

Project 32278_3:

Towards Near-Real Time InSAR Deformation Estimation

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The Hong Kong Polytechnic University



THREE-AND-FOUR-DIMENSIONAL-TOPOGRAPHIC-MEASUREMENT-AND-VALIDATION ¶

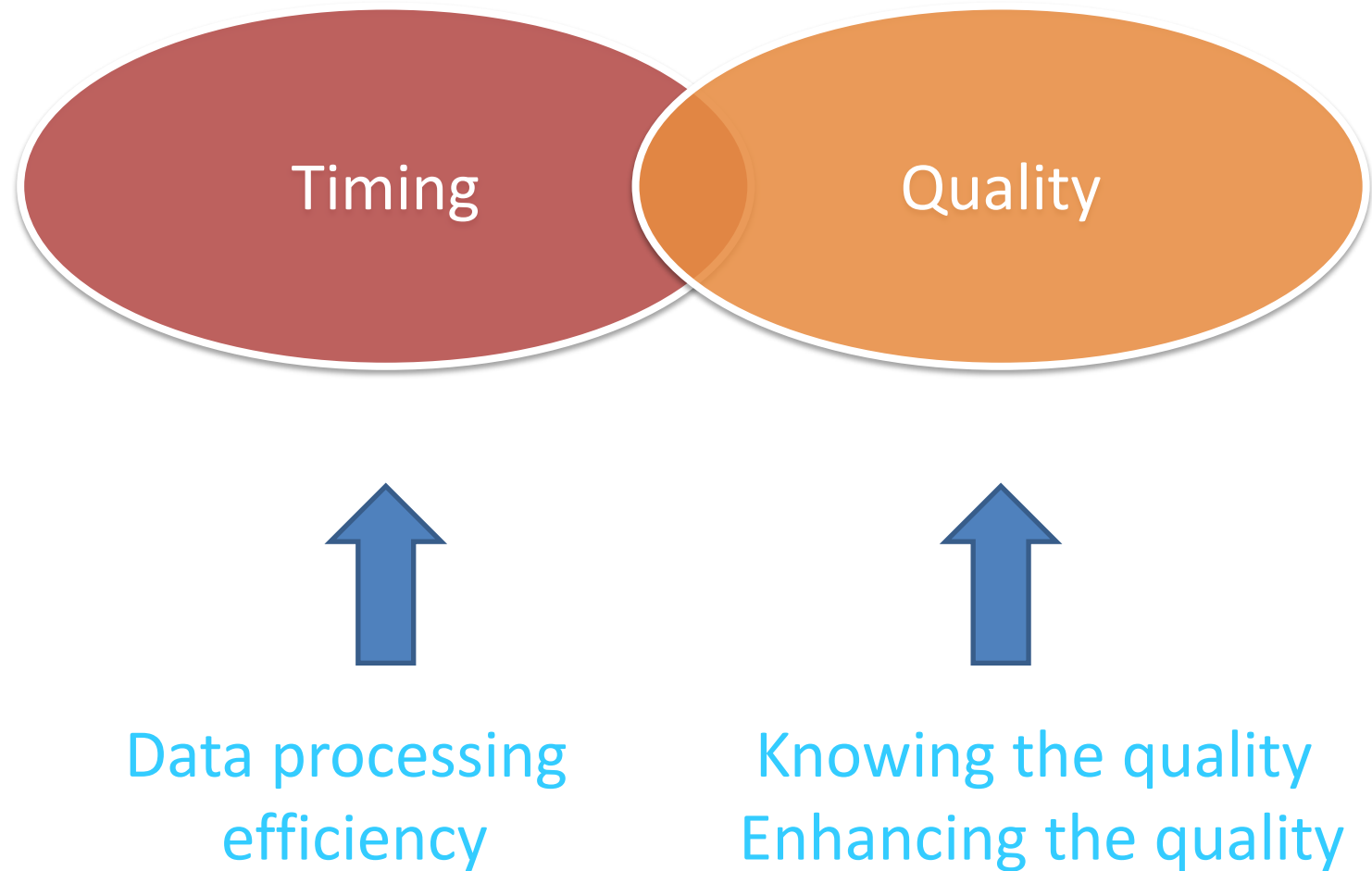
✕

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

List-of-Principal-Investigators-(PIs)¶

Topic·Nr. ✕	<u>PIs</u> ✕	<u>Title</u> ✕	✕ ✕
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 ✕	✕

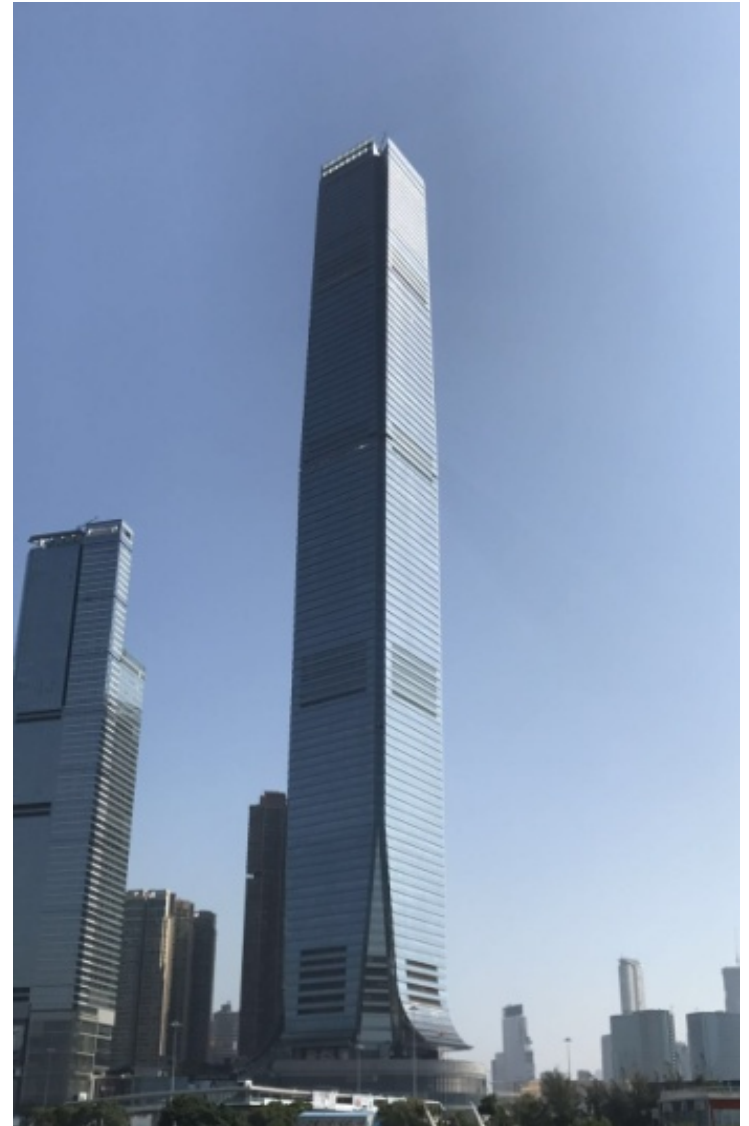
Towards Near-Real Time InSAR Deformation Estimation ?



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)

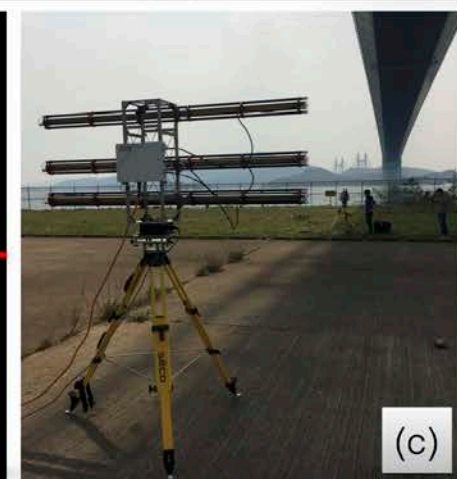
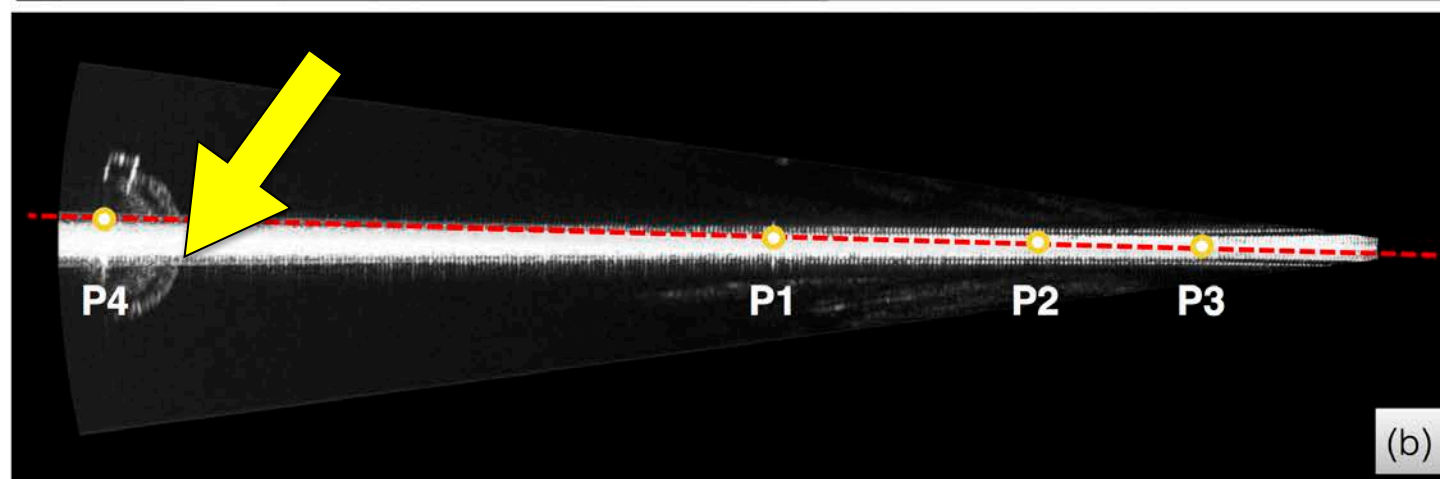
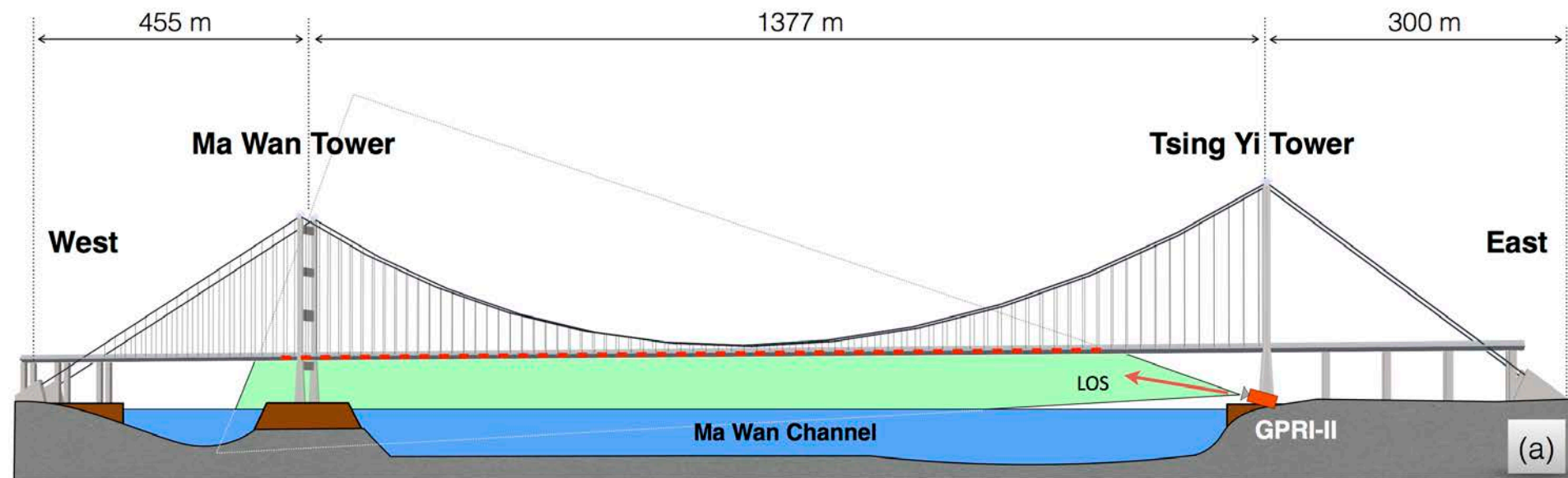
History

Opened 22 May 1997; 19 years ago

Statistics

Daily traffic trains and cars

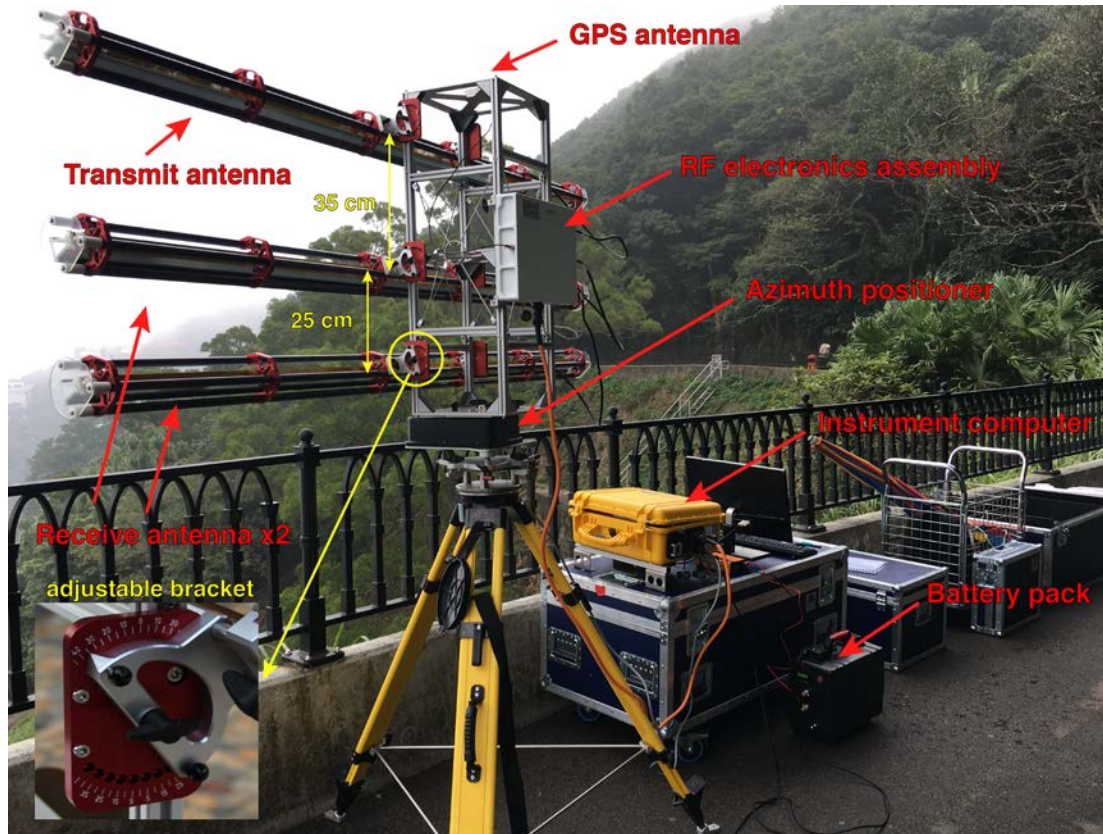
Toll HK\$30 (cars, combined with [Kap Shui Mun Bridge](#))



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
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Resolution of GPRI

❖ Slant Range Resolution

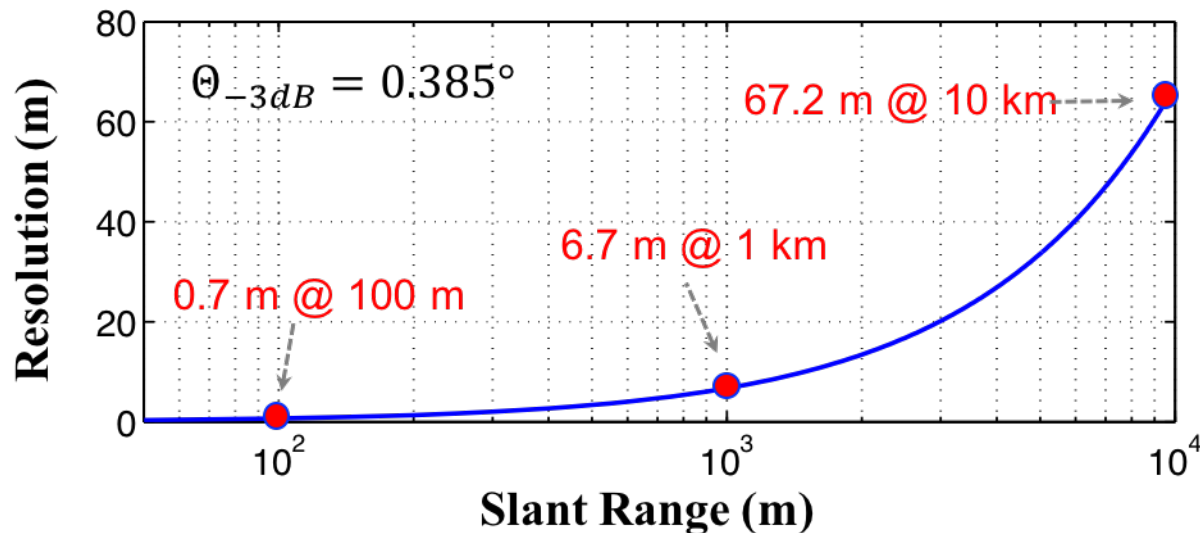
(Werner et. al, 2008)

$$\Delta R_{sr} = \frac{C \cdot \tau_p}{2} = \frac{C}{2 \cdot B_w} \quad (200 \text{ MHz}, \text{0.75 m})$$

❖ Azimuth Resolution

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

Bandwidth
Azimuth beamwidth
Slant range

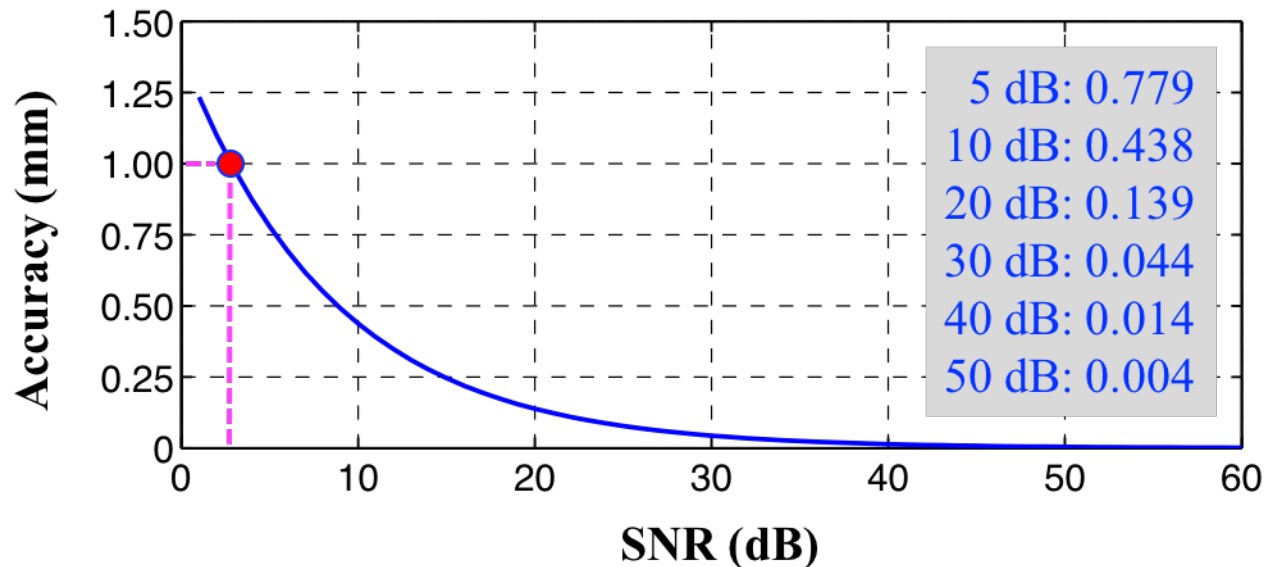


Relationship between azimuth resolution and slant range (azimuth beamwidth = 0.385 deg)

Accuracy of GPRI

❖ Accuracy of Deformation Measurement (ideal condition)

$$\hat{\sigma}_{d_{LOS}} = \frac{\lambda}{4\pi} \cdot \sigma_{\varphi} \approx \frac{\lambda}{4\pi} \cdot \frac{1}{\sqrt{SNR}} \quad (\text{Werner et. al, 2012})$$



❖ Accuracy of Deformation Measurement

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

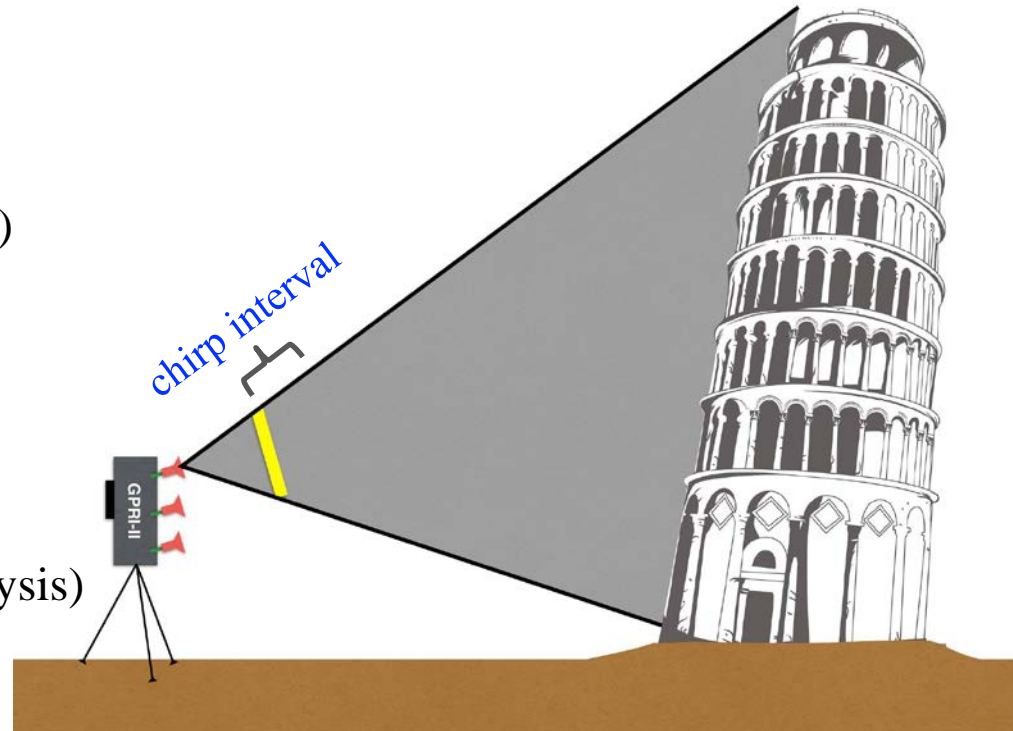
(dependent on the atmospheric phase screen along LOS)

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 μ s per sample)
- ✓ Dynamic monitoring
(rapid deformation & transient analysis)

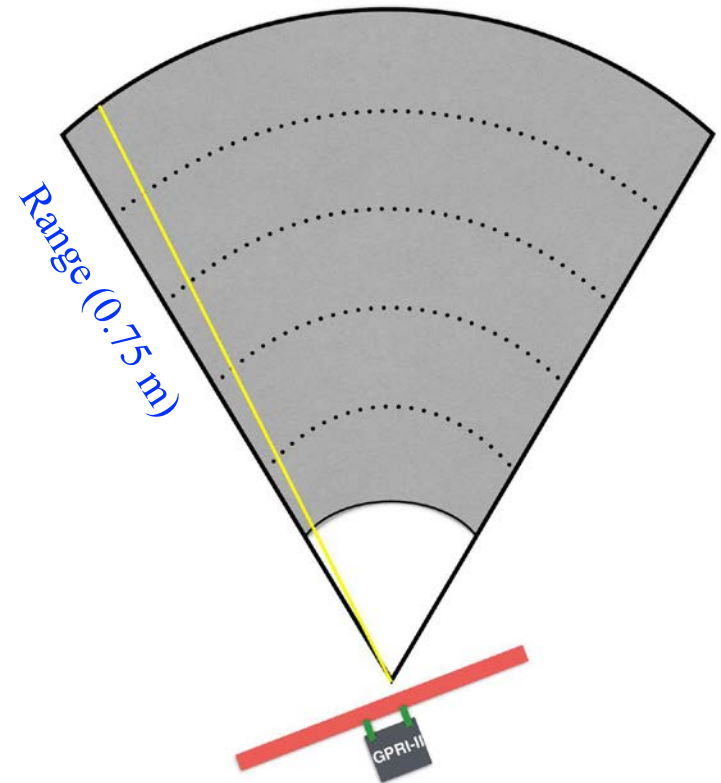


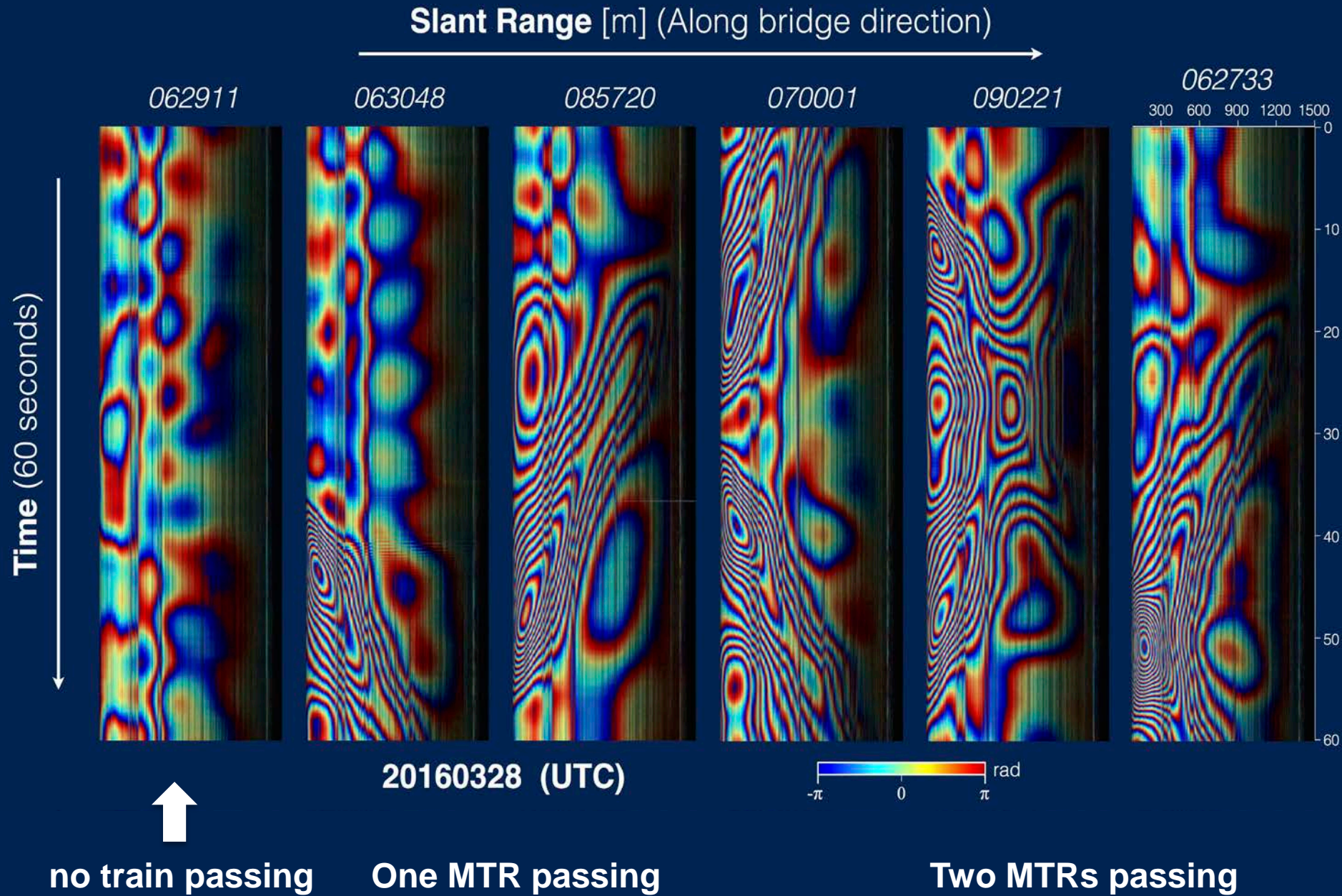
Types of Data Acquisition – RAS

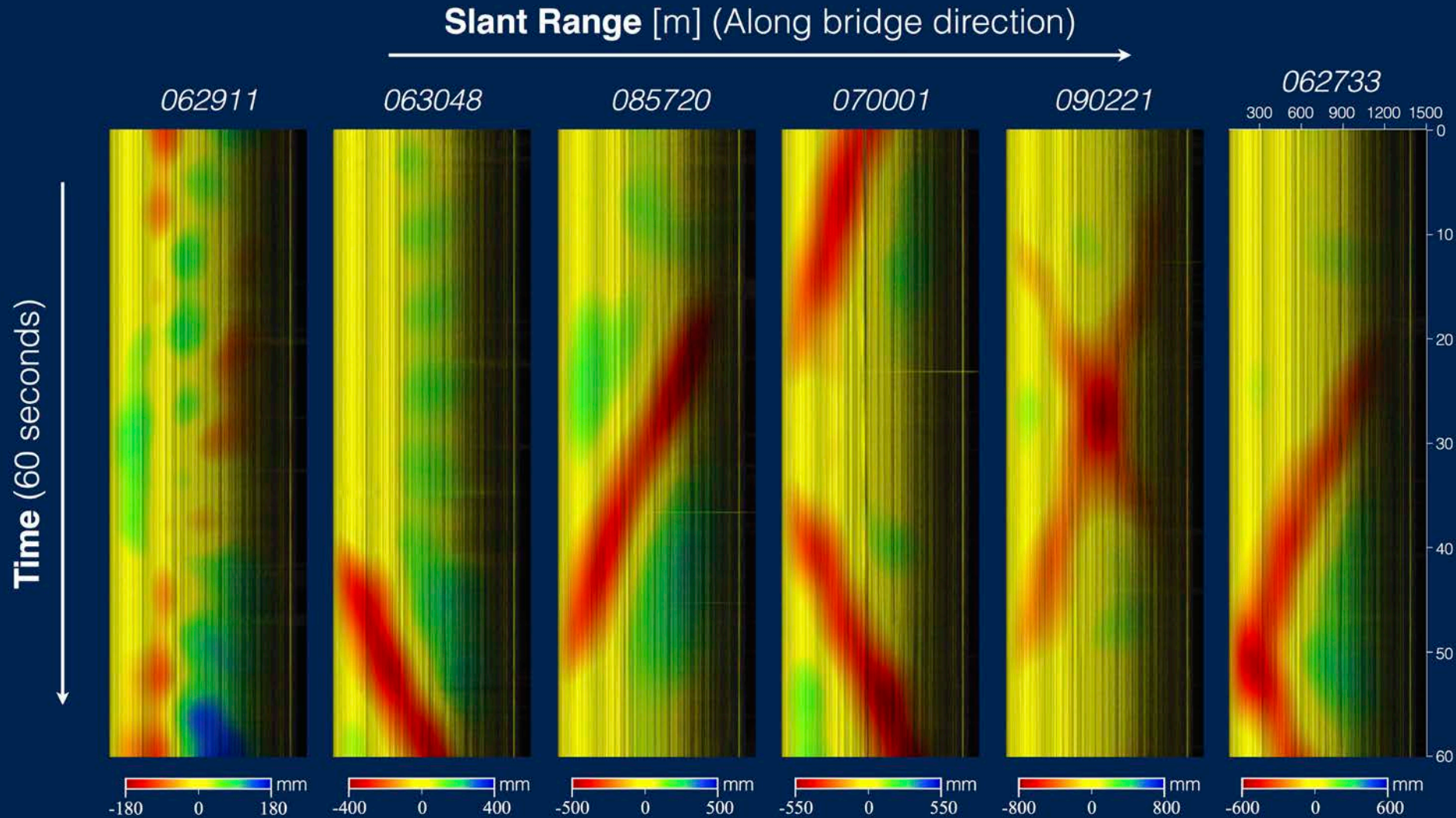
➤ Rotating azimuth scanning – RAS (2D)

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

- ✓ 2D map (range & azimuth)
- ✓ 360° with steps of approximately 0.1°
- ✓ Static monitoring
(large area & long-term deformation)

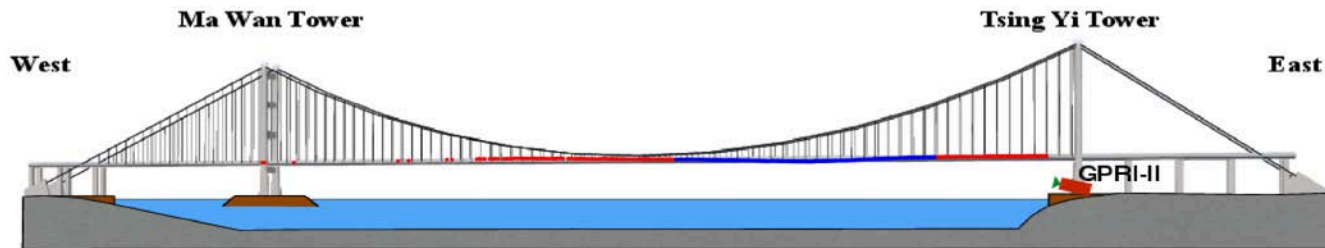




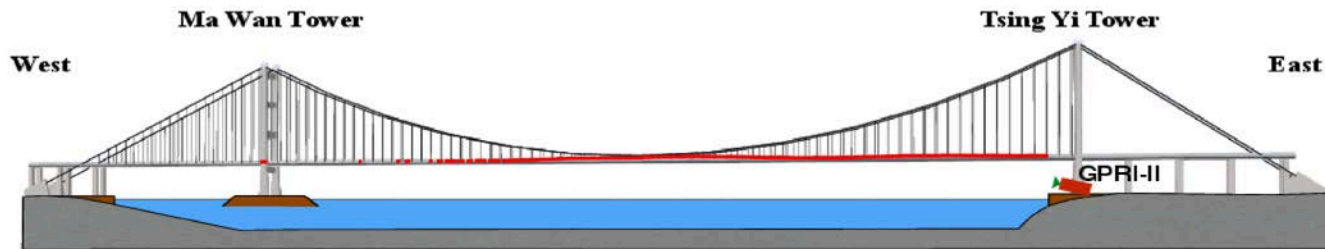


Vertical Displacement maps

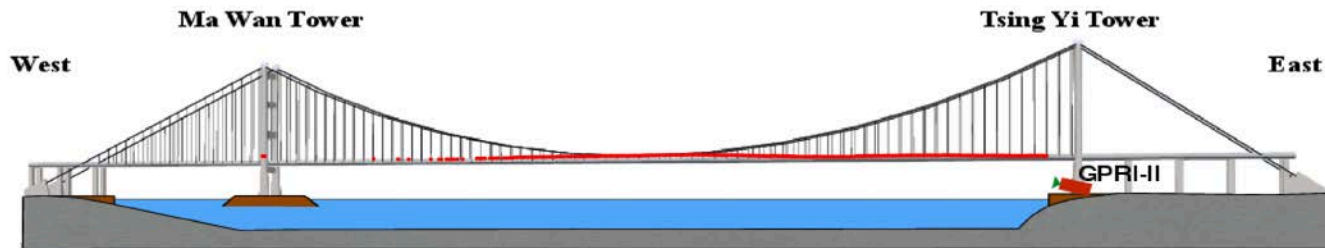
● Red (upward) ● Blue (downward)



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

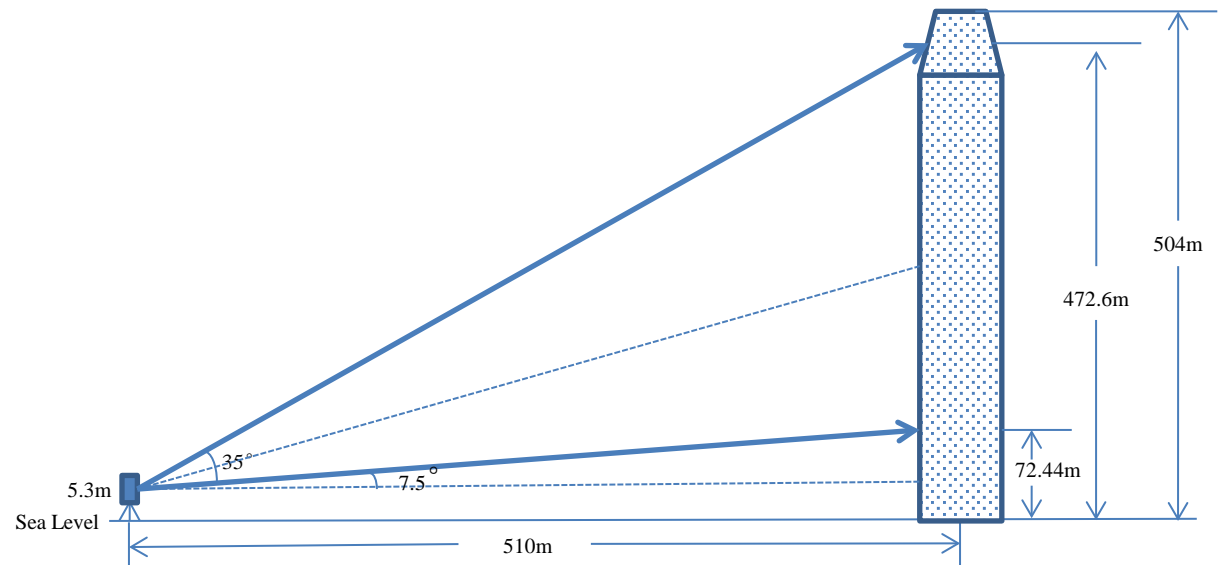
Observation date: 2016-12-10

Distance: 300-750m

Observation duration: 300 秒

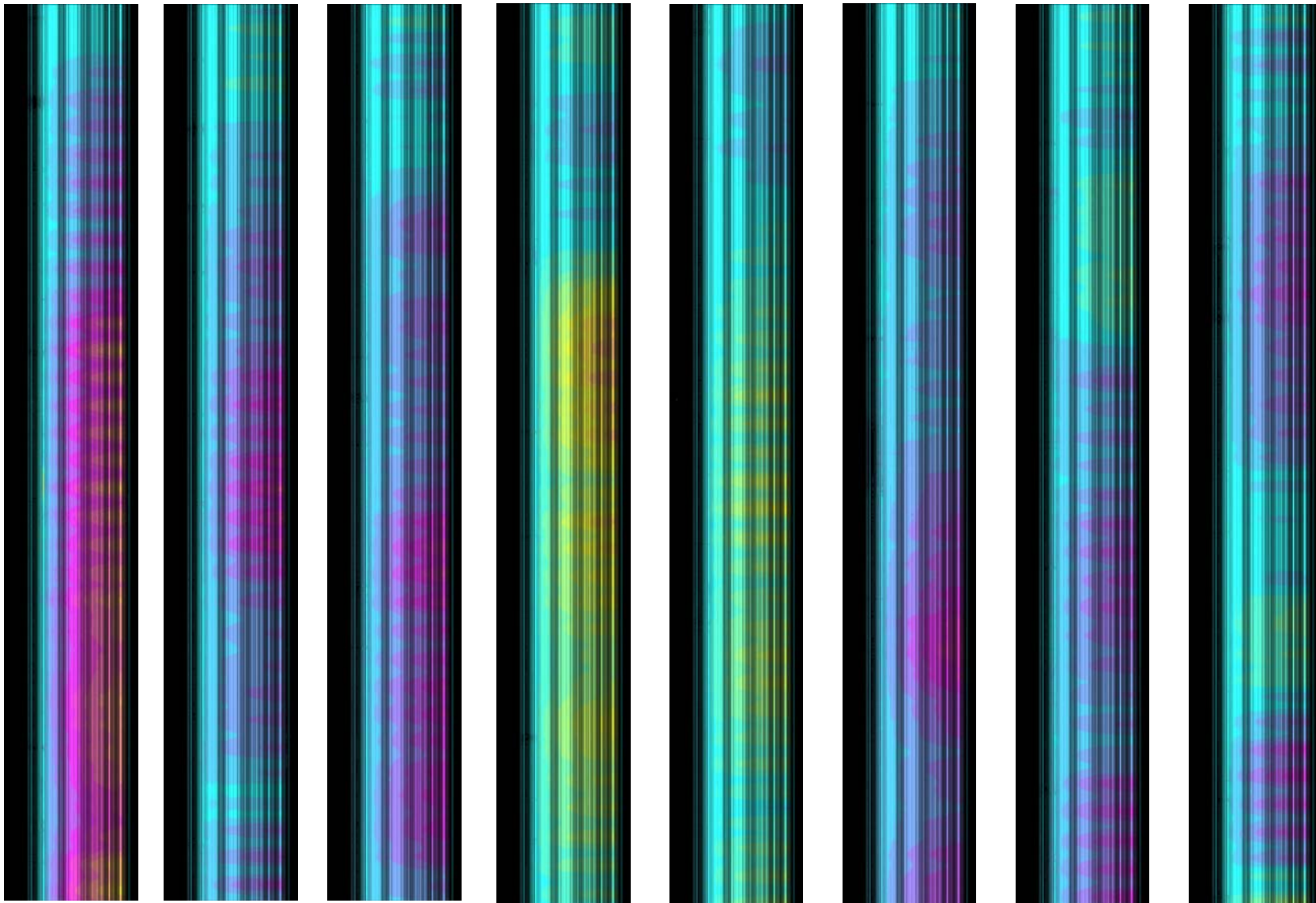
Samples: 12500

Antenna angle: 25°



Slant Range

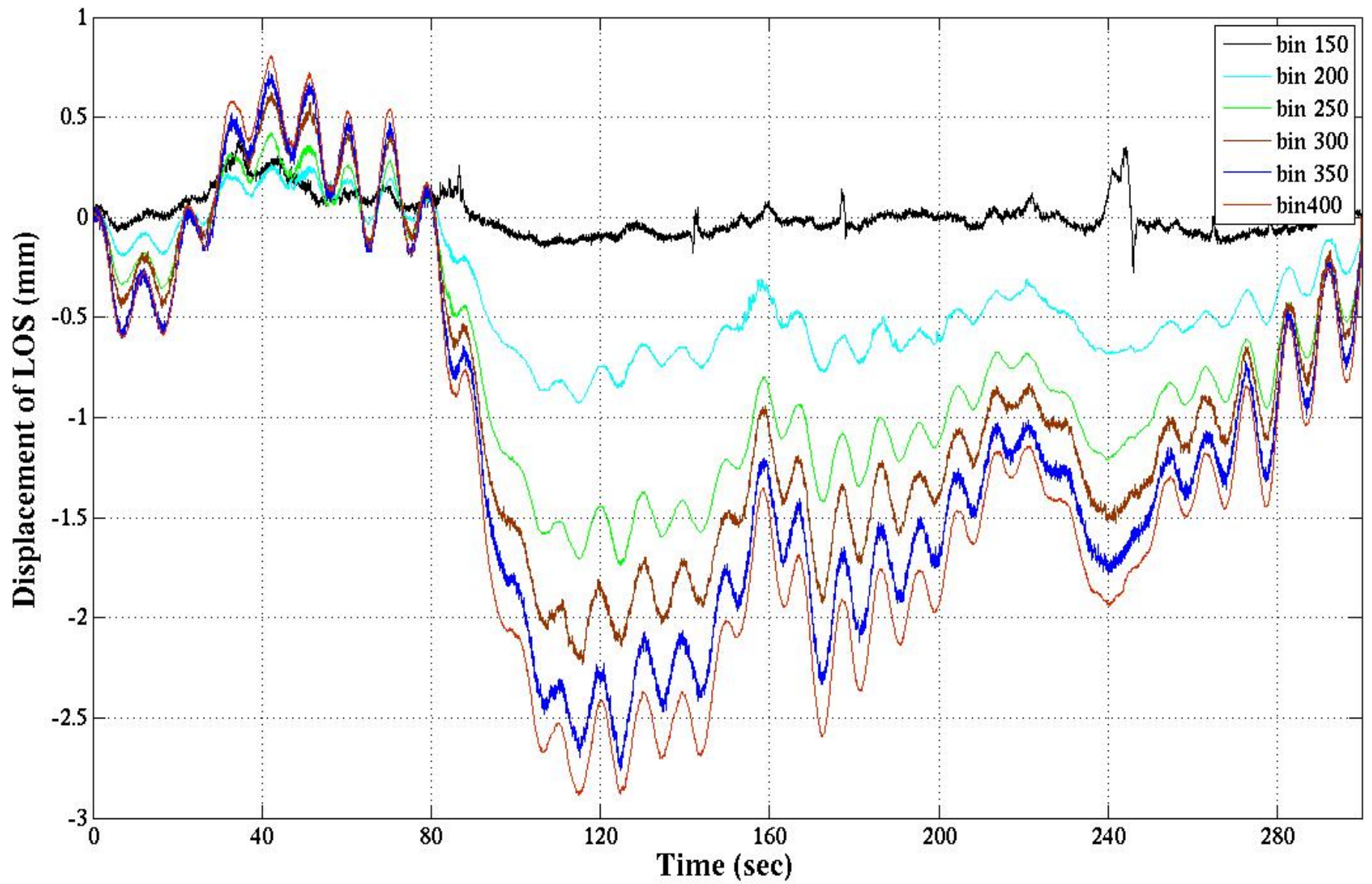
Time



20161210 (UTC)

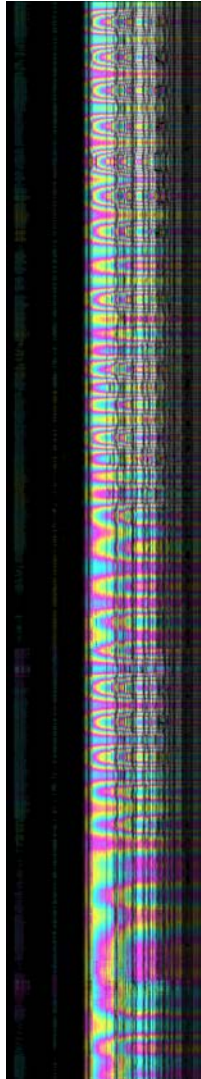
-8.7mm

8.7mm

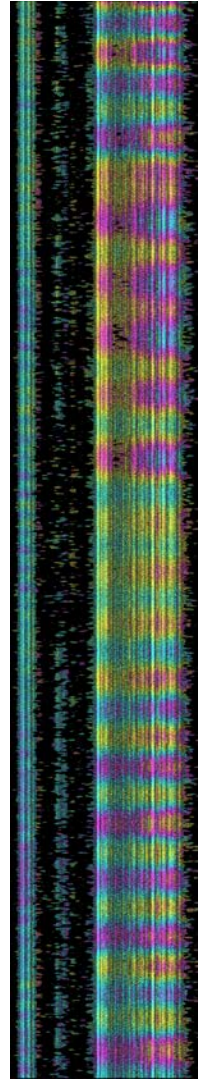
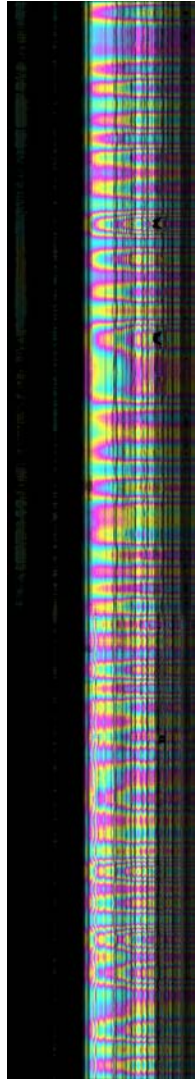
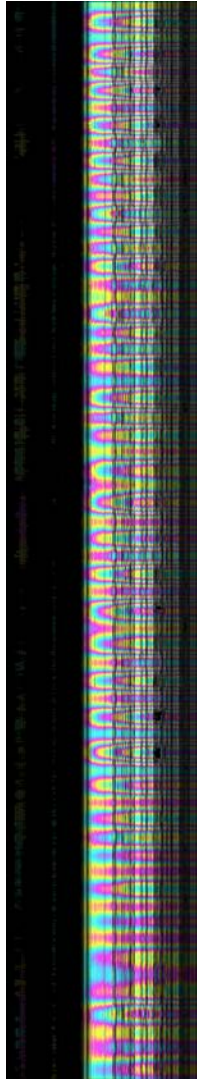


Time

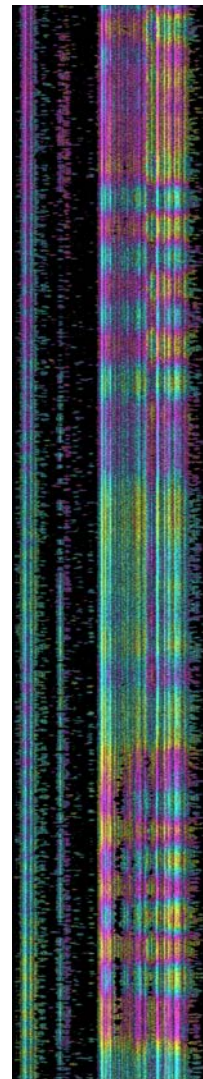
Slant Range



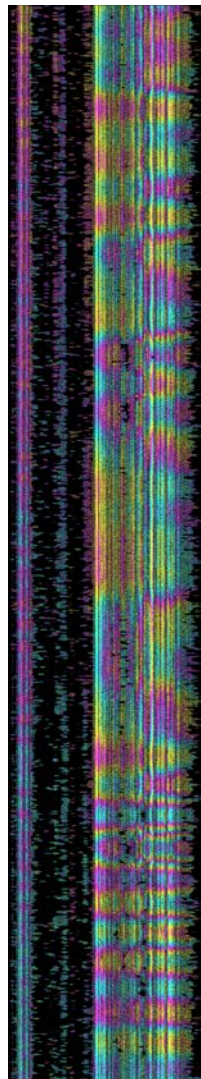
20161021(UTC)

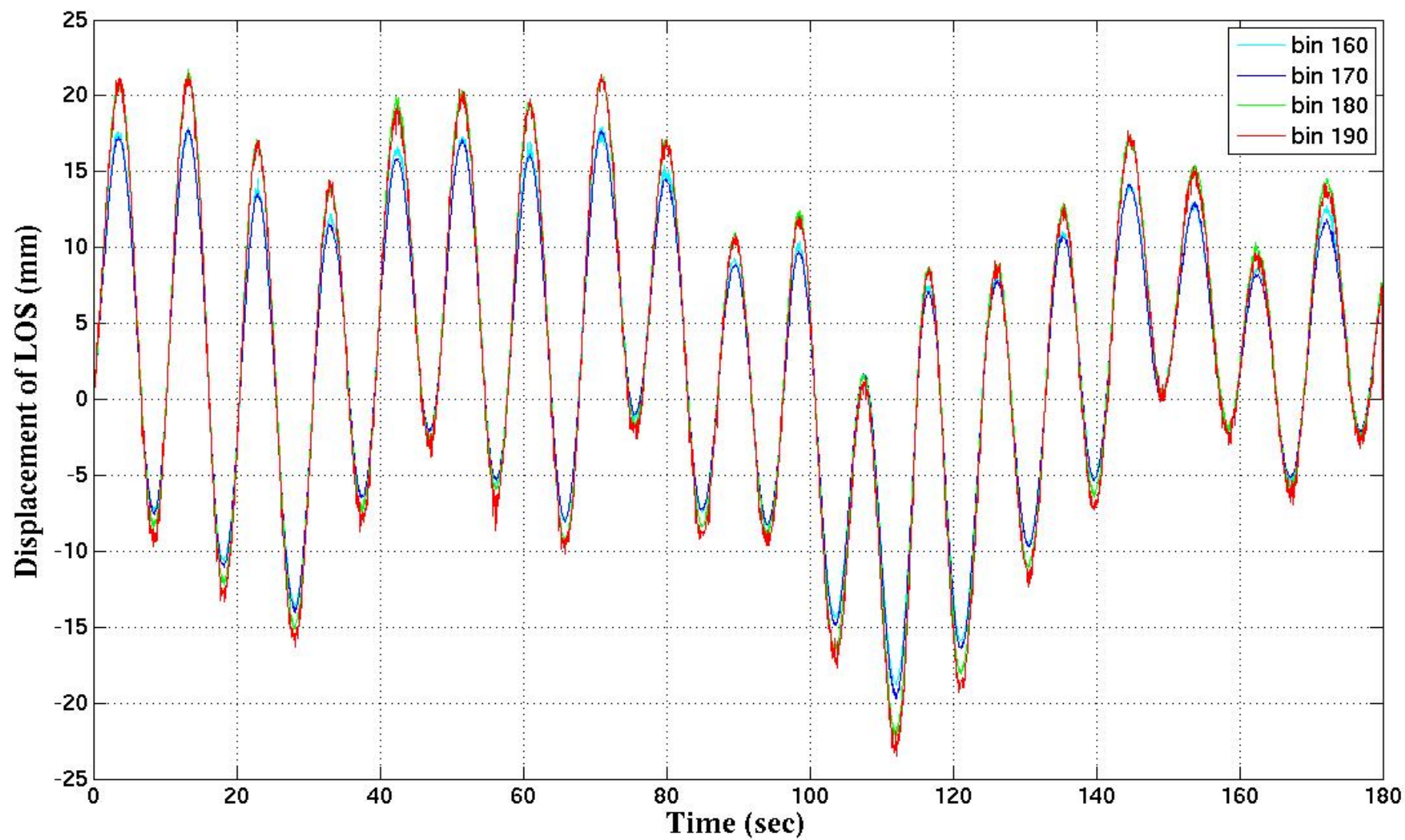


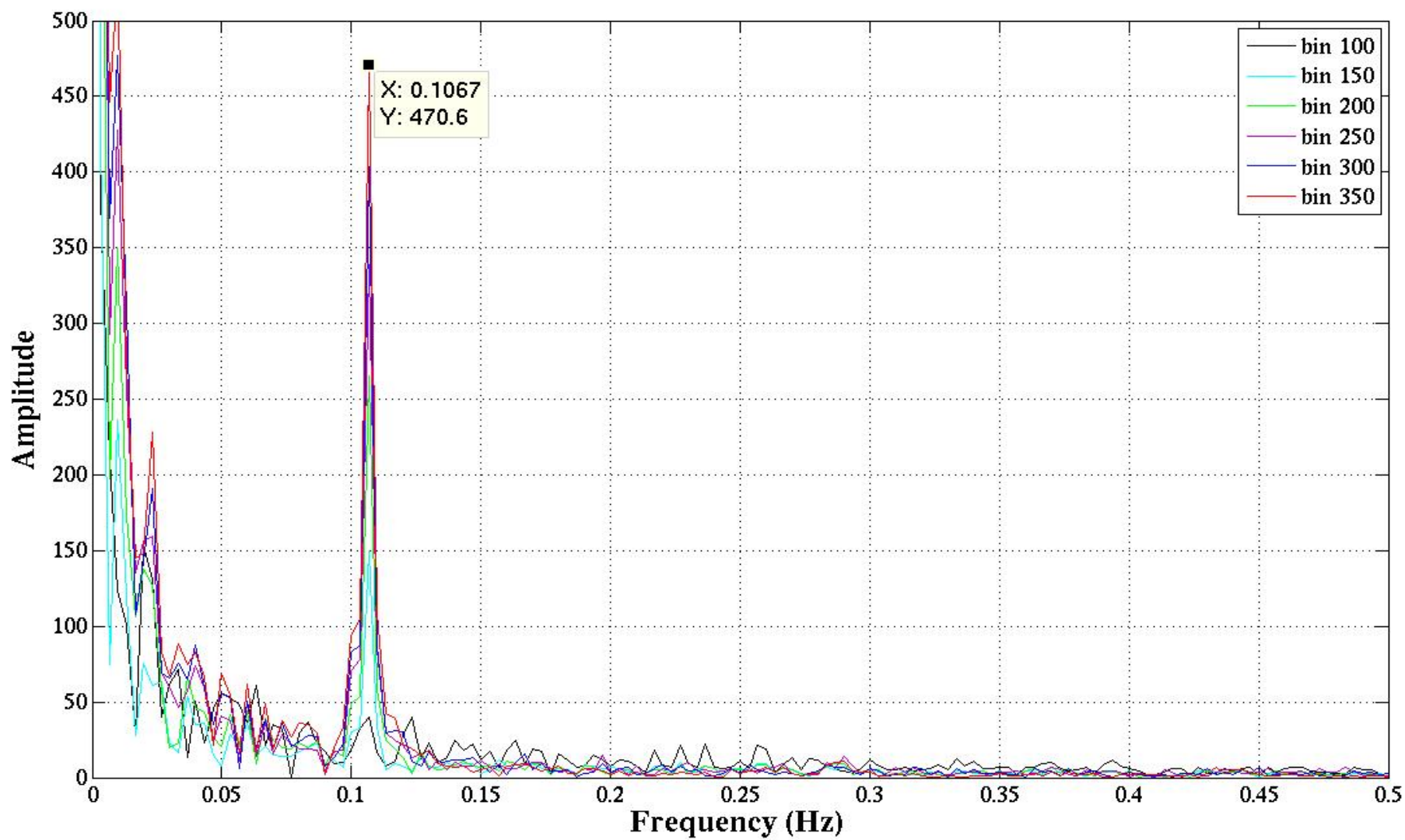
-8.7m



8.7mm





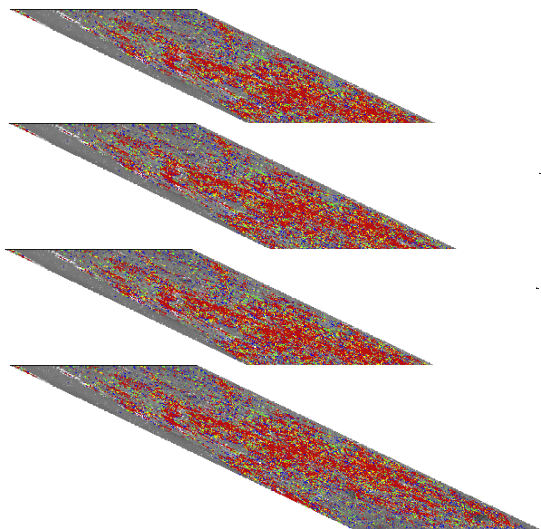




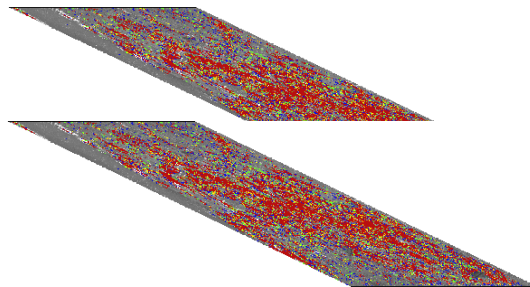
TCP InSAR Modeling

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



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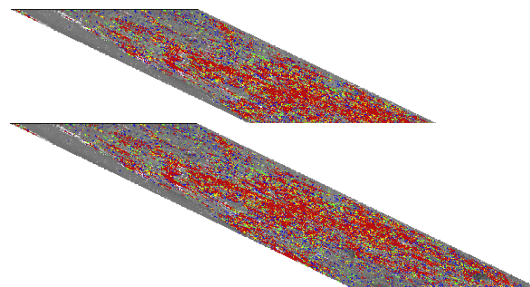


D_1, H_1, O_1, \dots

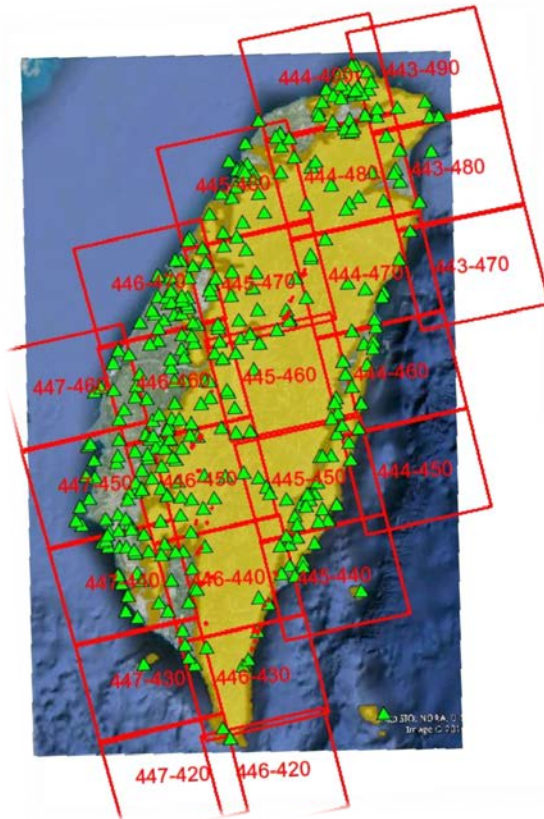
D_1, H_1, O_1, \dots

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台湾滑坡灾害普查：基于TCP和GNSS的广域监测实例



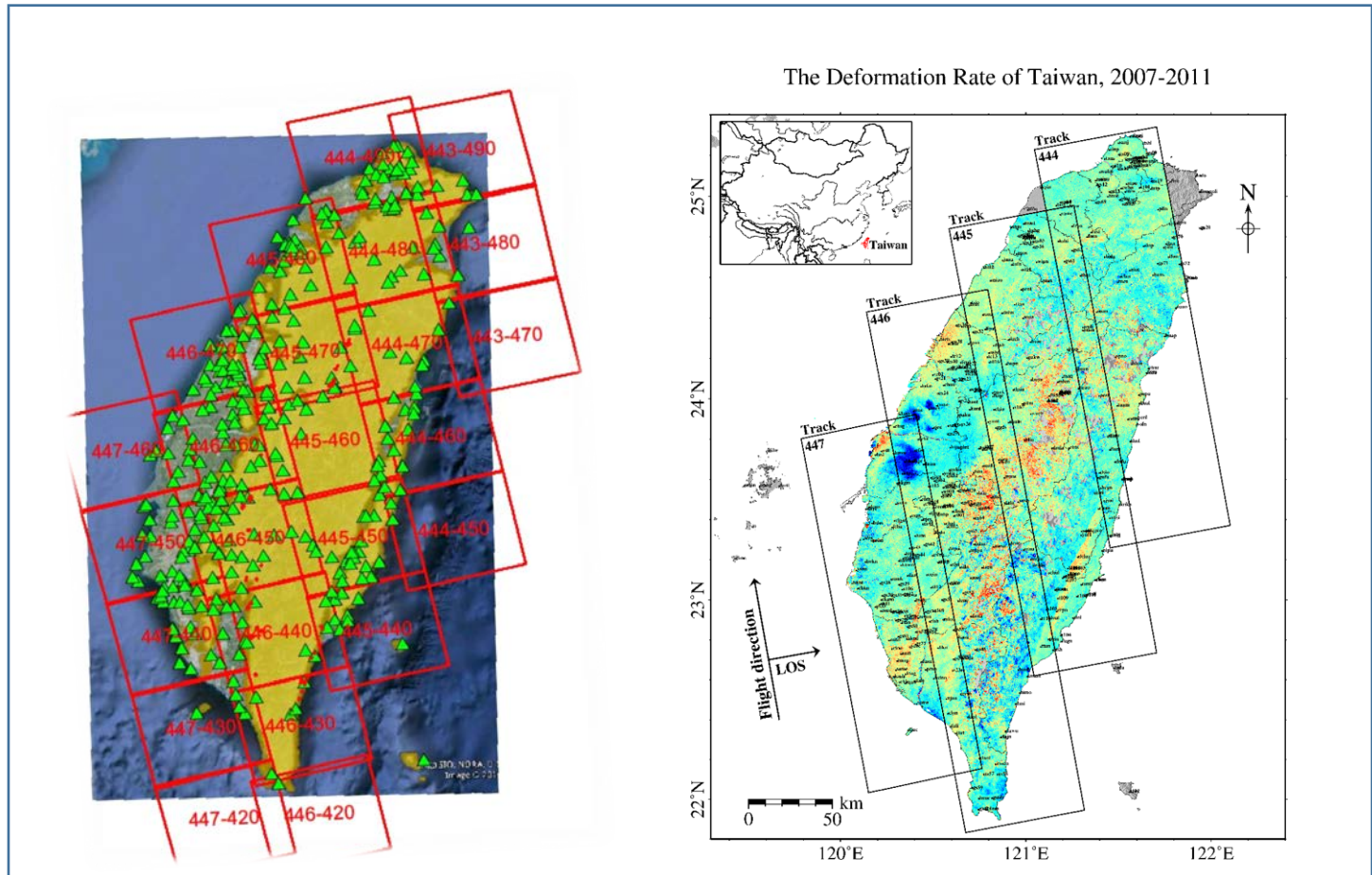
(1) 基于InSAR的全岛范围地质灾害普查

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



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

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