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and Multi-Risk Modeling for Disaster Management
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Estimation of building heights from high-resolution TerraSAR-X imagery

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- Background and objectives
- Study area and image data
- Height estimation
  - For low-rise buildings
  - For high-rise buildings
- Conclusions

Background and objectives

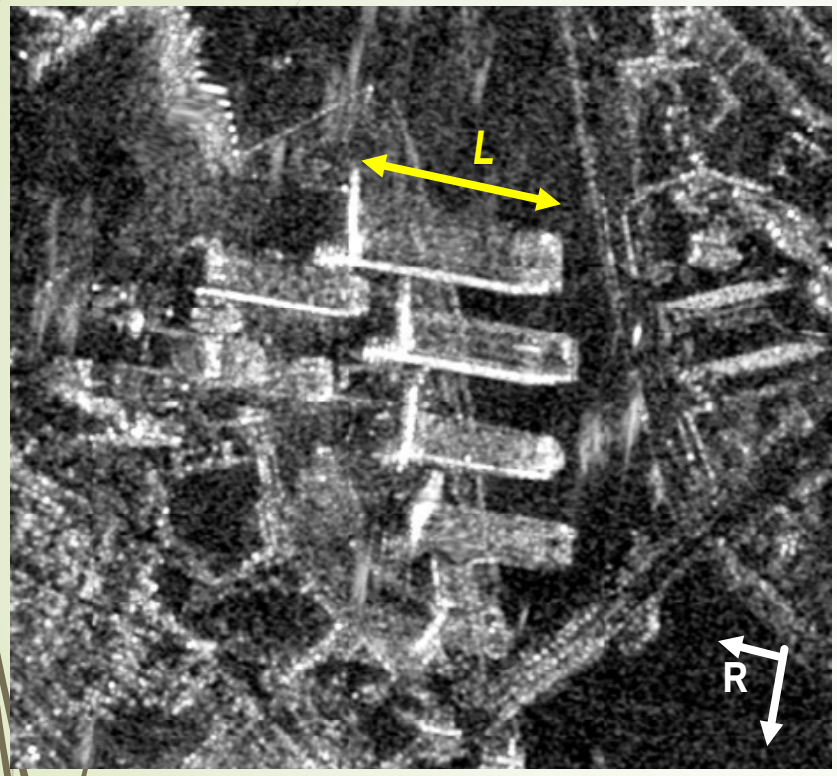
- Modeling and monitoring of urban areas
  > urban planning, environmental assessment and evaluating risk from natural disasters
- Collecting features of an individual structure
  > especially the height
- High-resolution SAR images are now available

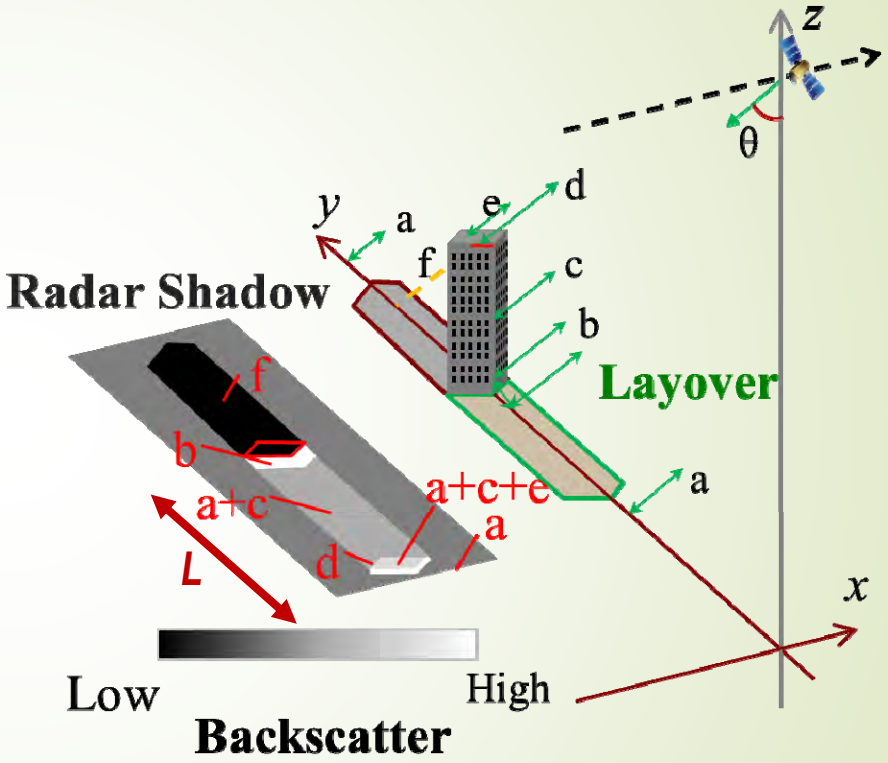
An method for estimating building heights from high-resolution SAR images

Related studies

- **Recent researches for height detection**
  - Measuring shadows from high-resolution optical images
  - Radiometric analysis
    - Local material information
  - Interferometric SAR (InSAR) analysis
  - Geometrical characteristic

Geometrical characteristic

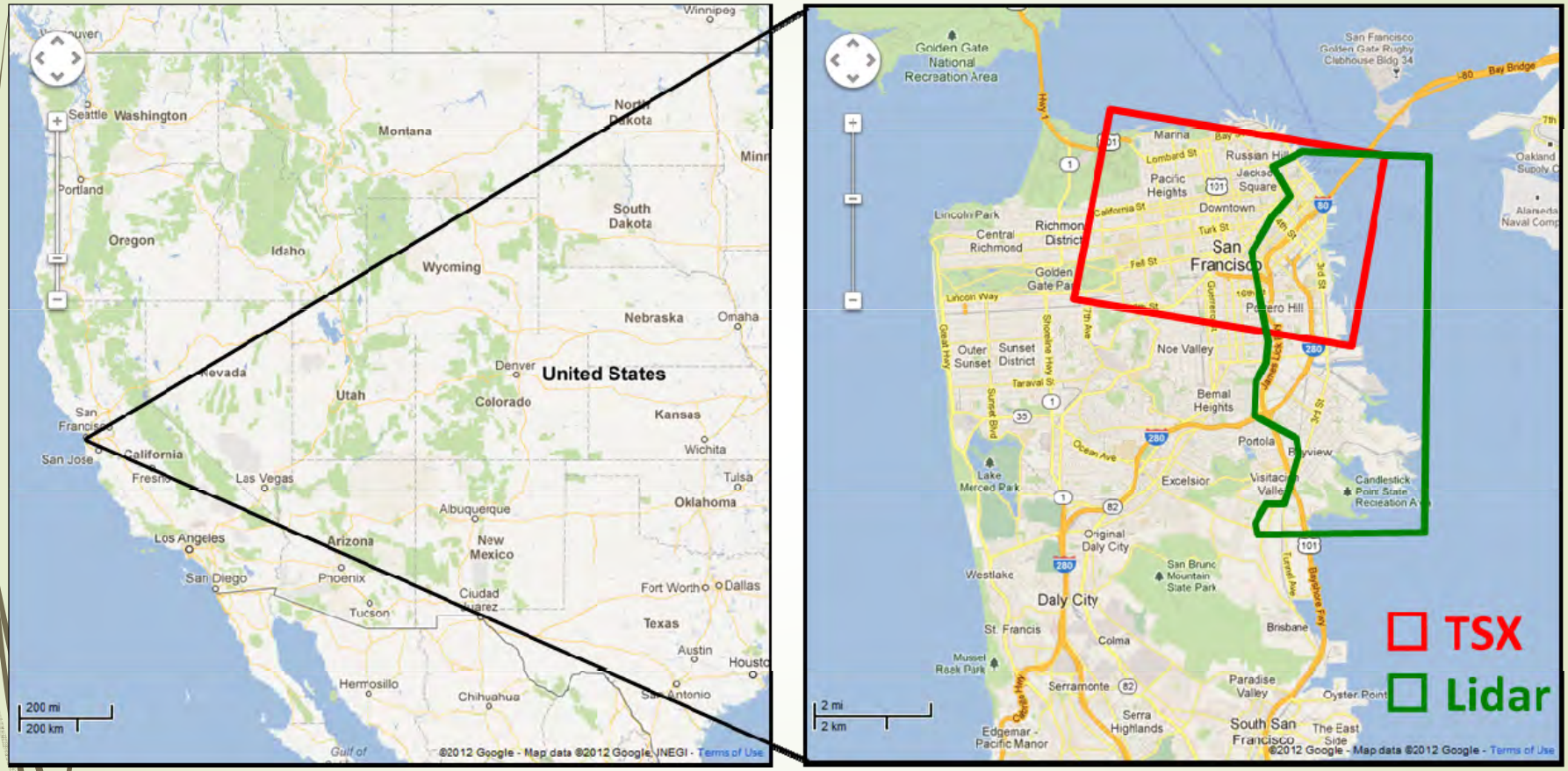




$$L = h / \tan\theta$$

- A building in a SAR image shows a layover from the actual position to the direction of the sensor.

Study area



- Three temporal TerraSAR-X data
- Lidar data (DSM and DEM)

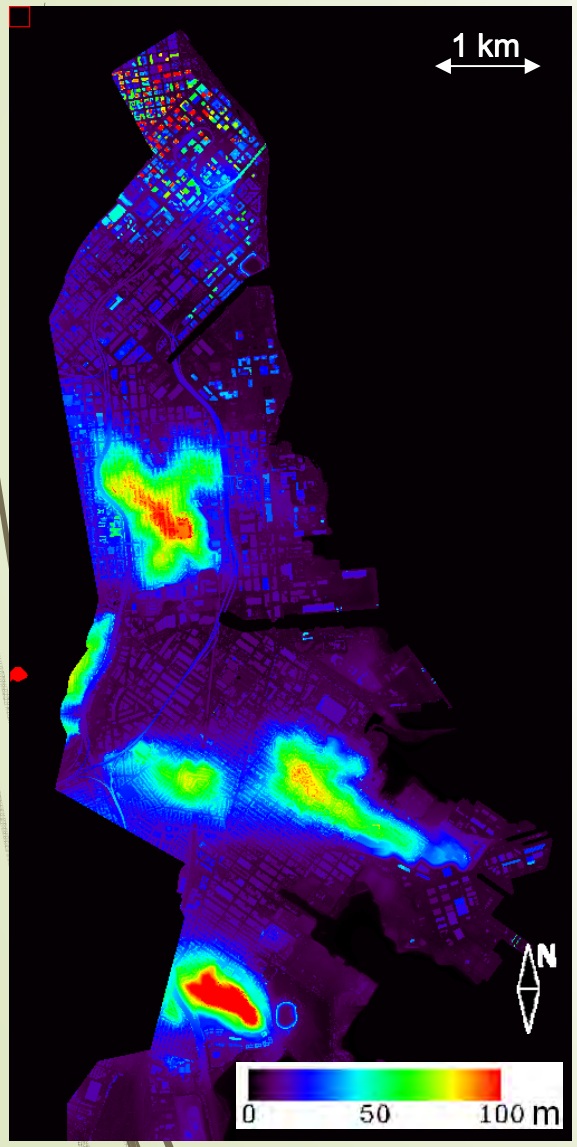
TerraSAR-X data

R: 2011/10/13
G: 2007/12/27
B: 2007/12/05

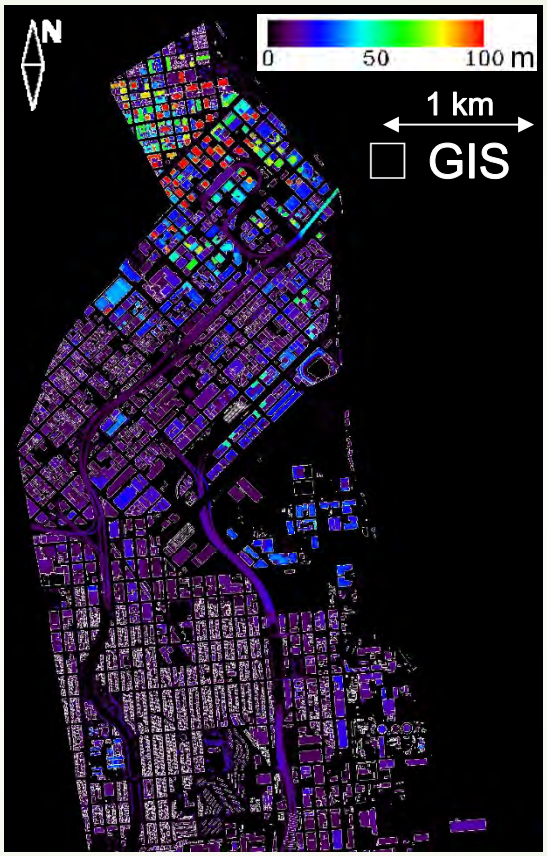
Polarization	HH
Mode	HighSpot
Resolution (RxA)	0.9 m x 1.1 m
Number of looks	2 x 2

Lidar data and pre-processing

DSM



Building height (reference)



TSX intensity image

- Lidar was taken in June 2010, with 6 cm vertical resolution and 2.0 m spatial resolution.
- SAR intensity images were geocoded according to the Lidar DEM and resampled as 0.5 m/pixel.

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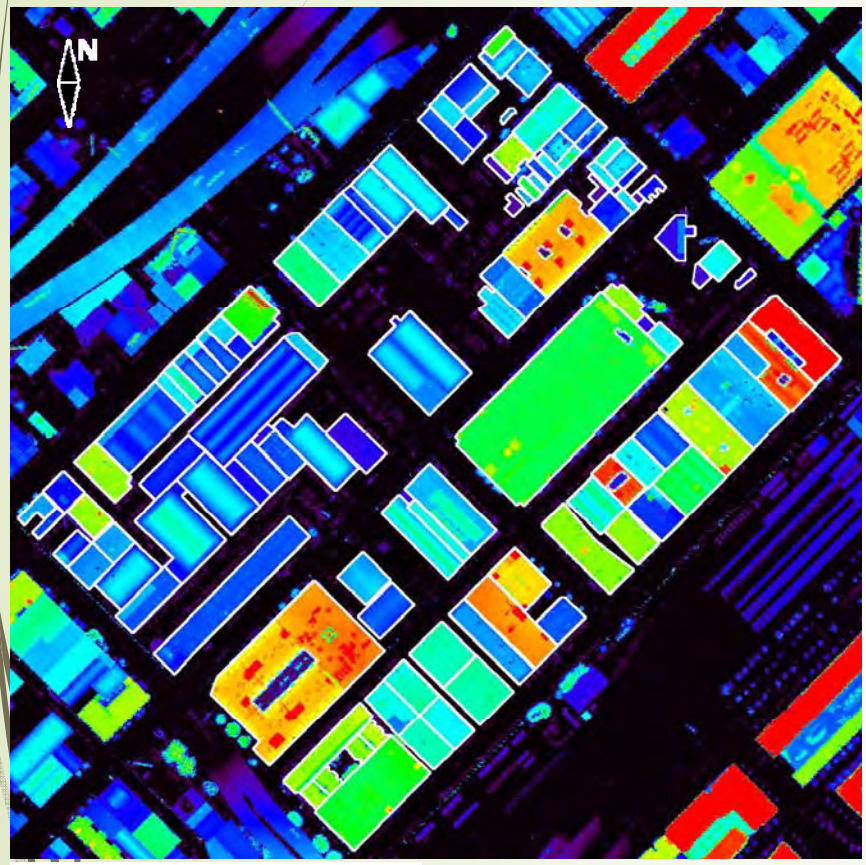
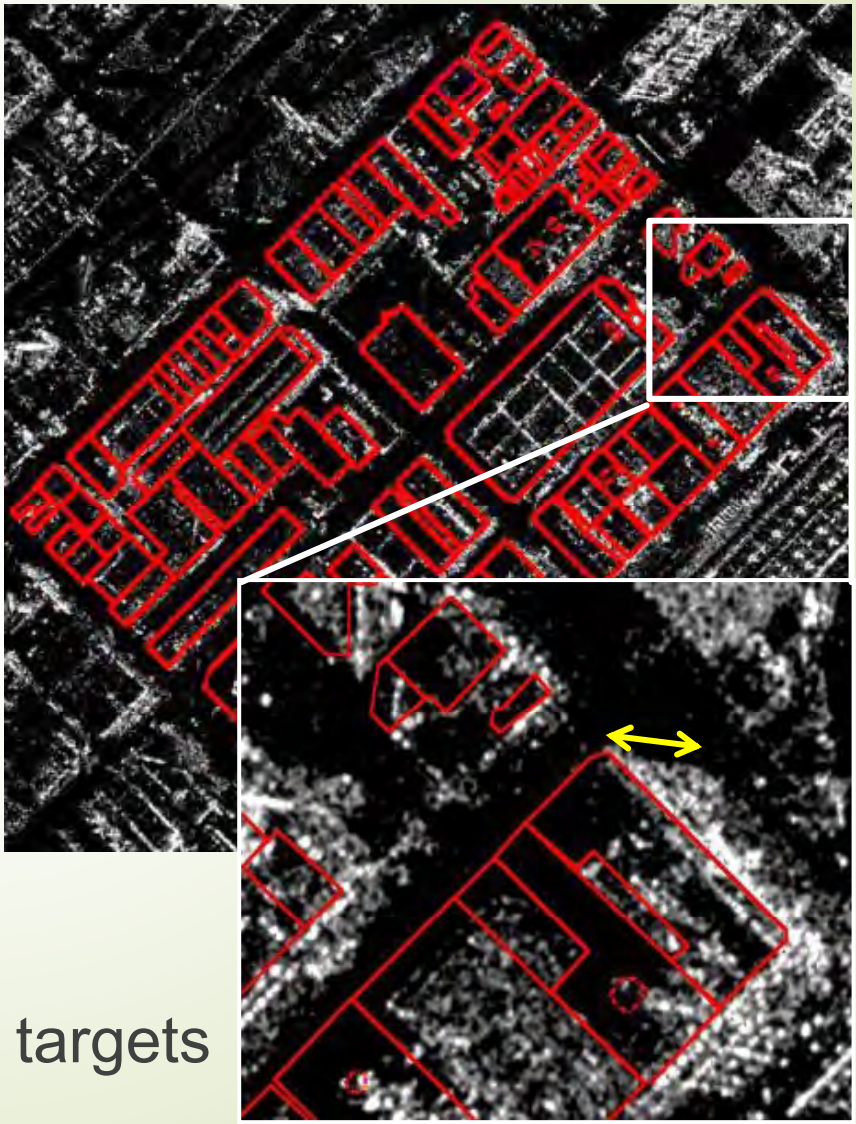
Target area I (low-rise buildings)

Building height (reference)

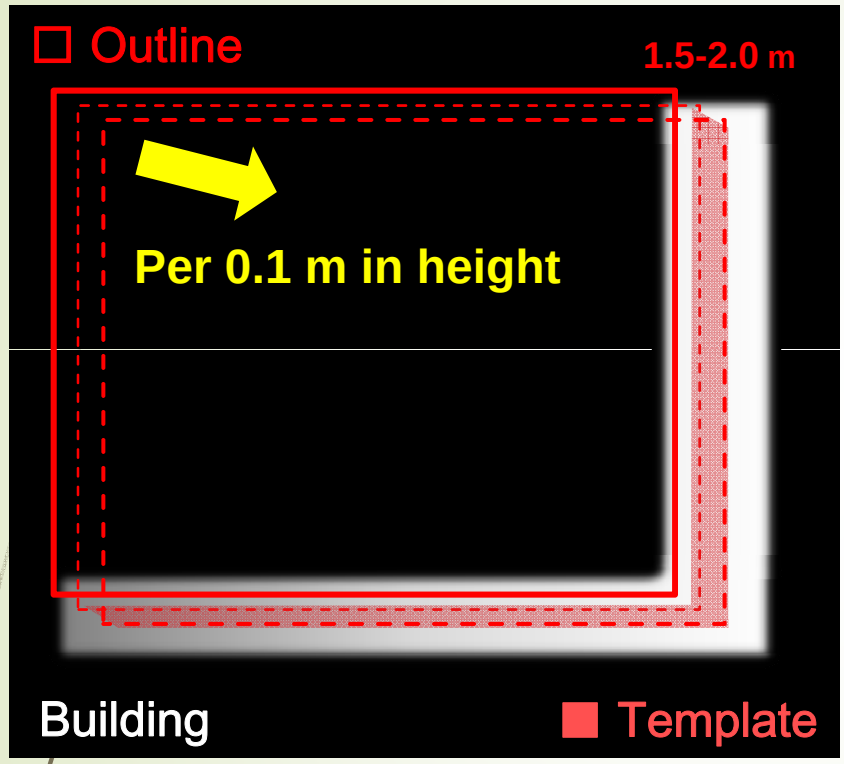


TSX intensity image (2011/10/13)

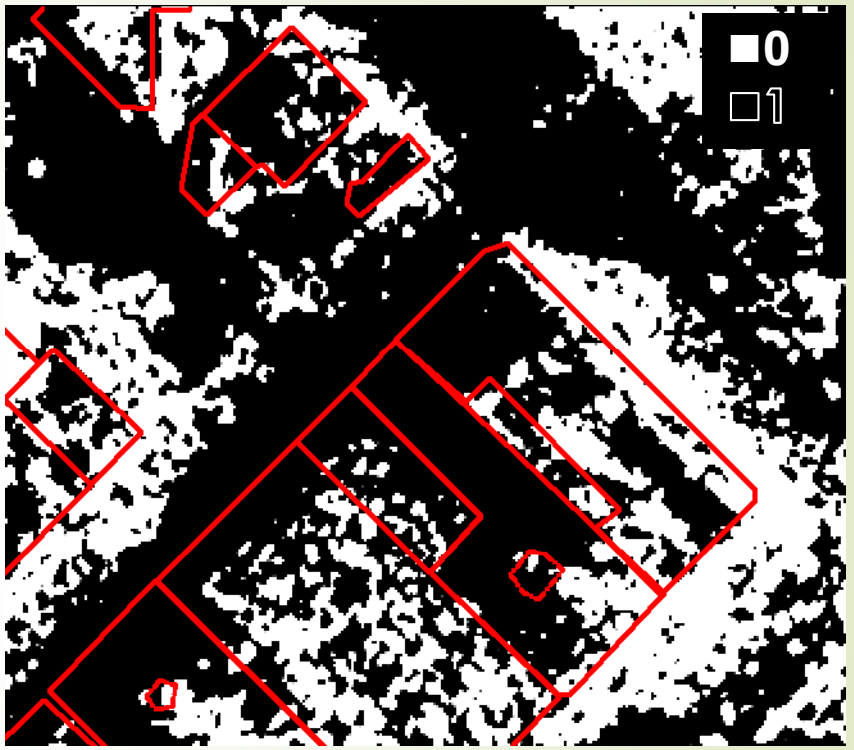


- 116 buildings were select as targets

Template searching for layover



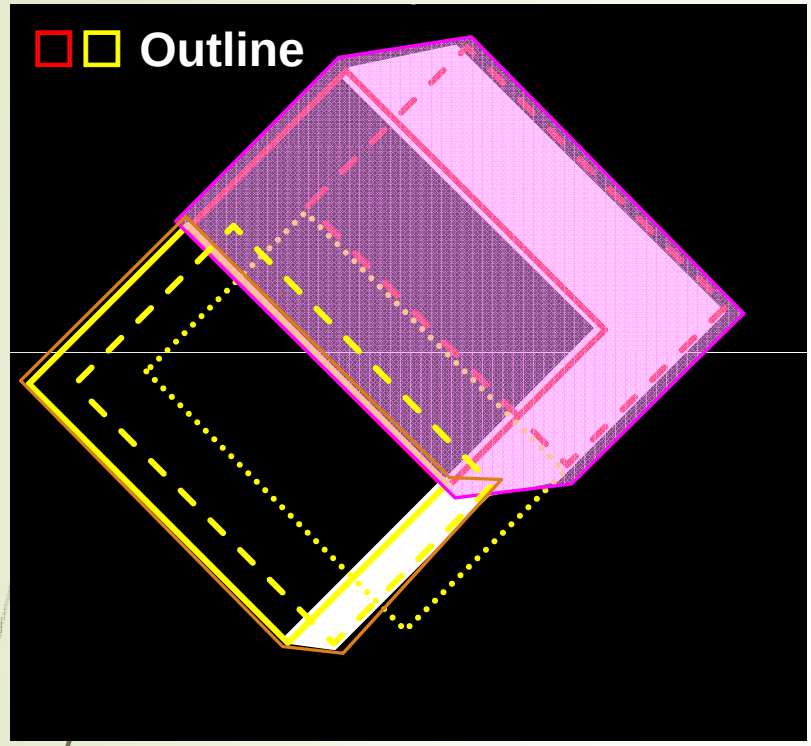
σ > -10.5 dB

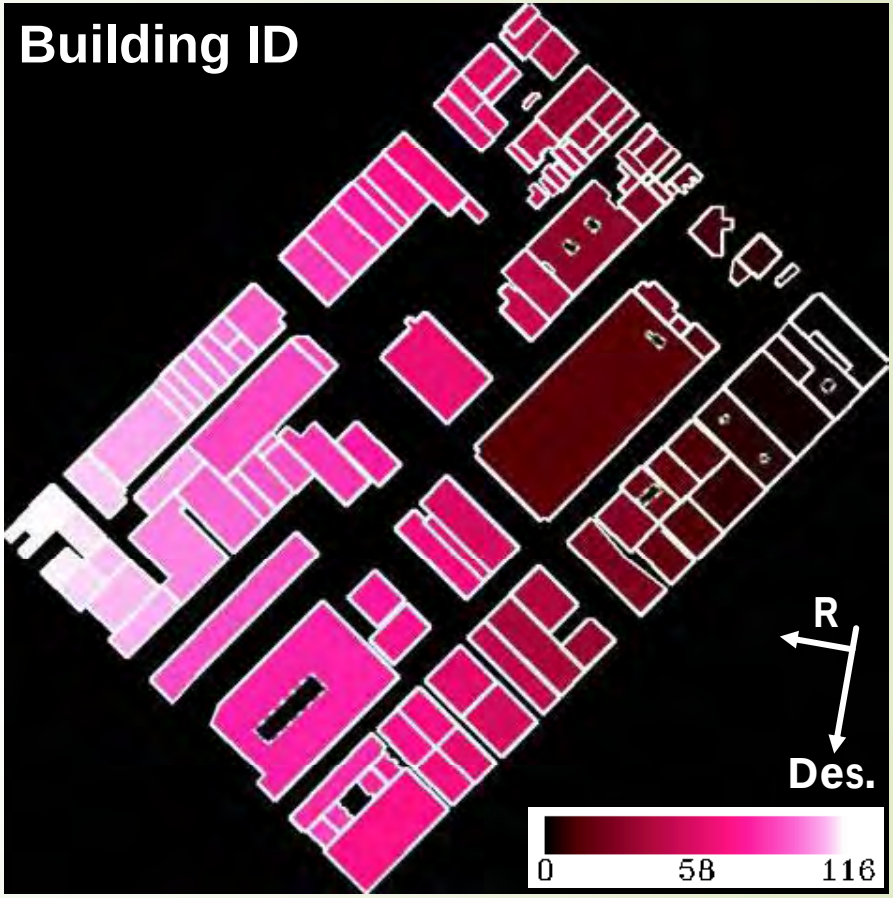


- Resize TSX image to 0.1 m/pixel
- An Initial template: between1.5 and 2.0 m high
- Shift to the sensor direction: 0.1 m interval in height
- Thresholds for the template

  σ> -10.5 dB (average value) $p_L \geqq 40\%$

Searching order

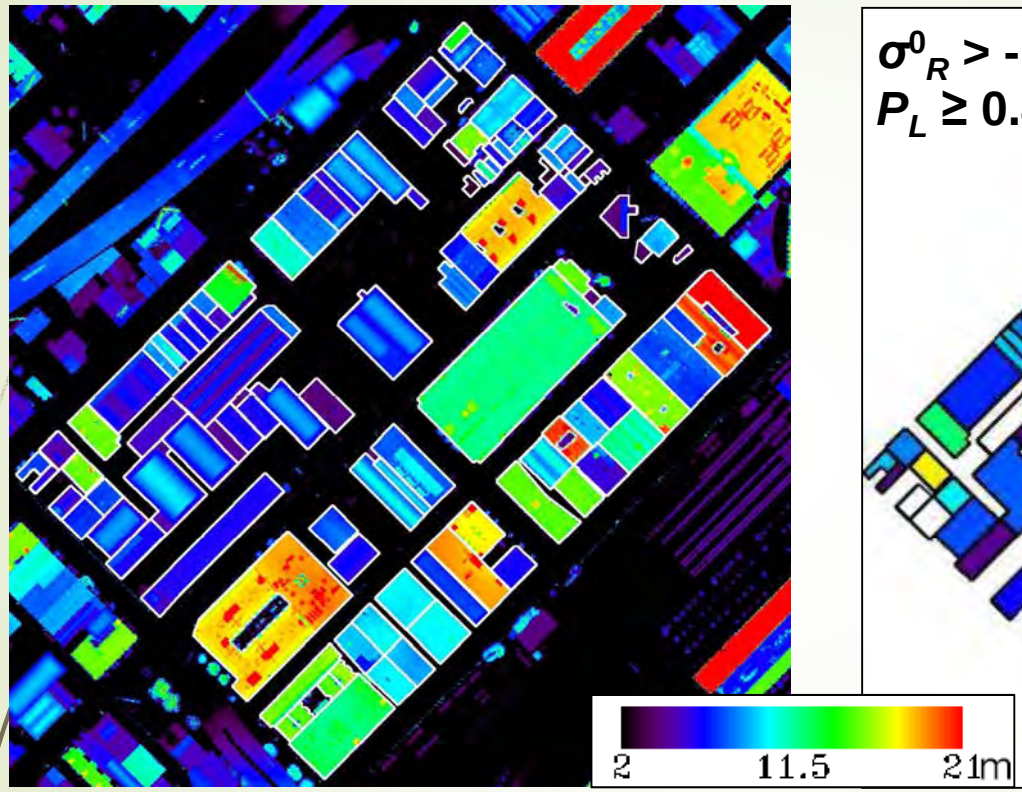




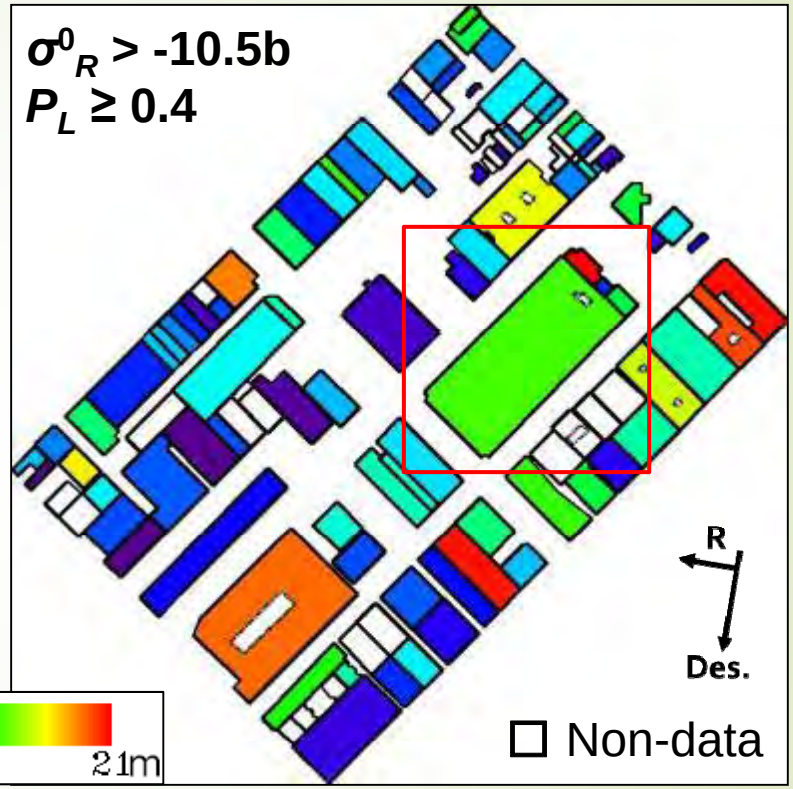
- ID number is assigned to each building.
- Searching is carried out in the order of ascending ID.
- Masked the building areas and the former searched layover areas

Result of estimation (Arear I)

Lidar data

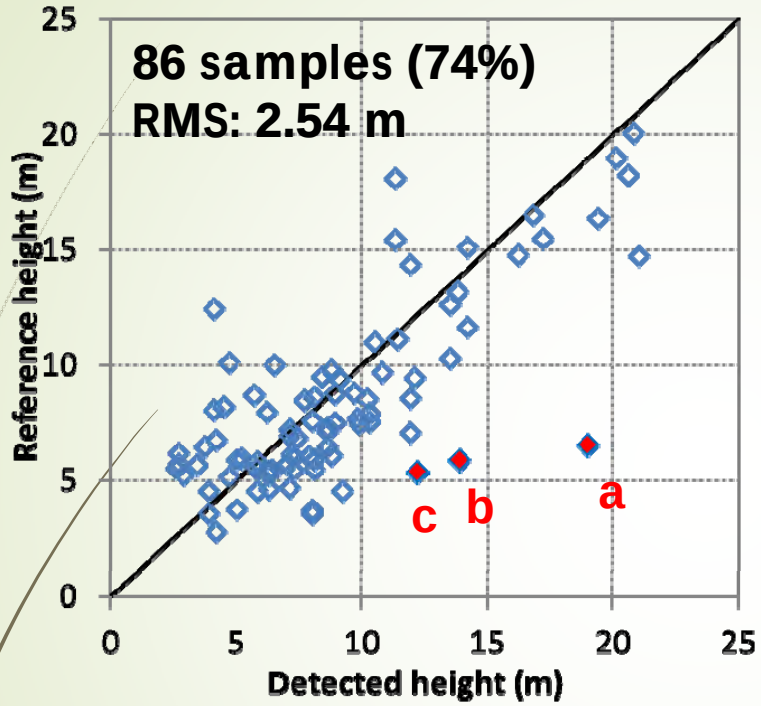


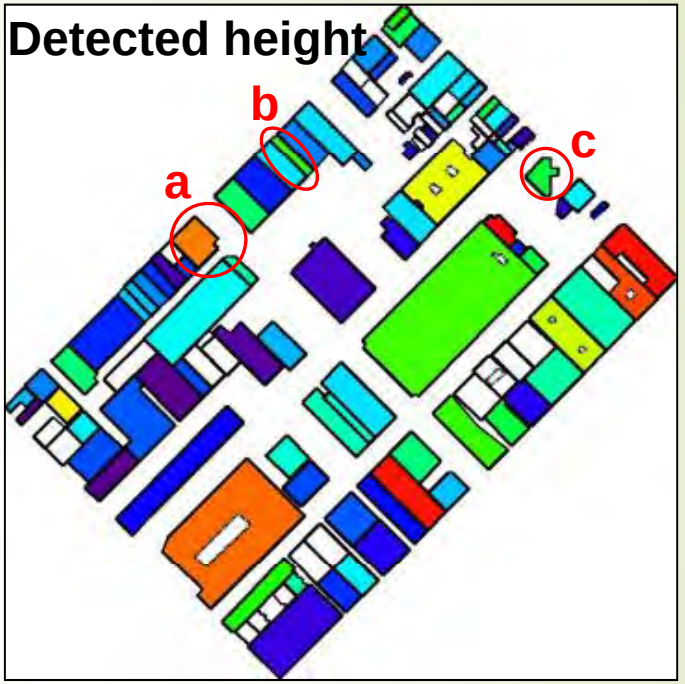
Detected results

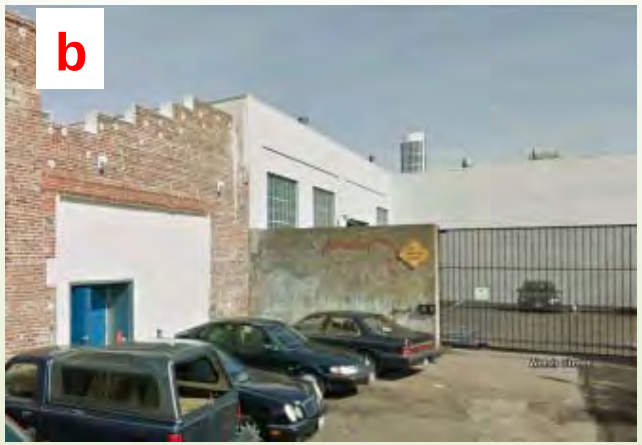


- 89 of 116 buildings' heights were detected.
- The building that behinds to other one in the range direction cannot be detected.

Verification of results (Area I)

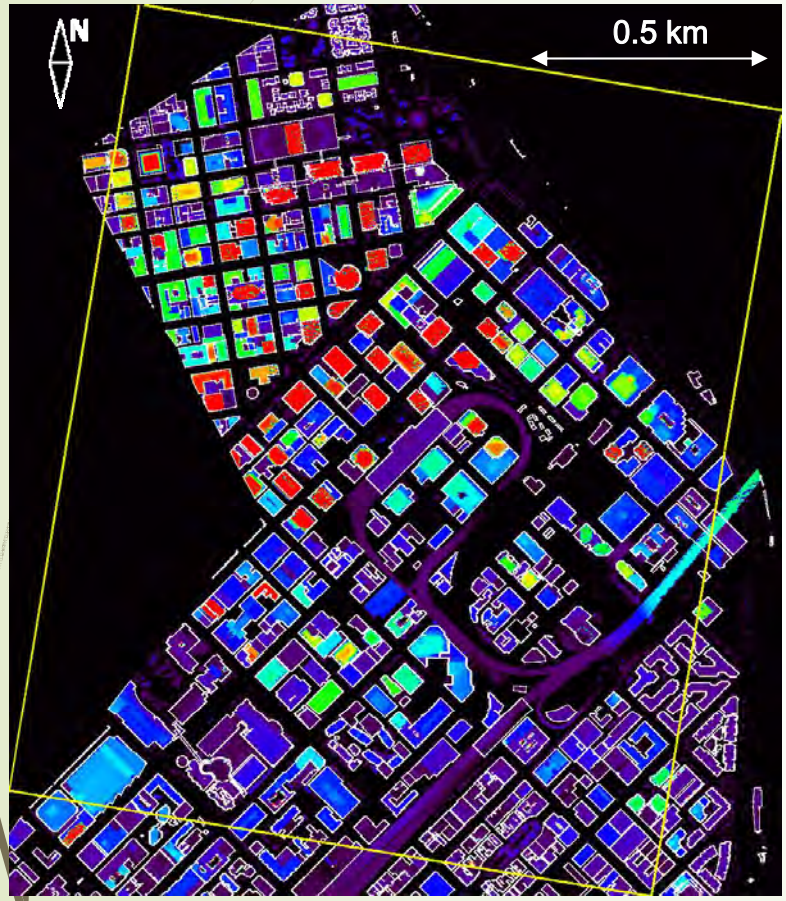




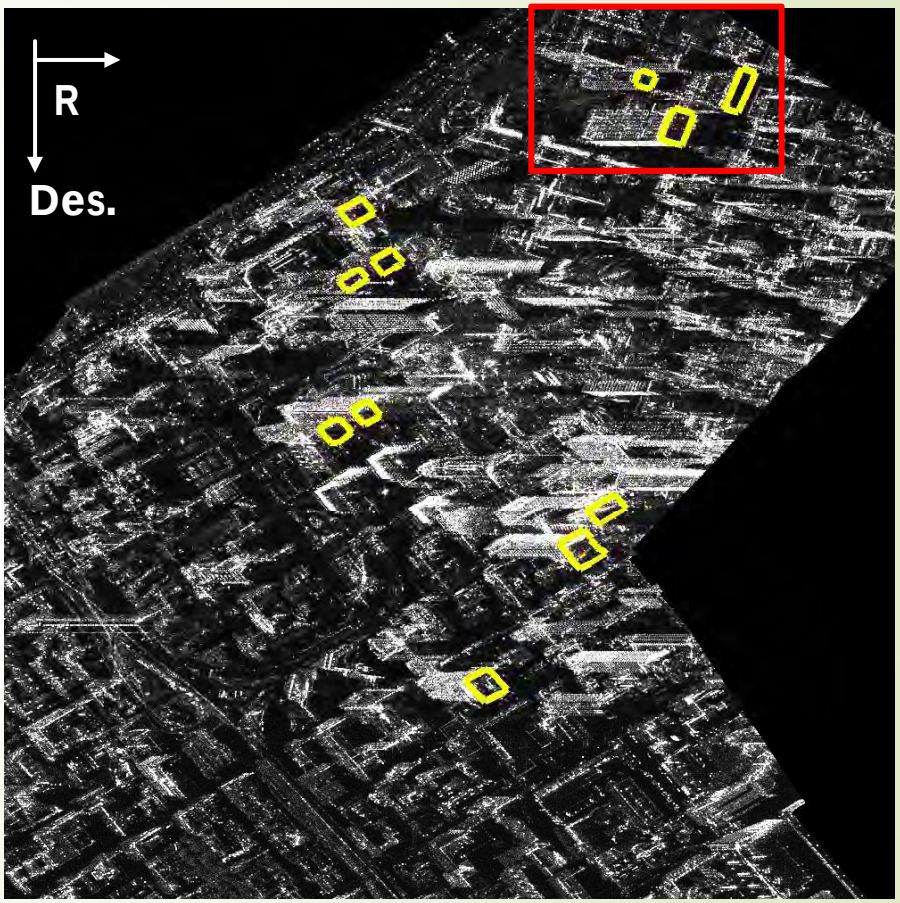


Target area II (high-rise buildings)

Building height (geocoded)



Slant range TSX intensity image (2007)



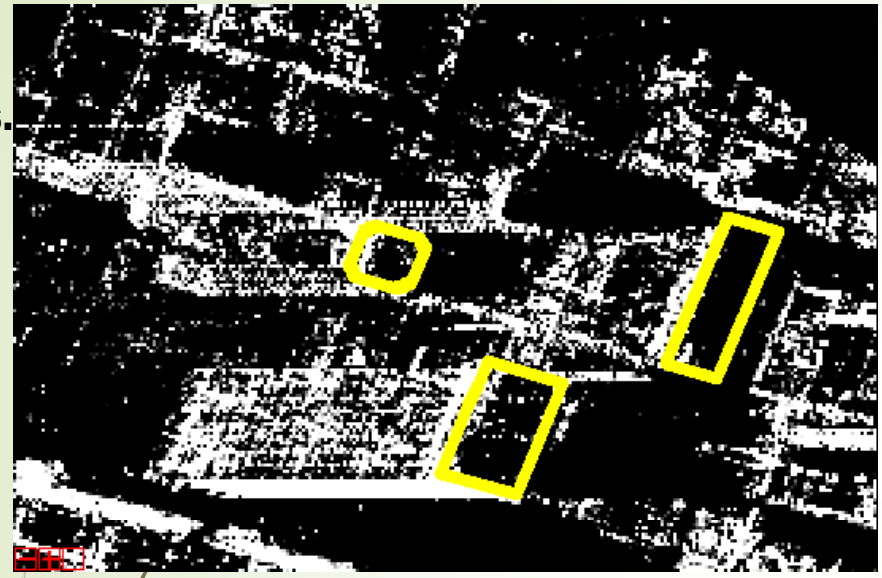
- 11 buildings more than 50 m high were select as targets

Layover of high-rise buildings

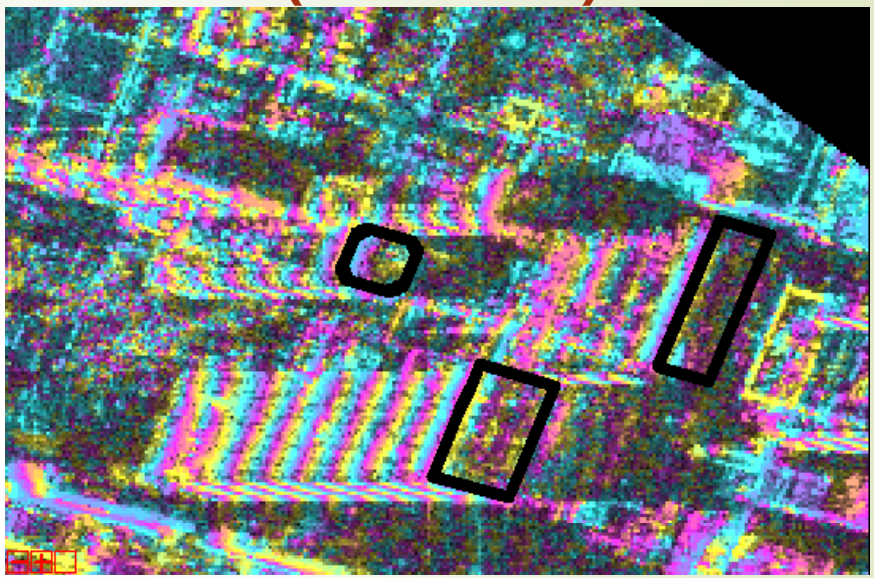
R

Des.

Intensity image



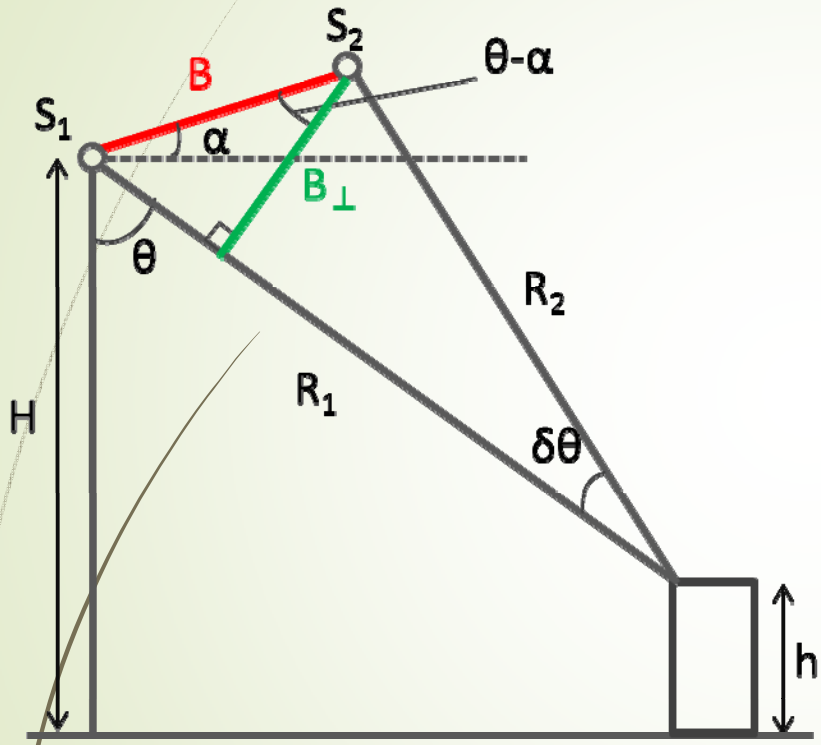
Phase image φ of InSAR analysis (12/05-12/27)



−π π

Building height and phase

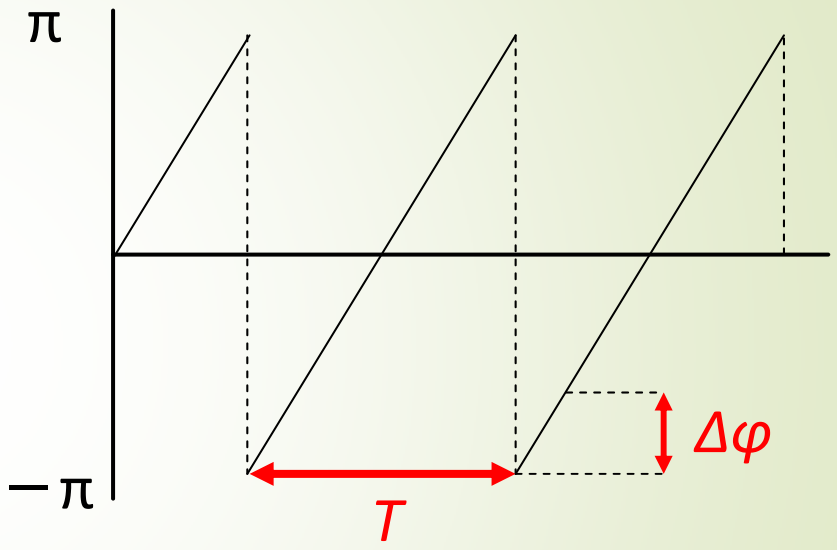
Building height from InSAR analysis



$$h = \frac{\lambda H \sin\theta}{4\pi B_{\perp} \cos\theta} \cdot \varphi$$

$$B_{\perp} = 561\,[\mathrm{m}] \Rightarrow h = 11.6\,[\mathrm{m/cycle}]$$

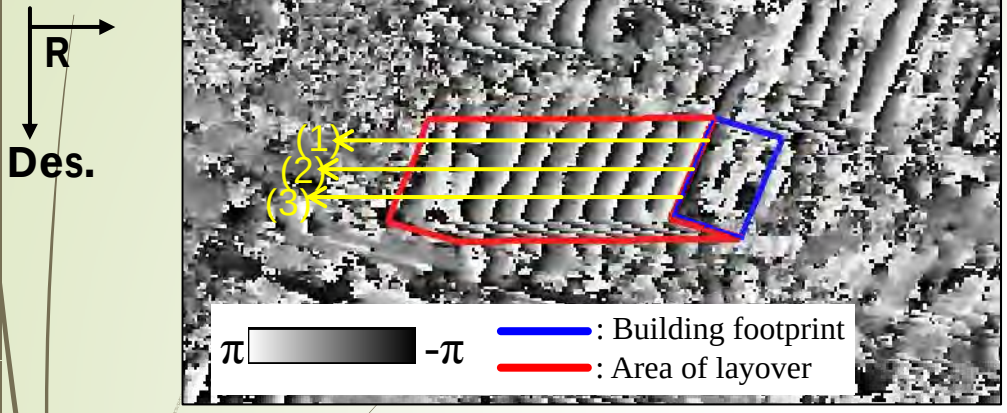
Stable phase cycles

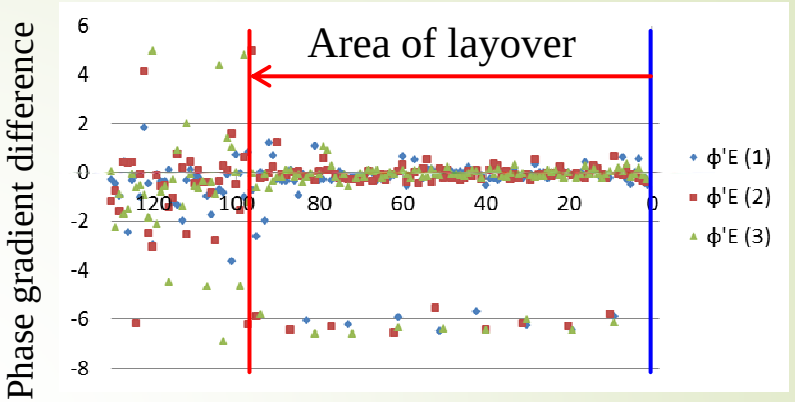


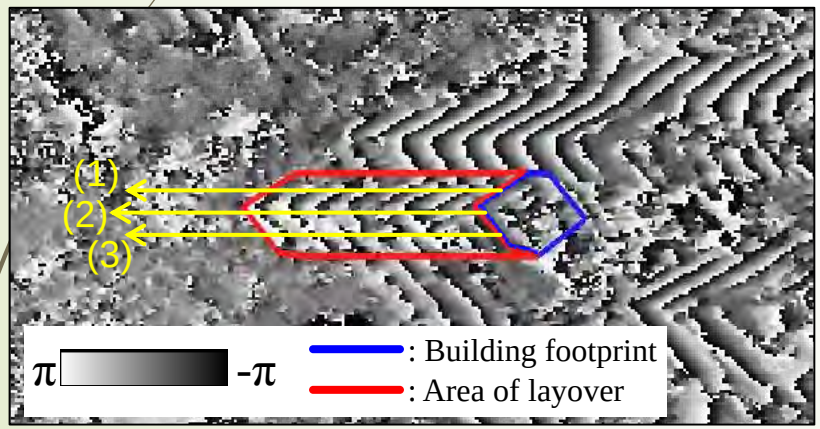
$$T = \frac{\lambda H \sin\theta}{2B_{\perp}} = 8.87\,[\mathrm{m}]$$

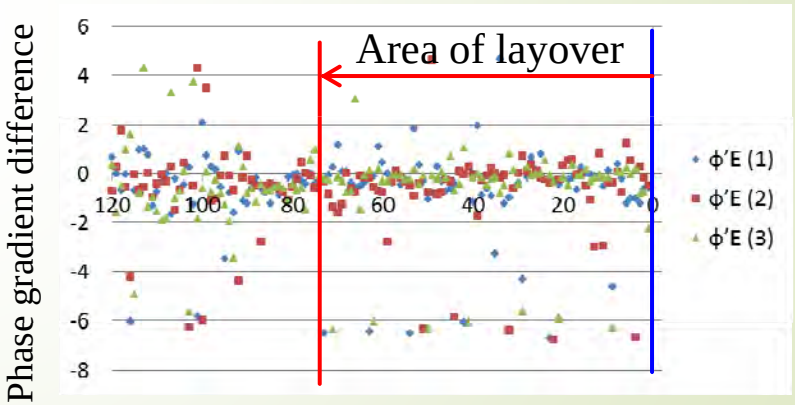
$$\Delta\varphi = \frac{4\pi B_{\perp}}{\lambda H \sin\theta} = 0.71\,[\mathrm{rad/m}]$$

Investigation of phase characteristics







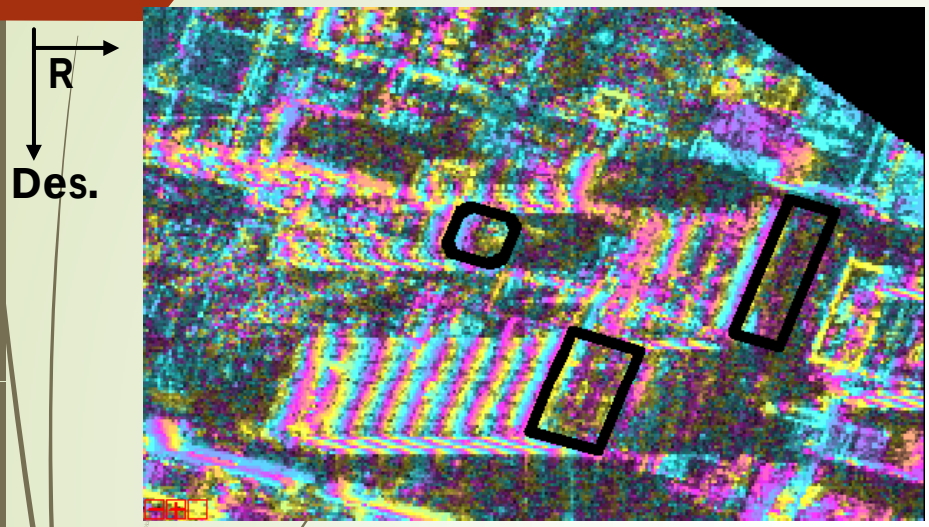


- Thresholds for stable phase

  $0 < \Delta\varphi < 1.3$ [rad/pixel] (0.65 in theory)

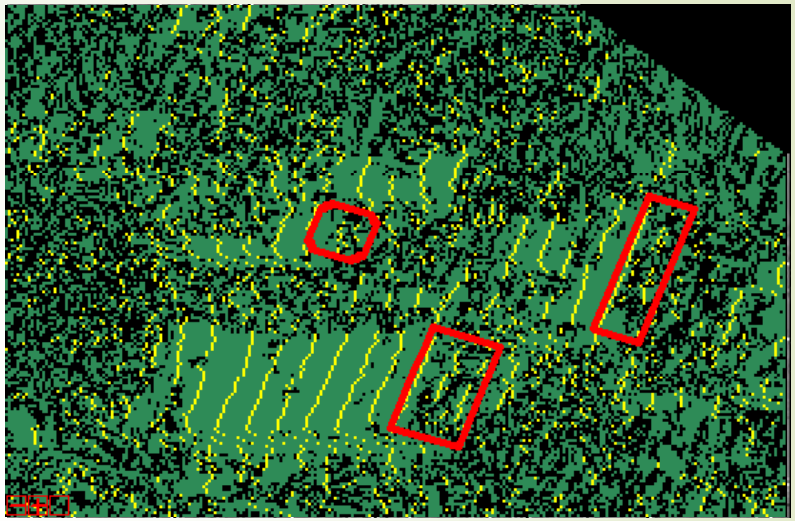
  $7 < T < 13$ [pixels] (10 in theory)

Extraction of layover



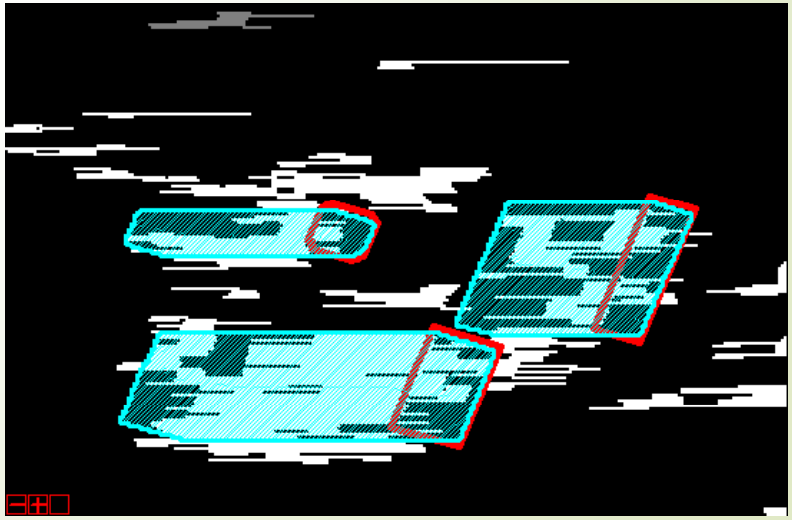
□GIS footprints

Phase gradient Δφ



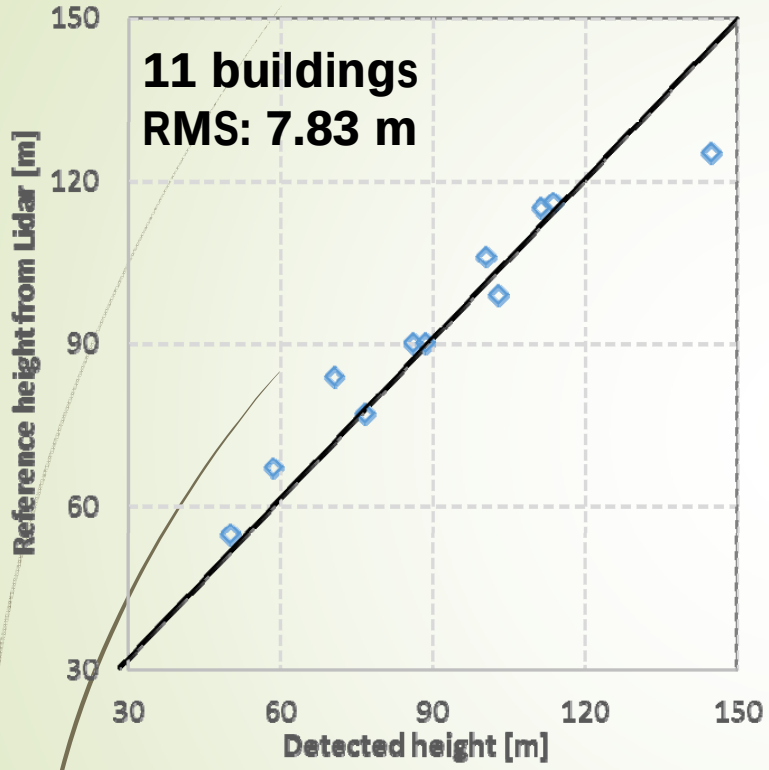
■0 < Δφ < 1.3 ■Wrap point

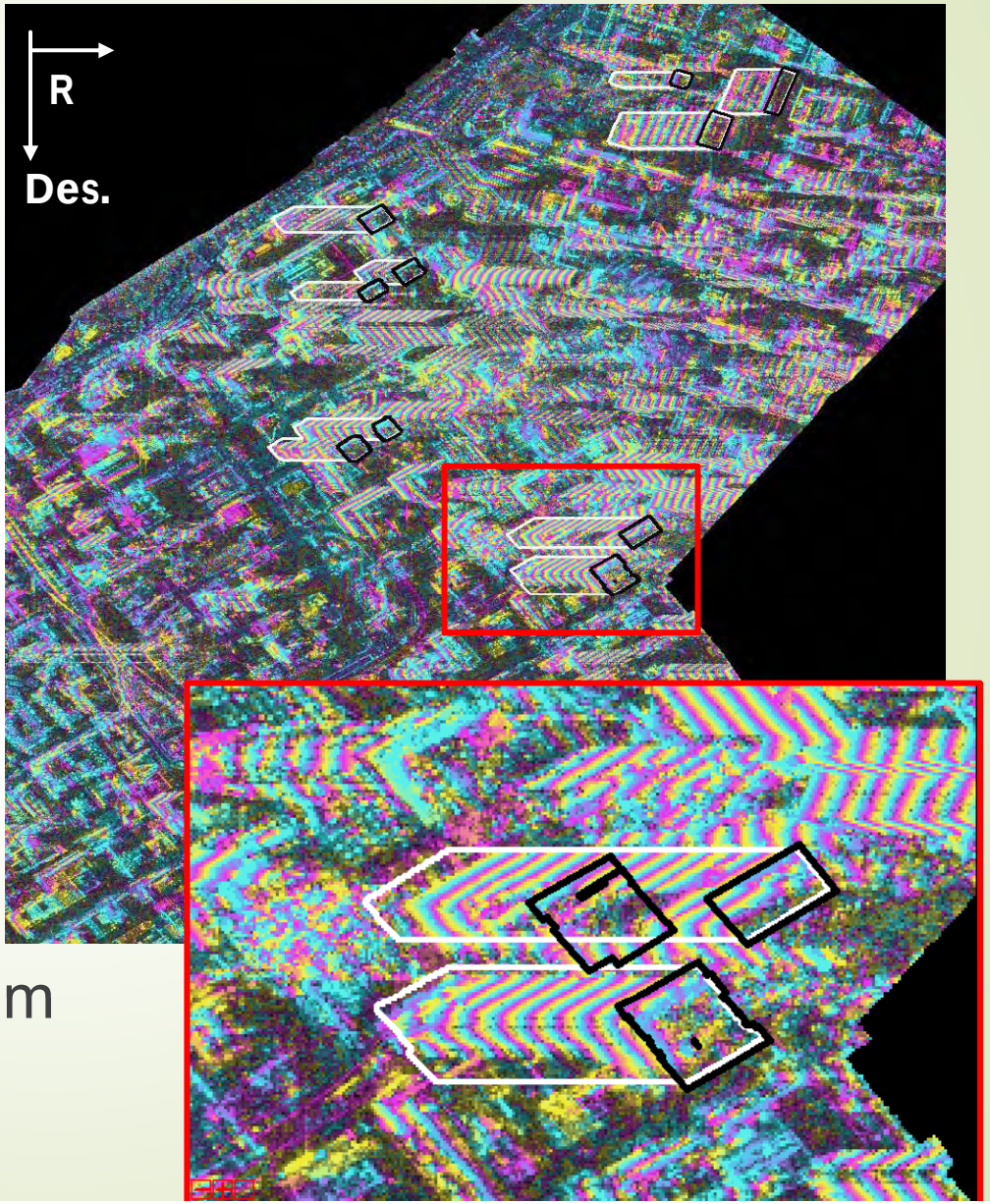
□Potential layover



■Extracted layover (p_L > 11%)

Verification of results (Area I)





- Maximum error : 20.1 m
- Average error: 5.5 m

Conclusions

- **Height detection was carried out from TSX images and building footprints.**
  - Heights were calculated according to the lengths of layovers
  - Two methods were proposed for low- and high-rise buildings, respectively.
  - The RMSE for low-rise buildings is 2.5 m, and the one for high-rise buildings is 7.8 m.
  - The accuracy of height detection depends on the surrounding conditions.
- **In the future, the method will be more tested and improved.**

Thank you very much !

Acknowledgement

The TerraSAR-X images and Lidar data used in this study were provided from 2012 IEEE Geoscience and Remote Sensing Society Data Fusion Contest.