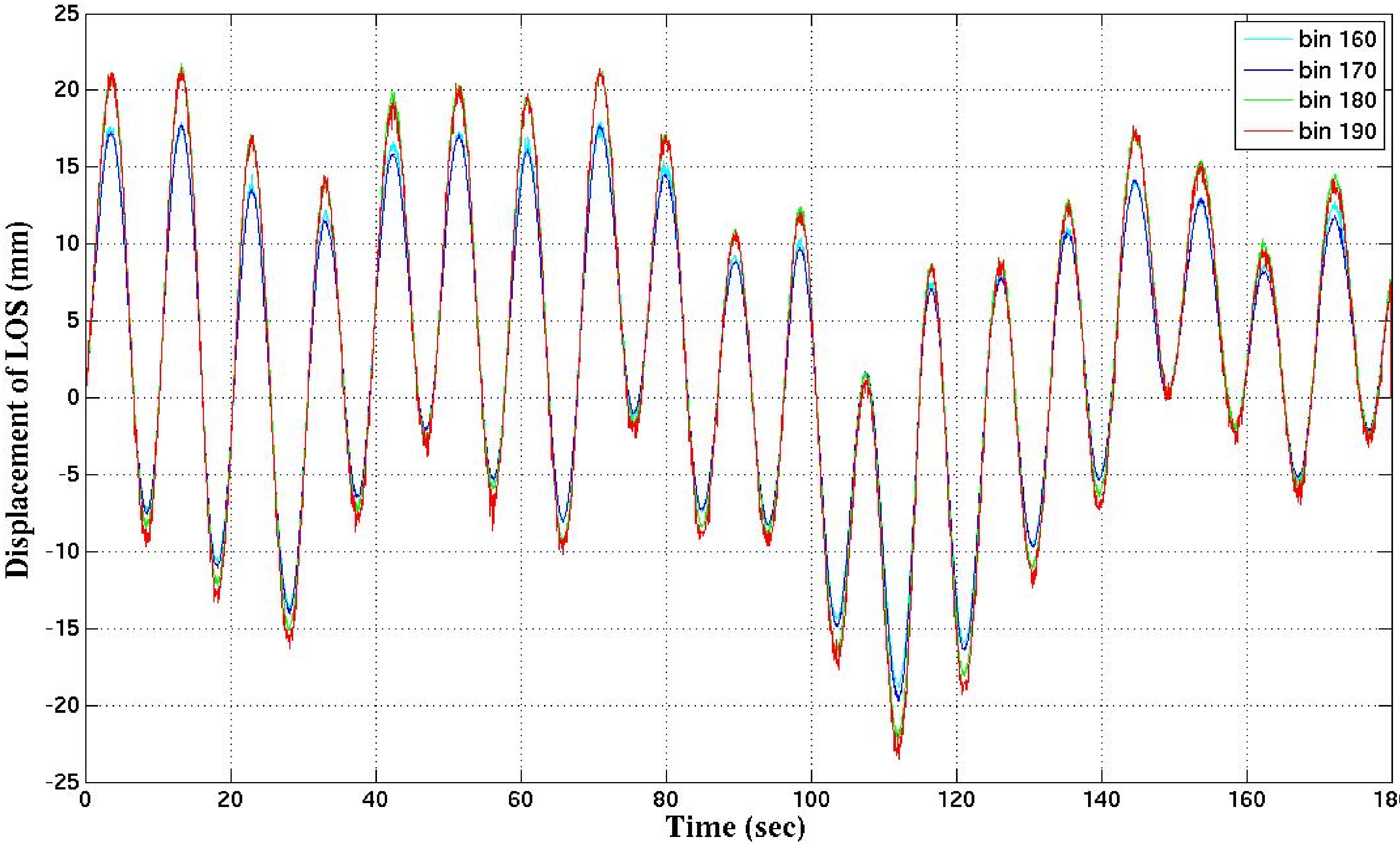


20161210 (UTC)

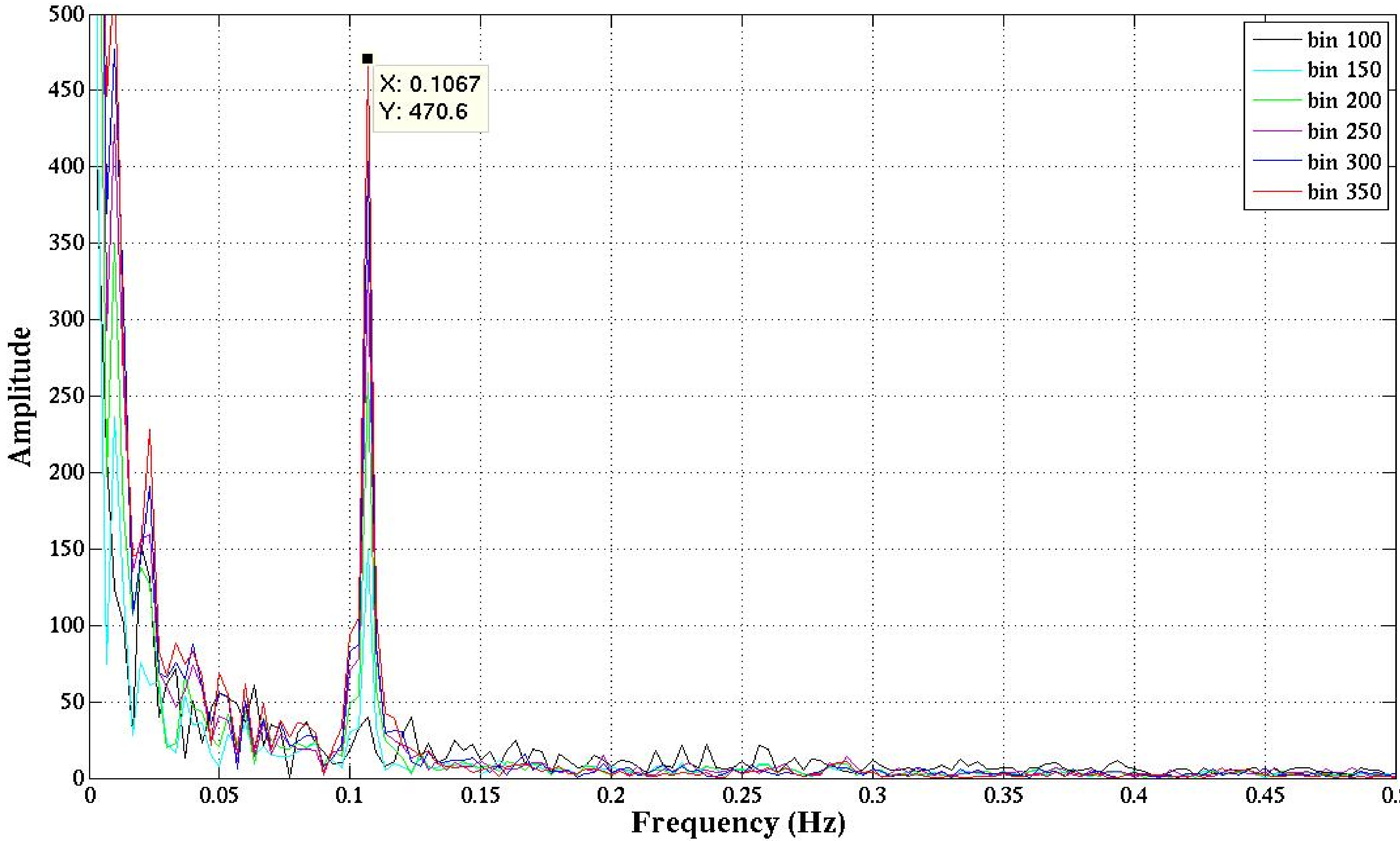


bin 150
bin 200
bin 250
bin 300
bin 350
bin400
Displacement of LOS (mm)
Time (sec)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
40
80
120
160
200
240
280


Slant Range
Time
20161021(UTC)
-8.7m
8.7mm



Displacement of LOS (mm)
Time (sec)
bin 160
bin 170
bin 180
bin 190
25
20
15
10
5
0
-5
-10
-15
-20
-25
0
20
40
60
80
100
120
140
160
180



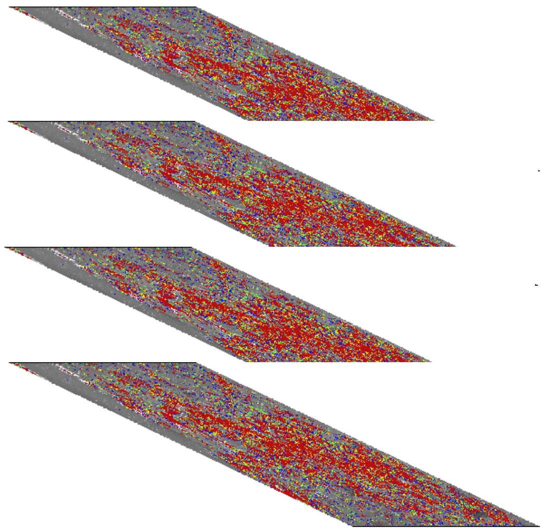
X: 0.1067
Y: 470.6
bin 100
bin 150
bin 200
bin 250
bin 300
bin 350
Amplitude
Frequency (Hz)
0
50
100
150
200
250
300
350
400
450
500
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

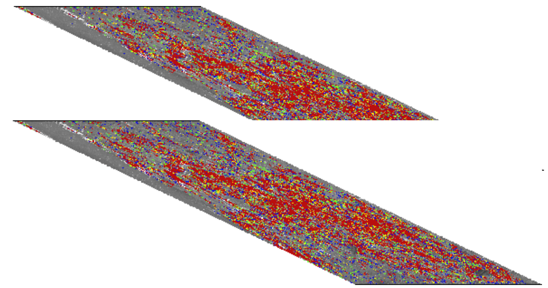

CRH
GPR

TCP InSAR Modeling

Features of TCP Method

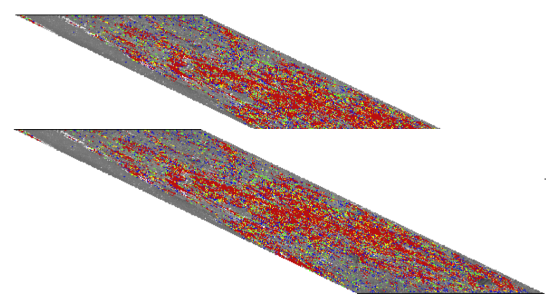
- May include temporarily coherent points
- Easily parameterize various errors and estimate them (e.g., deformation, topographic errors, orbit errors)
- Rigorous least squares solution





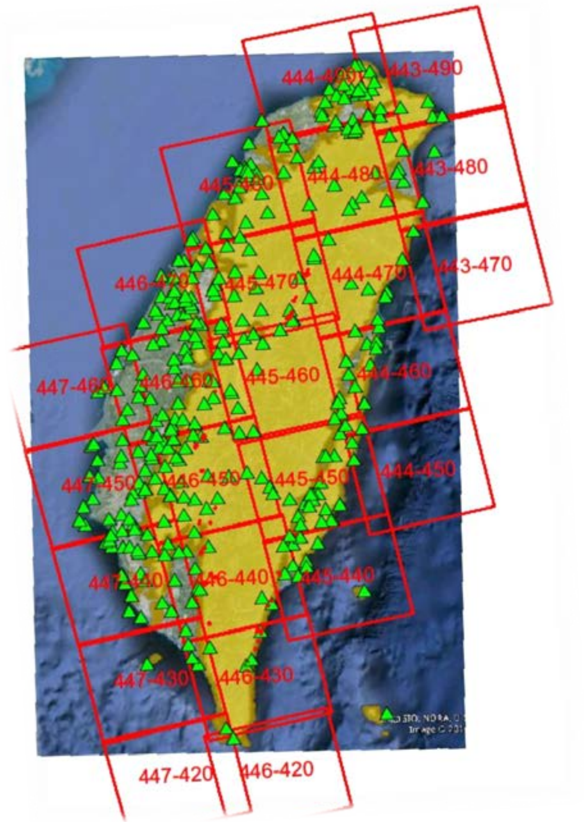
D_1, H_1, O_1, …

D_1, H_1, O_1, …



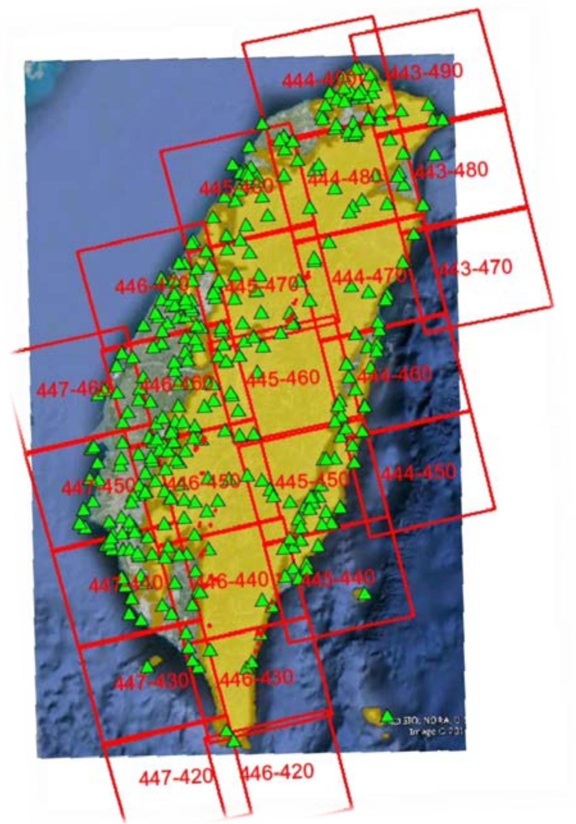
?

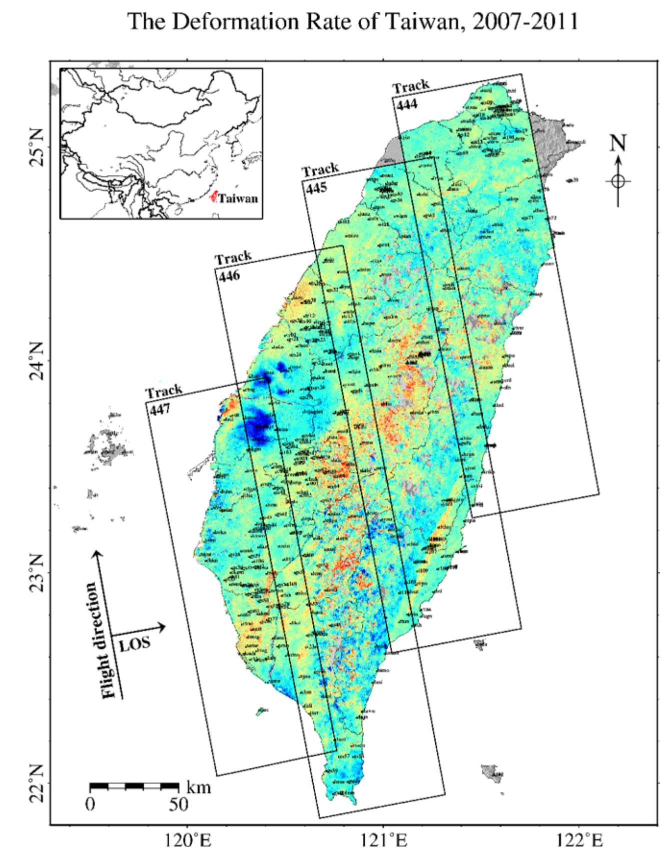
台湾滑坡灾害普查：基于TCP和GNSS的广域监测实例



（1）基于InSAR的全岛范围地质灾害普查

数据：L波段ALOS/PALSAR数据（>350景）
时间：2007-2011
处理：TCPInSAR软体
产品：全岛范围的地表形变速率及形变序列


444-490
443-490
445-480
444-480
443-480
446-470
445-470
444-470
443-470
447-460
446-460
445-460
444-460
447-450
446-450
445-450
444-450
447-440
446-440
445-440
447-430
446-430
447-420
446-420


The Deformation Rate of Taiwan, 2007-2011
Taiwan
Track 444
Track 445
Track 446
Track 447
N
Flight direction
LOS
0
50
km
25°N
24°N
23°N
22°N
120°E
121°E
122°E

Least squares solution in TCP:

$$\hat{X} = (A^T P A)^{-1} A^T P L$$

Covariance of least squares solution:

$$C_{\hat{X}} = \sigma_0^2 (A^T P A)^{-1}$$

THANK YOU

X.L. Ding

The Hong Kong Polytechnic University

xl.ding@polyu.edu.hk