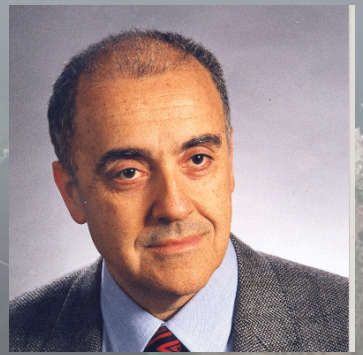

NRSCC
esa
ESA–MOST Dragon Cooperation
中国科技部-欧洲空间局“龙计划”合作
2017 DRAGON 4 SYMPOSIUM
2017年“龙计划”四期学术研讨会
Three- and Four-Dimensional Topographic Measurement and Validation
（ID：32278）
26–30 June 2017 | Copenhagen, Denmark
2017年6月26-30日，丹麦 哥本哈根

Three- and Four-Dimensional Topographic Measurement and Validation

（ID： 32278）

Prof. Deren Li

Prof. Fabio Rocca



Main objectives

- Absolute geo-coordinate estimation of artificial targets in optical and SAR imagery and the validation of their accuracy
- Digital elevation model (DEM) generation and validation
- Near-real time surface motion estimation with multi-baseline InSAR
- Glacier motion and 3D subsurface information retrieval
- Polarimetric TomoSAR analysis for forest parameter retrieval
- Stereo-Radargrammetry analysis for incoherent forest height change retrieval

Three research groups

1.Topographic Mapping - Validation

Prof. Timo Balz – Prof. Norbert Haala

Wuhan University – University Stuttgart

2. Multi-baseline SAR processing for 3D/4D reconstruction

Prof. Mingsheng Liao – Prof. Stefano Tebaldini

Wuhan University – POLIMI

3. Towars Near-Real Time InSAR Deformation estimation

Prof. Xiaoli Ding – Prof. Ramon Hanssen

PolyU Shenzhen Research Institute – Delft University of Technology

MULTI-BASELINE SAR PROCESSING FOR 3D/4D RECONSTRUCTION

Mingsheng LIAO[1], Lu ZHANG[1], Timo BALZ[1], Tianliang YANG[2], Deren LI[1]

1. LIESMARS, Wuhan University, China
2. Shanghai Institute of Geological Survey, China

liao@whu.edu.cn

Main Objectives

- Continue the research on PS-InSAR based techniques and continue the work on analyzing of landslides, subsidence due to mining or underground water extraction, and seismic activity.
- Focuses on the use of polarimetric SAR tomography to investigate distributed media, such as forests and ice. This is especially valuable for the estimation of biomass in tropical and boreal forests.

Main Topics

- Multi-baseline SAR for 3D and 4D information retrieval

- Tomographic SAR analysis in urban areas

- Polarimetric TomoSAR analysis for forest parameter retrieval

- Stereo-Radargrammetry analysis for incoherent forest height change retrieval

- Glacier motion and 3D subsurface information retrieval

Research activities & Results – Part I

Application of InSAR Combined with StereoSAR in High-precision Topographic Mapping of Mountainous Area

1. Introduction

Problems of InSAR technique for topographic mapping:

The height accuracy of InSAR DSM is easily affected by the interferometric phase error, which is mainly induced by the following factors:

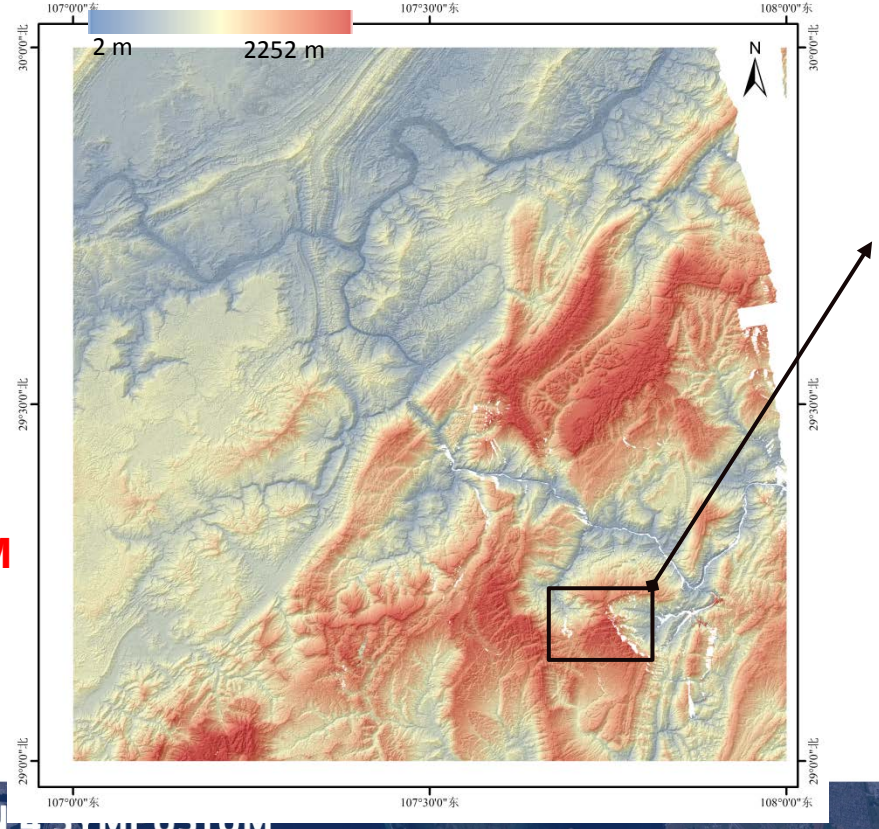
1) atmospheric effect.

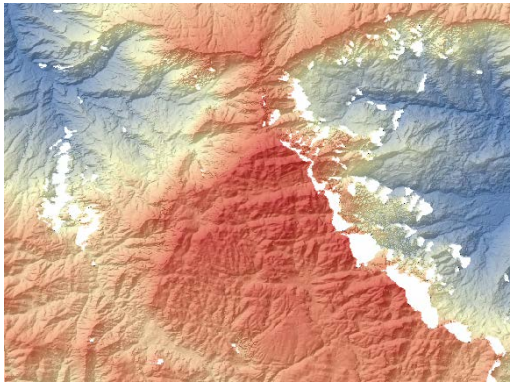
2) decorrelation factors, e.g. temporal, volume scattering decorrelation etc..

3) image geometric distortions caused by layover or shadow.

1. Introduction

WorldDEM





Comparison of StereoSAR and InSAR mapping

✓StereoSAR makes use of the **amplitude** information; InSAR takes use of the **phase** information.

✓InSAR is more sensitive to topographic details than StereoSAR.

⇨ **Fix-up InSAR DSM data voids with StereoSAR DSM.**

✓StereoSAR measures the **absolute slant range difference** while the interferometric phase is wrapped into $(-\pi, \pi)$.

⇨ **Calibrate the InSAR unwrapped phase with some high-precision StereoSAR height.**

2. Methodology

StereoSAR DSM generation process

✓StereoSAR DSM generation is composed of two steps:

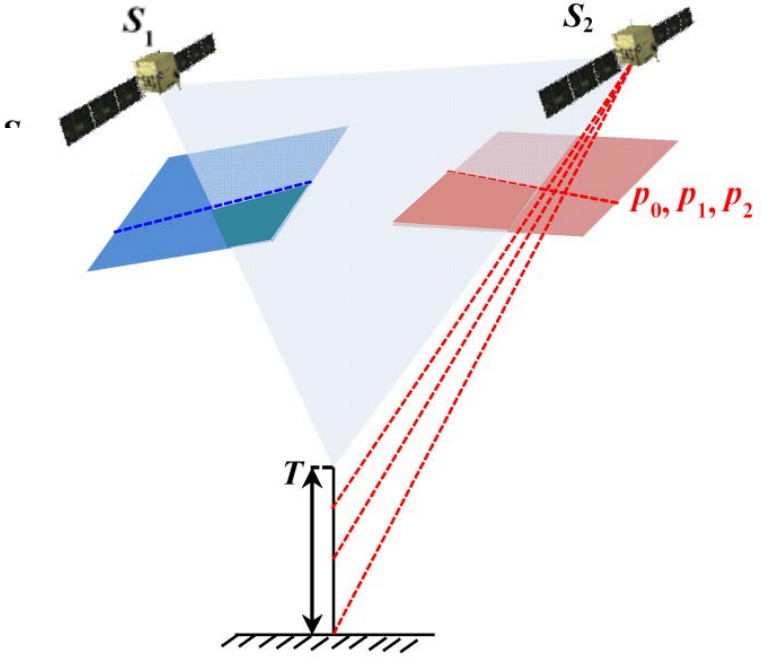
1) image matching to identify the homologous points;
2) space forward intersection to determine the ground coordinates;

✓The bottleneck for StereoSAR is image matching especially in mountainous areas due to the severe geometric distortion.

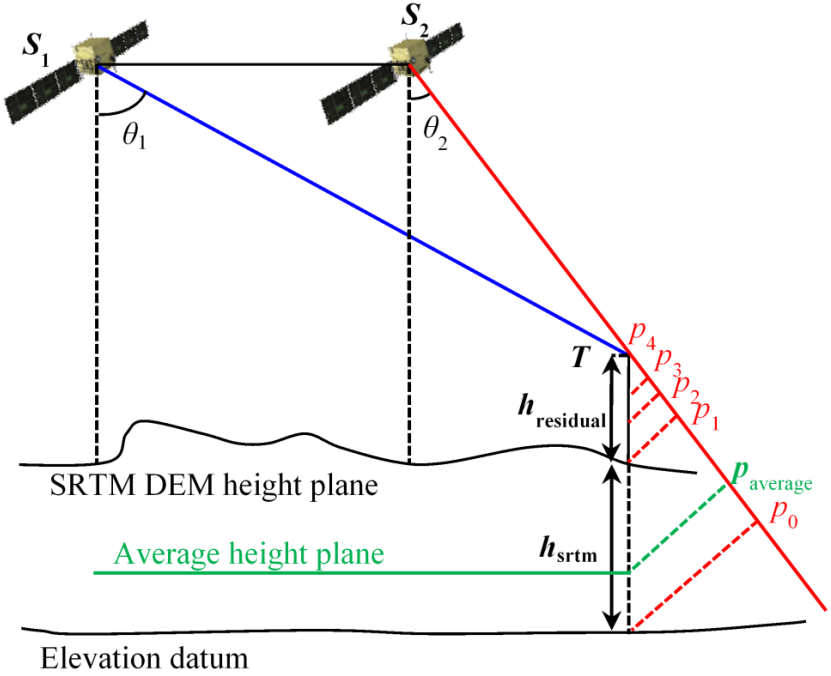
⇨ Therefore, adaptive window Least Square Matching algorithm has been proposed (AW-LSM).

Adaptive window Least Square Matching (AW-LSM)

Step 1: enhanced epipolar image generation

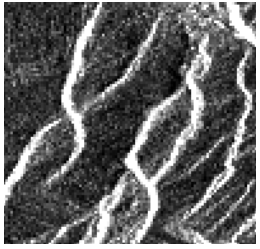
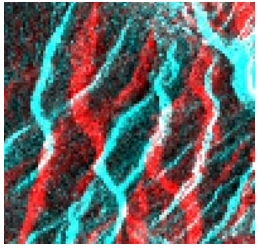
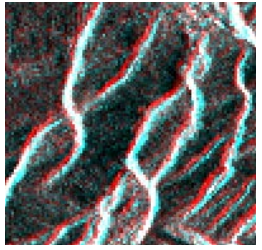
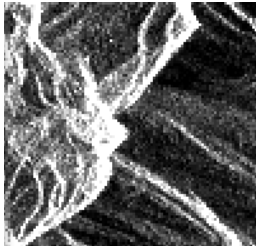
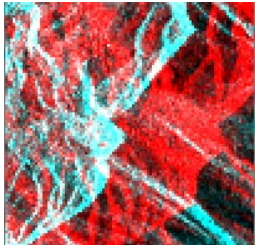
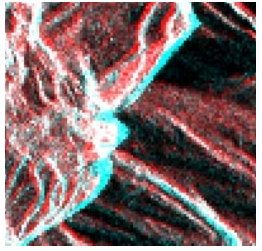
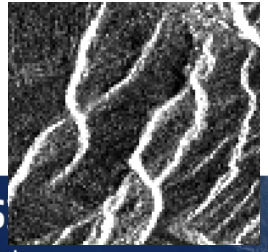
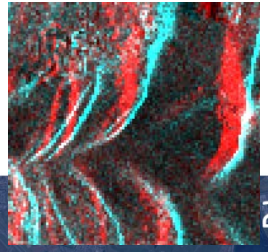
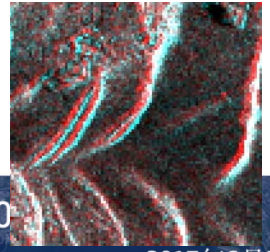


Geometric relation of photogrammetry



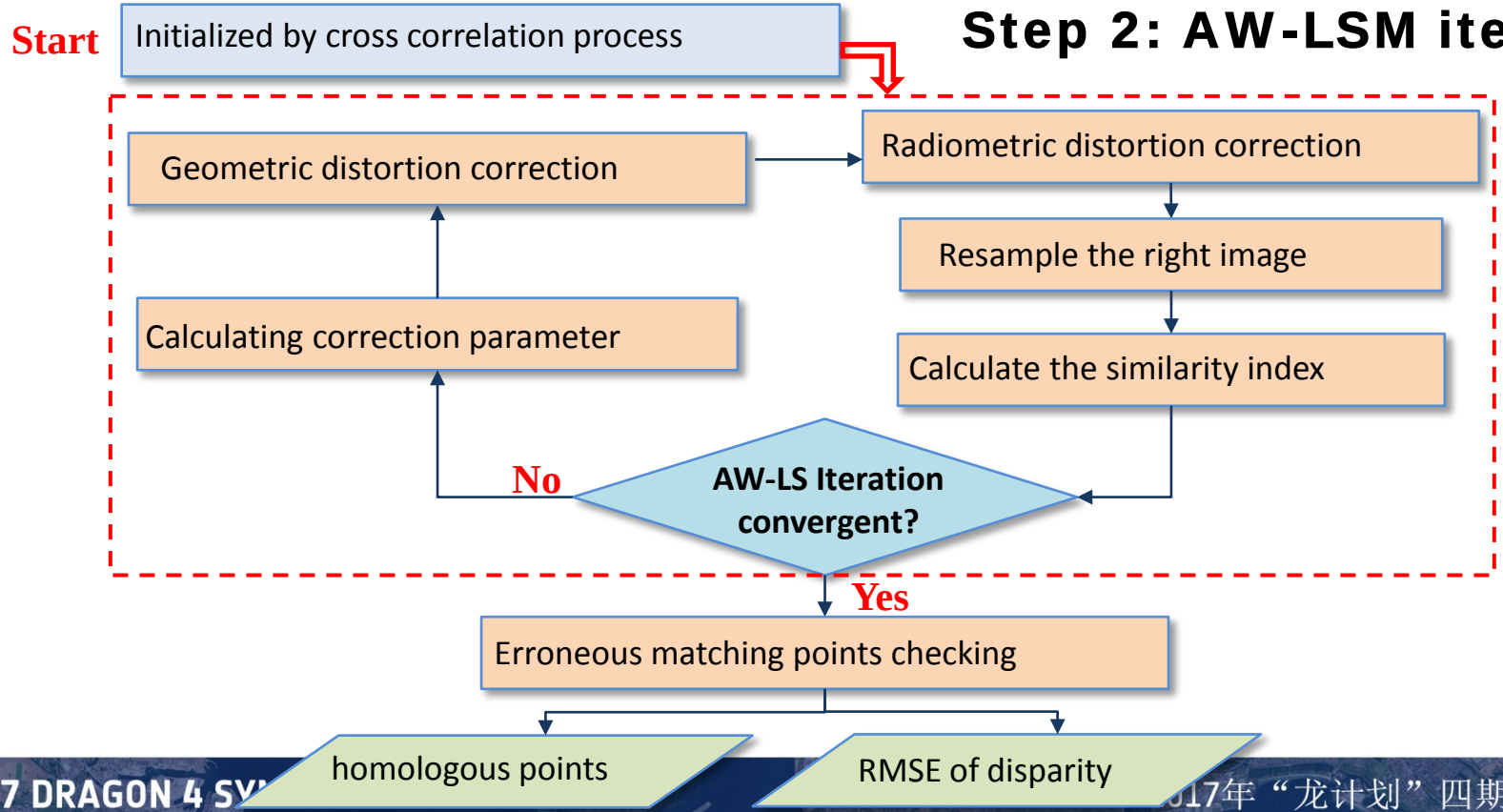
Geometric relation of radargrammetry

Adaptive window Least Square Matching (AW-LSM)

	left image	right image	quasi-epipolar image	enhanced epipolar image
Test area 1				
Test area 2				
Test area 3				

Adaptive window Least Square Matching (AW-LSM)

Step 2: AW-LSM iteration



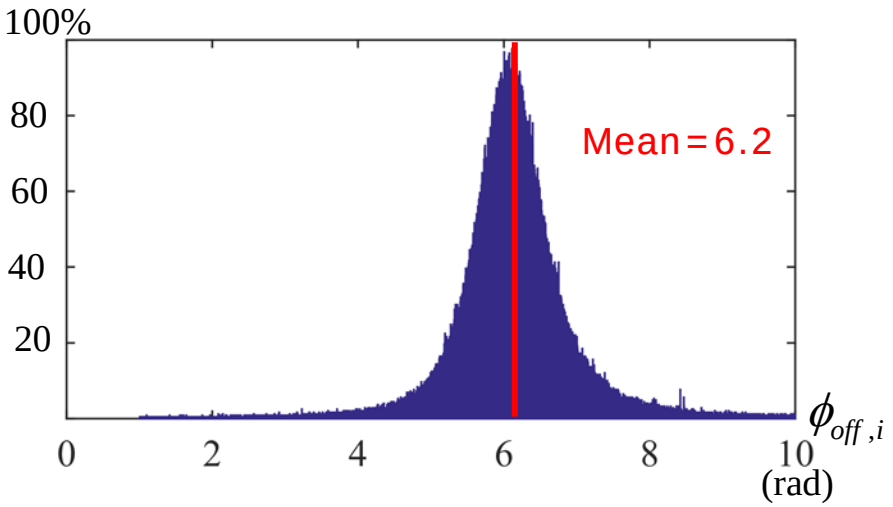
InSAR phase calibration assisted by StereoSAR

✓Collecting the sample points all over the StereoSAR DSM with **high height precision**.

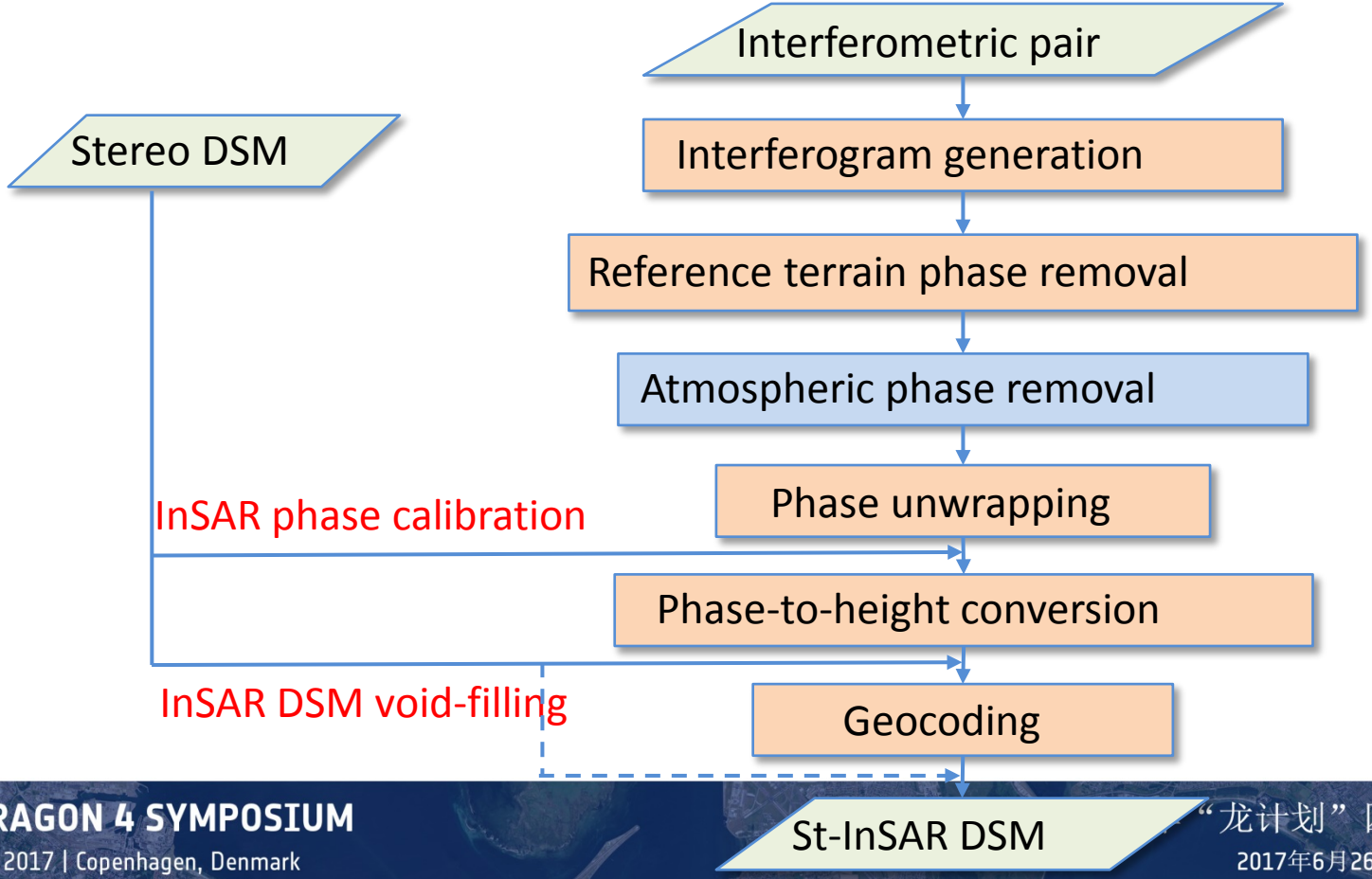
✓Calculate the $\phi_{off,i}$ for each sample points.

✓Plot the **frequency histogram** of $\phi_{off,i}$.

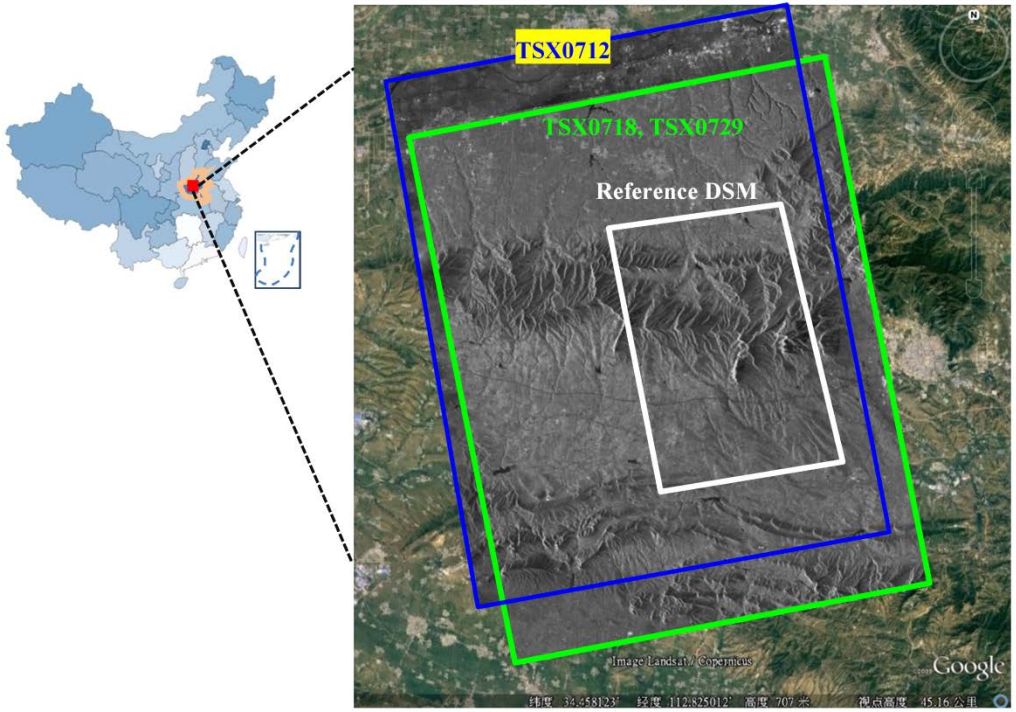
✓Calculate the **mean value** of $\phi_{off,i}$.



Stereo-assisted InSAR DSM generation



3. Experiments



- Mount Song in Henan province of central China;
- The elevation ranges from 150 m to 1500 m above sea level, and the slopes in the central part are very steep;
- Densely vegetated;

Experimental area

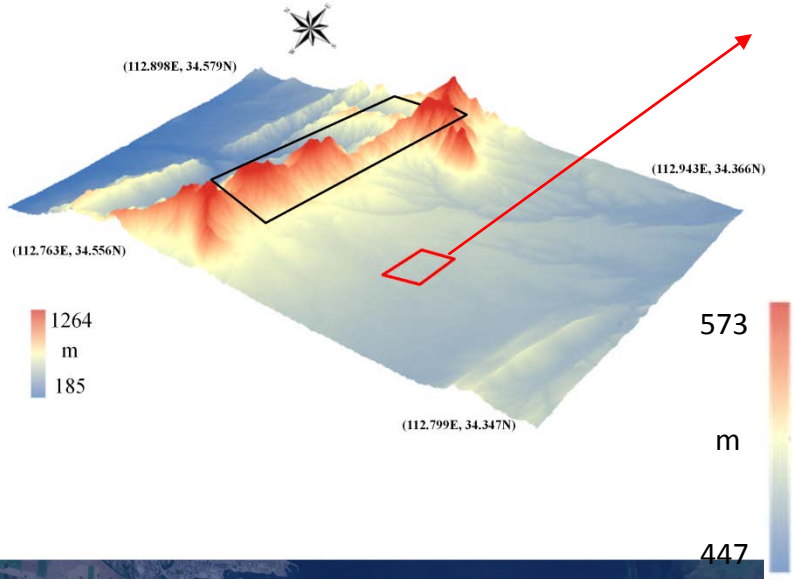
Experimental data

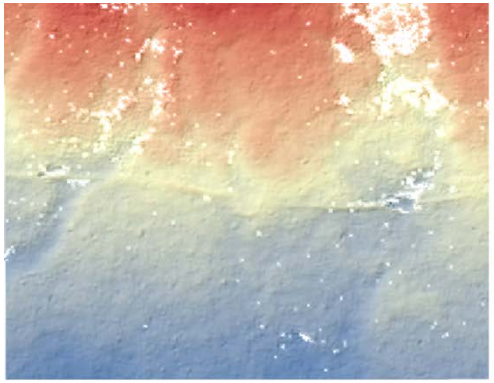
ID	Acquisition Mode	Acquisition Date	Orbit Direction	Incidence Angle (°)	Resolution rg/az* (m)
0712	Stripmap	2011-07-12	Ascending	44.5	1.8/3.3
0718	Stripmap	2011-07-18	Ascending	28.9	1.2/3.3
0729	Stripmap	2011-07-29	Ascending	28.9	1.2/3.3

Photogrammetric DSM with spatial resolution of **1 m** has been used as **reference DSM** to evaluate the accuracy of the generated DSM.

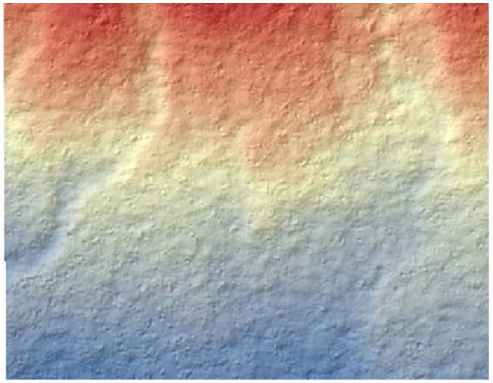
Interferometric pair	0718-0729
Temporal baseline	11 d
Normal baseline	194 m
Height ambiguity	22 m

Accuracy evaluation of generated DSMs

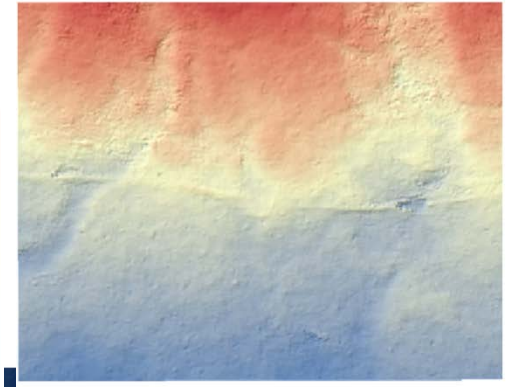




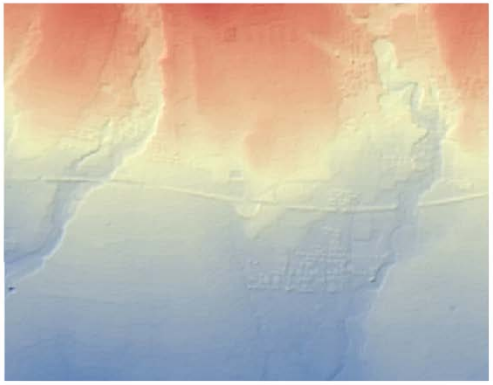
(a) InSAR DSM



(b) StereoSAR DSM

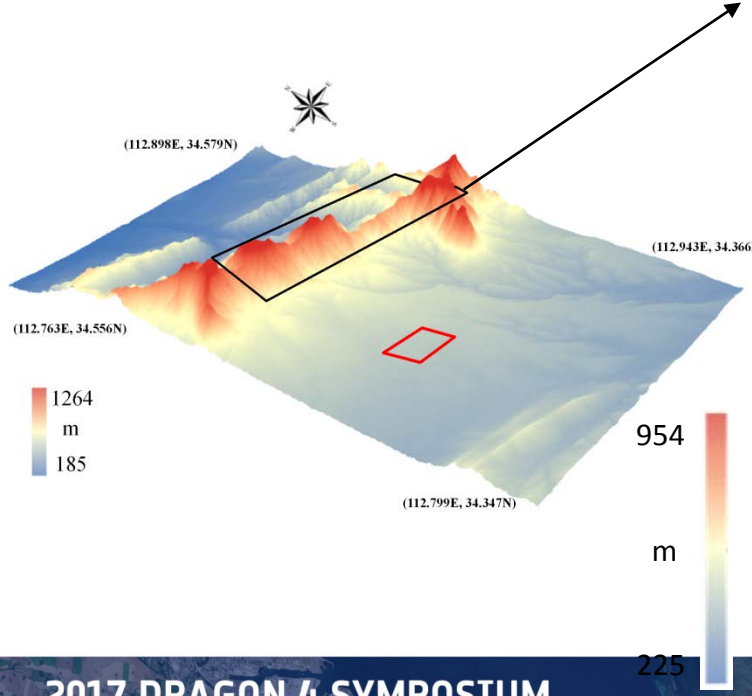


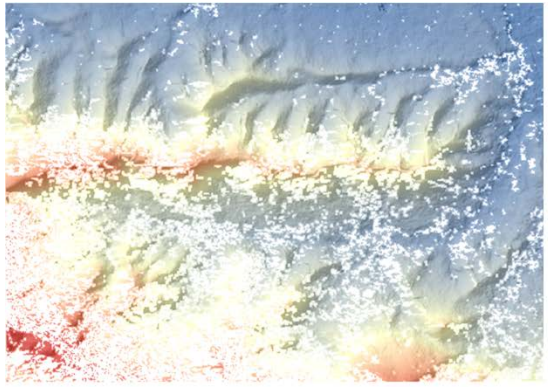
(c) Generated DSM



(d) Photogrammetric DSM

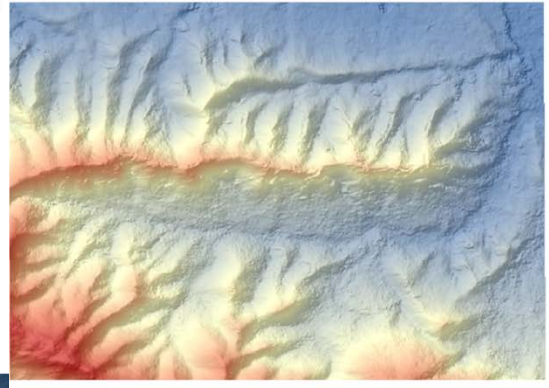
Accuracy evaluation of generated DSMs



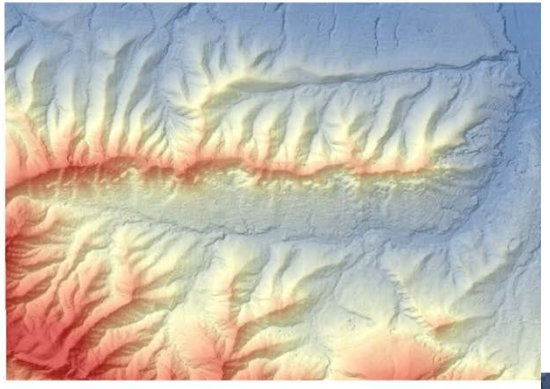


(a) InSAR DSM

(b) StereoSAR DSM



(c) Generated DSM



(d) Photogrammetric DSM

Accuracy evaluation of generated DSMs (m)

	SRTM DEM			Stereo DSM			generated DSM		
	Mean	RMSE	90% LE	Mean	RMSE	90% LE	Mean	RMSE	90% LE
All	2.7	7.9	13.7	2.5	7.3	12.6	2.3	6.9	11.9
Plains	1.4	2.3	3.9	1.7	1.9	3.3	1.1	1.8	3.2
Mountains	2.6	10.8	18.7	1.7	10.3	17.8	0.9	9.9	17.2

Summary for DEM reconstruction

✓The AW-LSM algorithm is effective for stereo image matching in mountainous areas with serious geometric distortions.

✓Since StereoSAR takes use of the amplitude information, it can be a good complement for decorrelated areas of InSAR data.

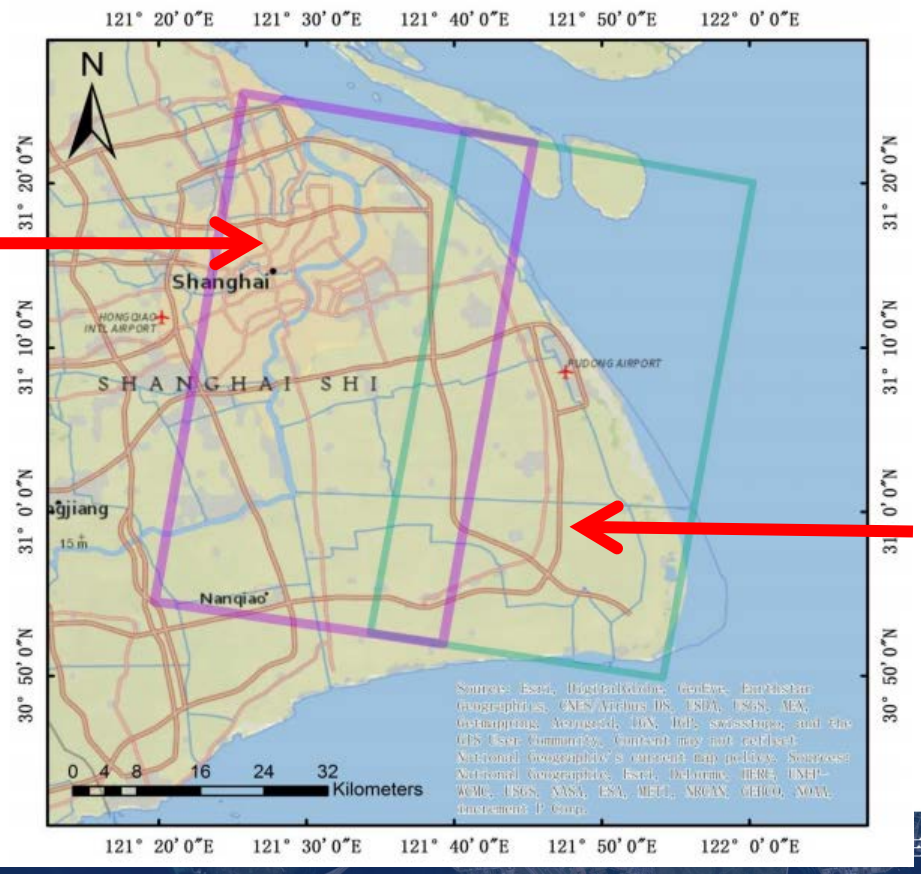
✓The points with high height accuracy in StereoDSM can be automatically selected for InSAR phase calibration.

✓The generated DSM has fewer data voids than InSAR DSM and higher height accuracy than StereoDSM.

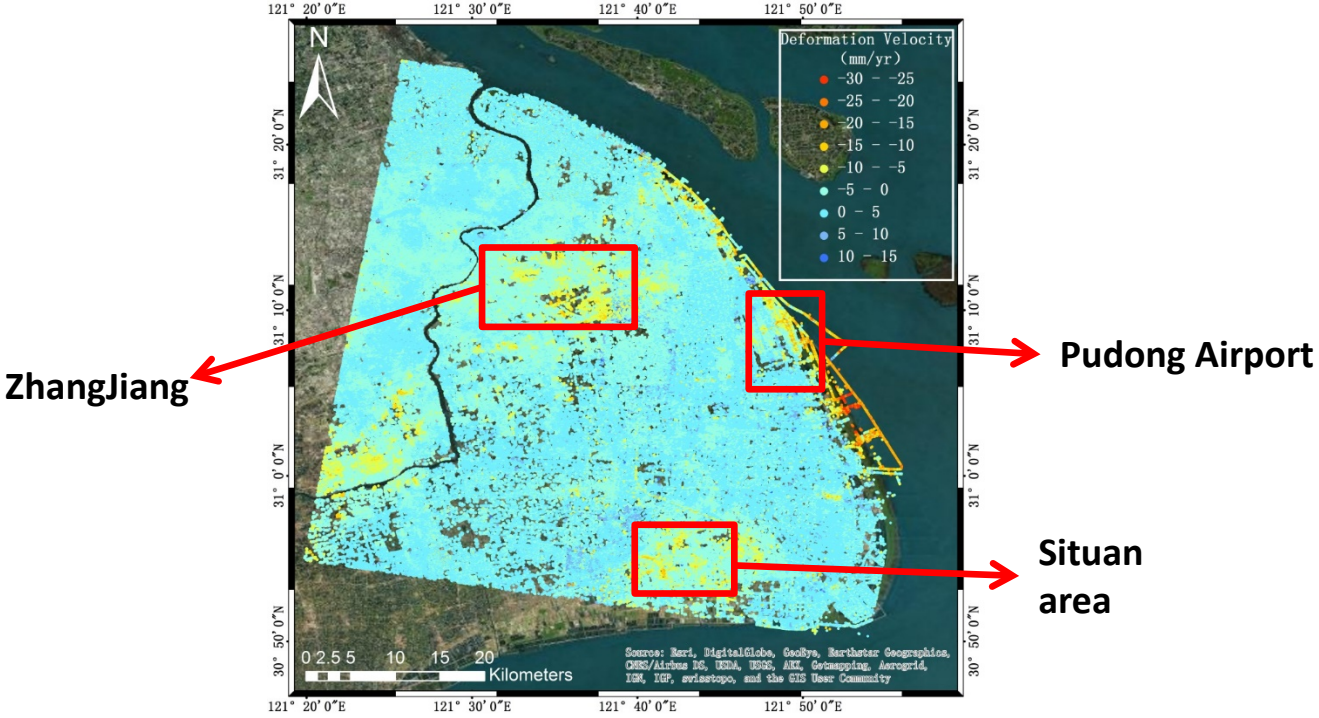
Research activities & Results – Part II

Monitoring subsidence and structure health of infrastructures

Coverage of TSX data stacks in Shanghai

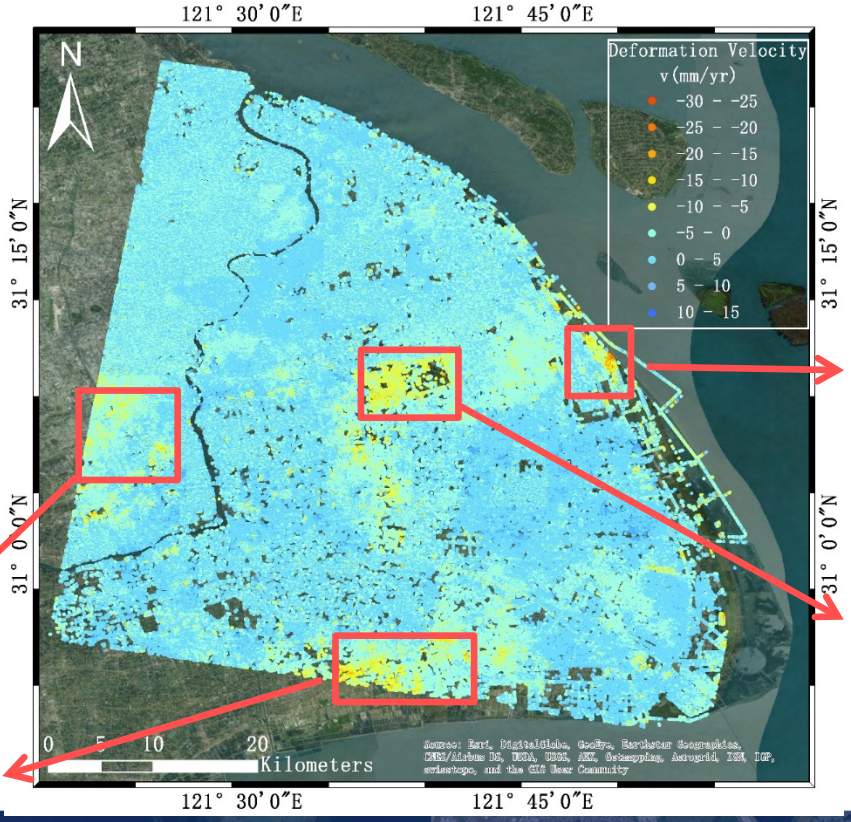


2013.9-2014.10 TSX result (13+13 images)



2014 subsidence data from TerraSAR-X

2014.9-2015.10 TSX result (12+12 images)



Pudong Airport

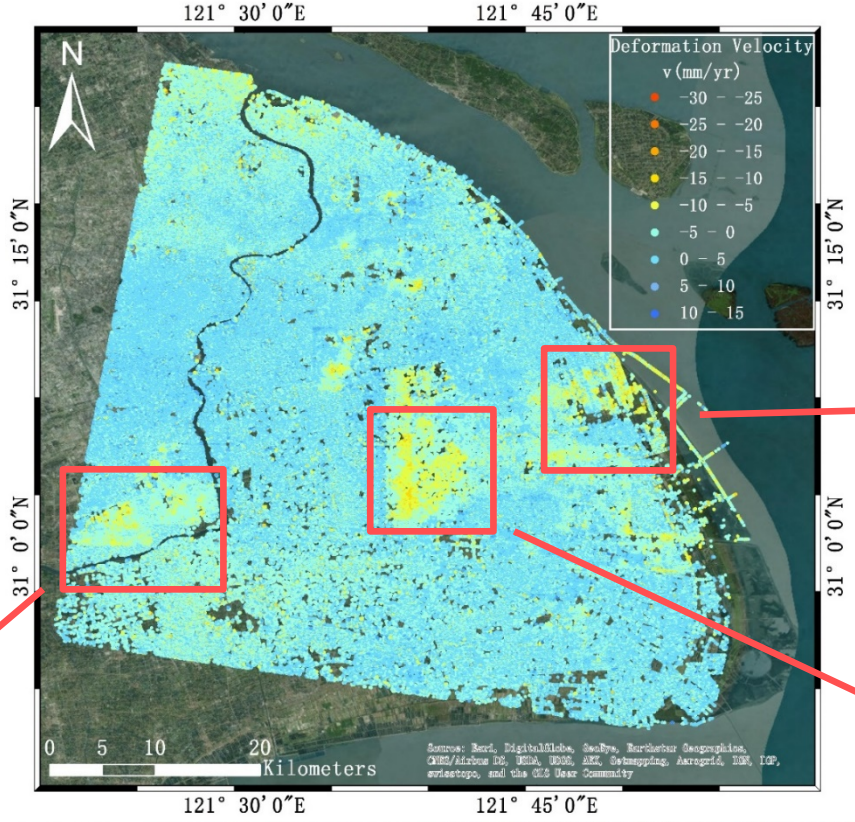
Disneyland

Meilong Town

Tangwan Town

2015 subsidence data from TerraSAR-X

2015.9-2016.10 TSX result (12+12 images)



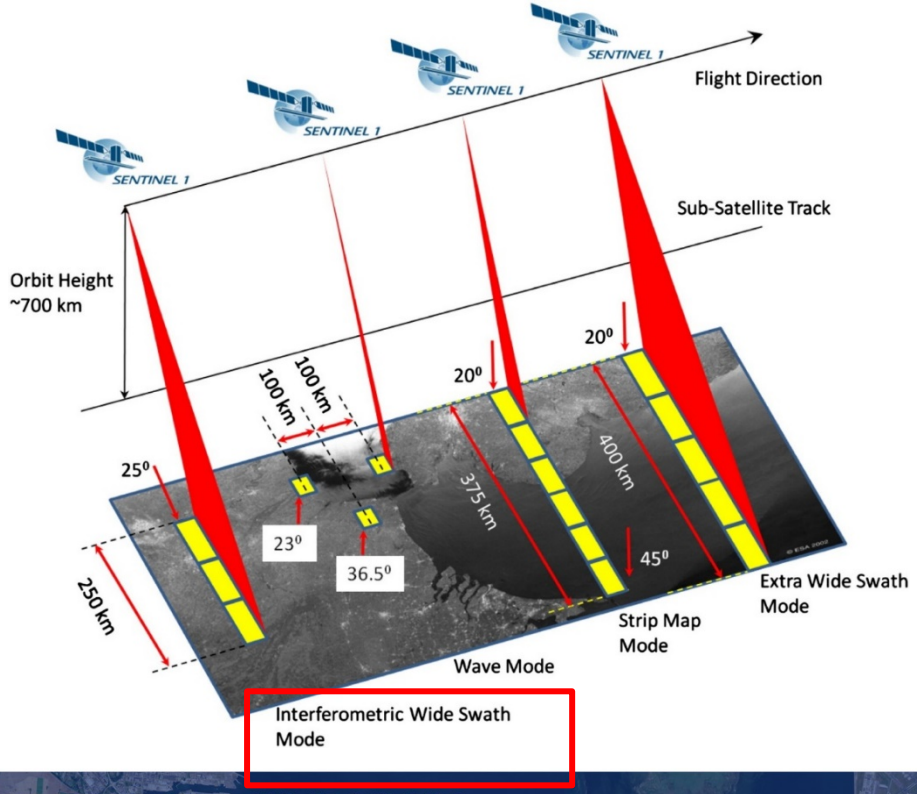
Pudong Airport

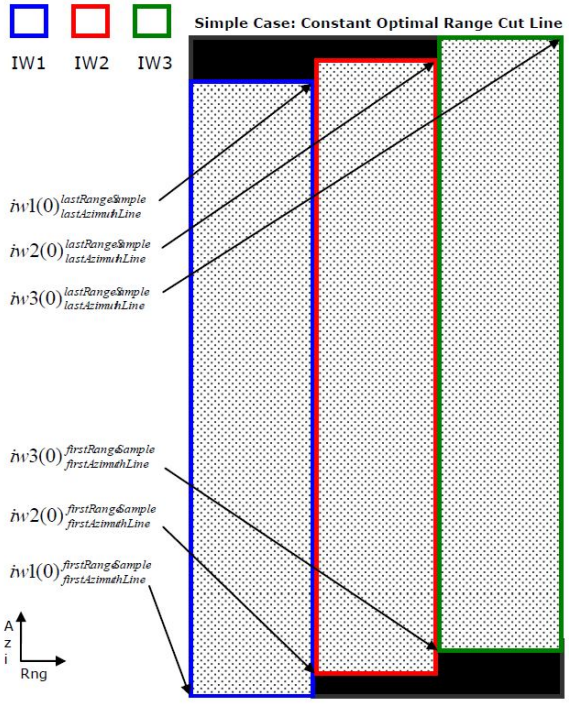
Wujing Town

Pujiang town and Zhoupu Town

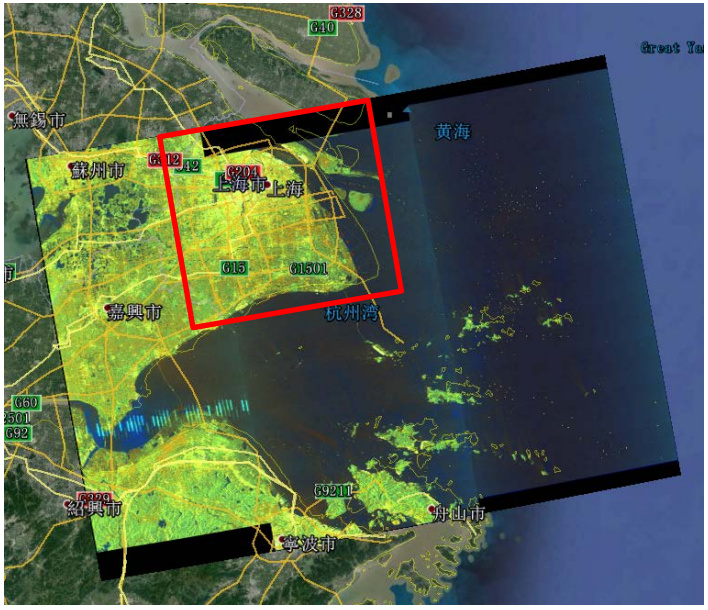
2016 subsidence data from TerraSAR-X

Sentinel-1 Acquisition modes





Data and results



Data coverage

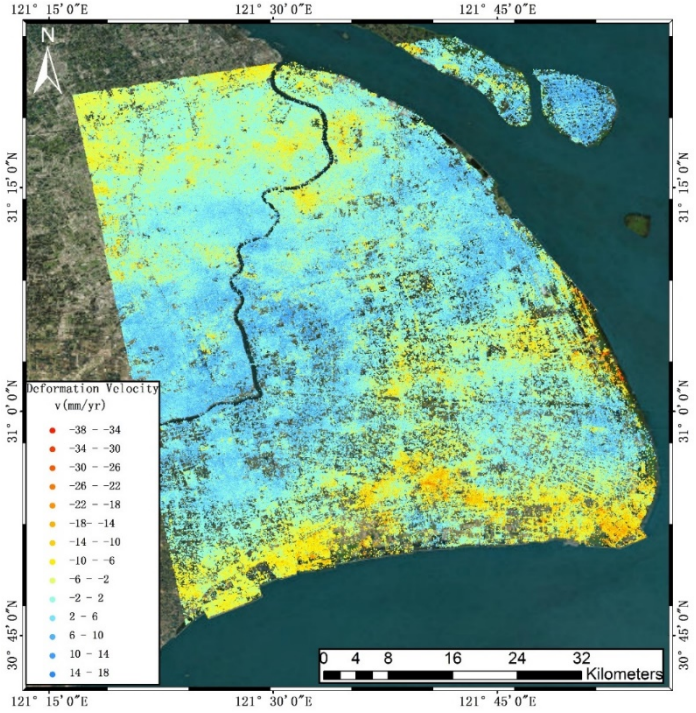
Shanghai subsidence

Pass:
Ascending

archives:
21 images

Dates:
2015-07-08~2016-10-30

Data and results



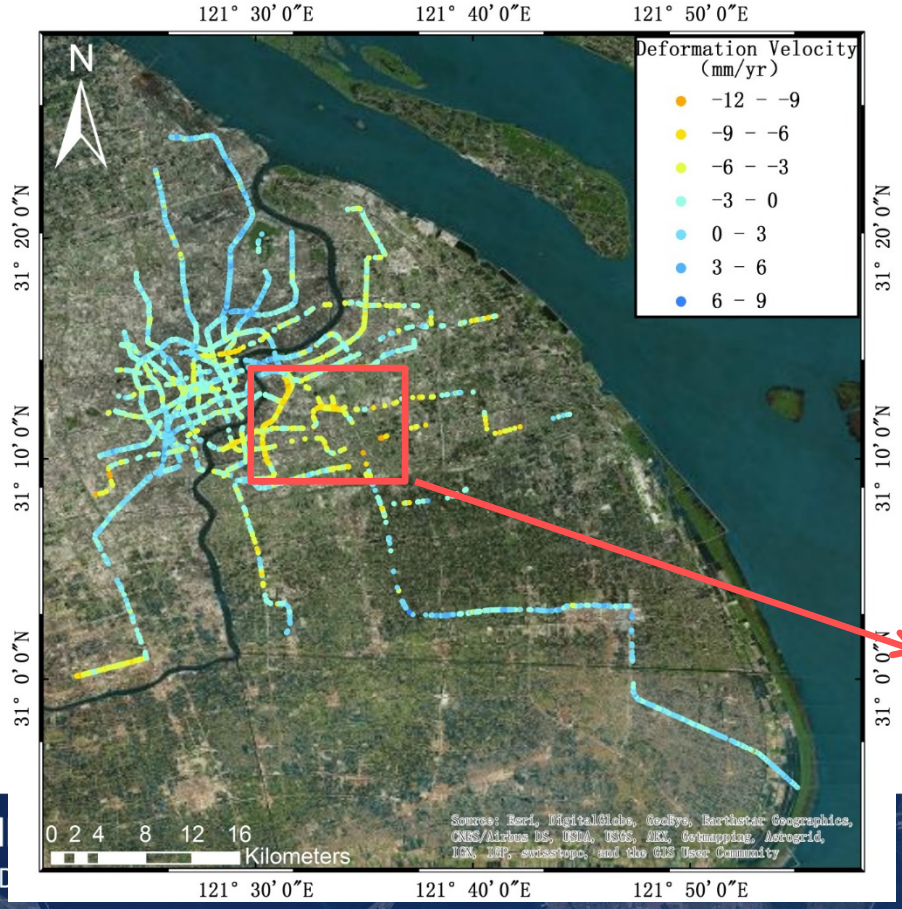
Shanghai subsidence

Pass:
Ascending

archives:
15 images

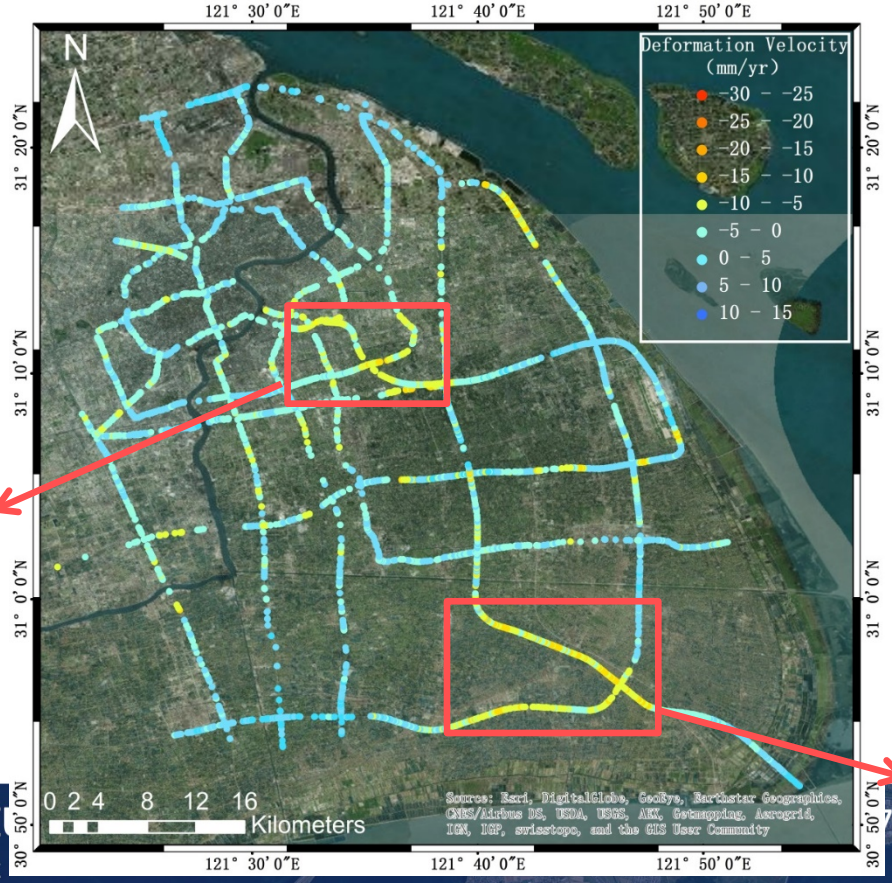
Dates:
2015-07-08~2016-07-26

Results of Subway Subsidence



ZhangJiang

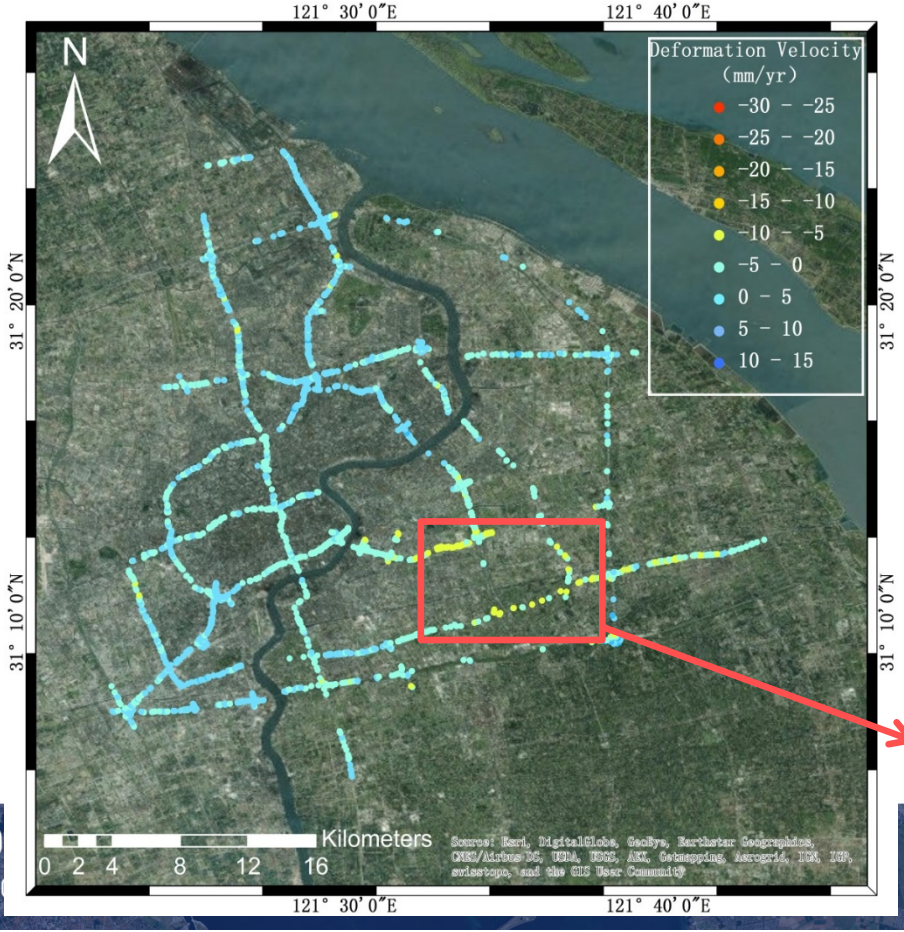
Results of Main Road Network



ZhangJiang

Situan Town

Results of Main Road Network



Elevated roads are more stable except a few sections within ZhangJiang settlement area

ZhangJiang

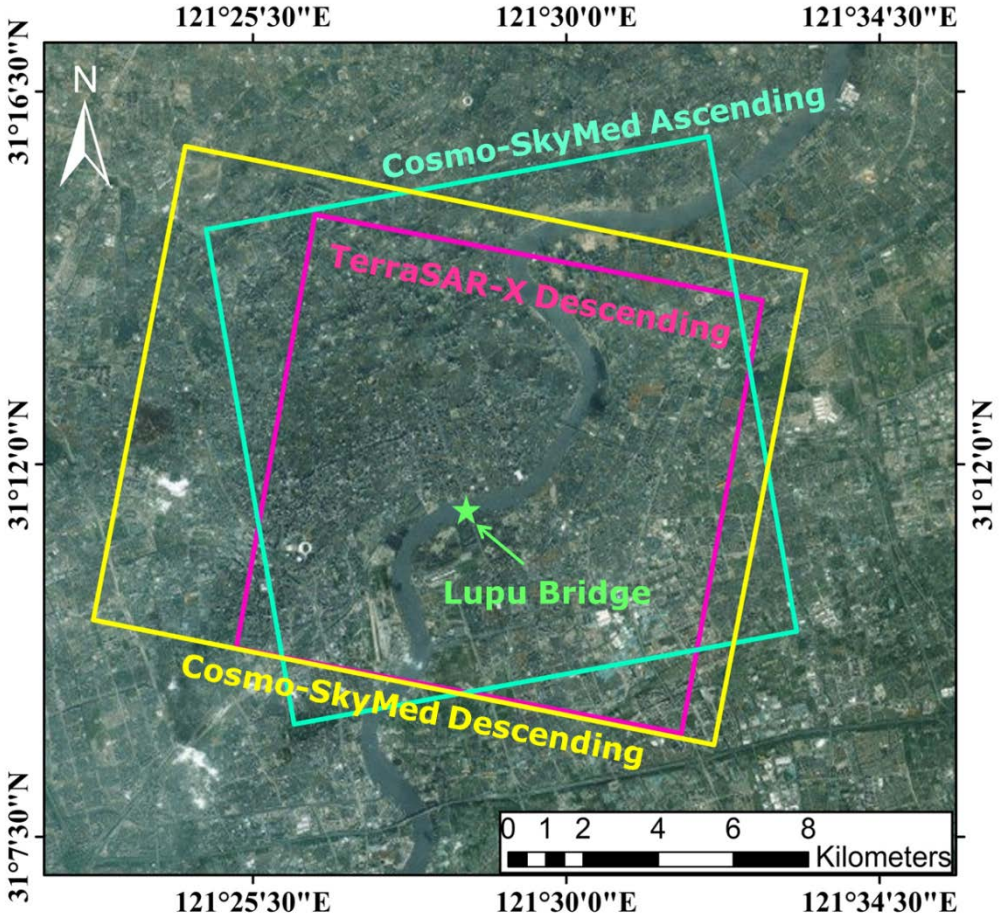
Lupu Bridge - landscape

The second longest span of steel arch bridge in the world

Take the main transportation tasks in and out of the Shanghai Expo Park

Famous Landmark in Shanghai

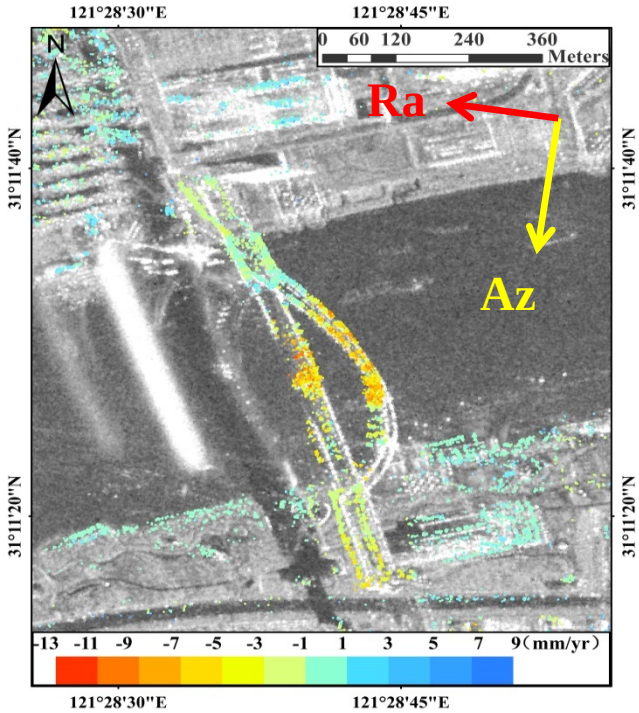
Lupu Bridge - Datasets



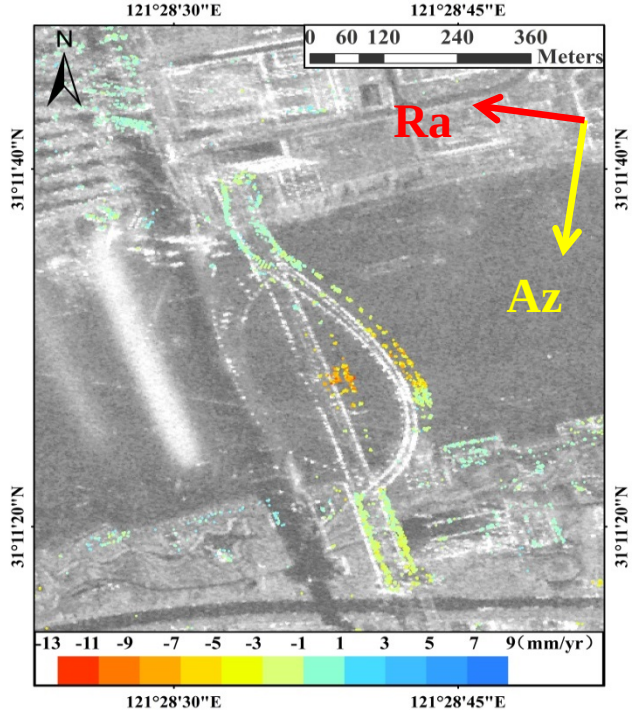
- *Lupu Bridge*
  - 550 m
  - Built:2000/10-2003/06
- *TerraSAR-X*
  - 18 descending images
  - 2009/03-2010/01
- *Cosmo-SkyMed*
  - 18 descending & ascending images
  - 2009/02-2010/01

Lupu Bridge - Results

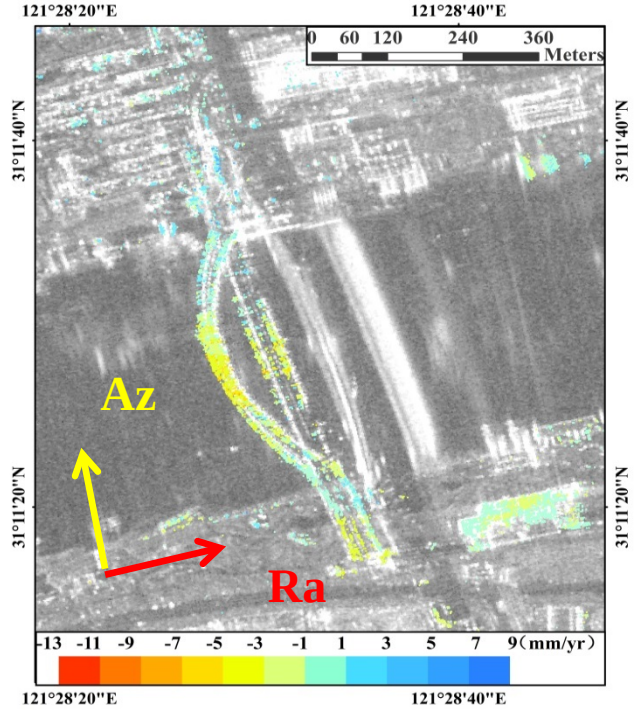
TerraSAR-X（Desc）



Cosmo-SkyMed（Desc）



Cosmo-SkyMed（Asc）

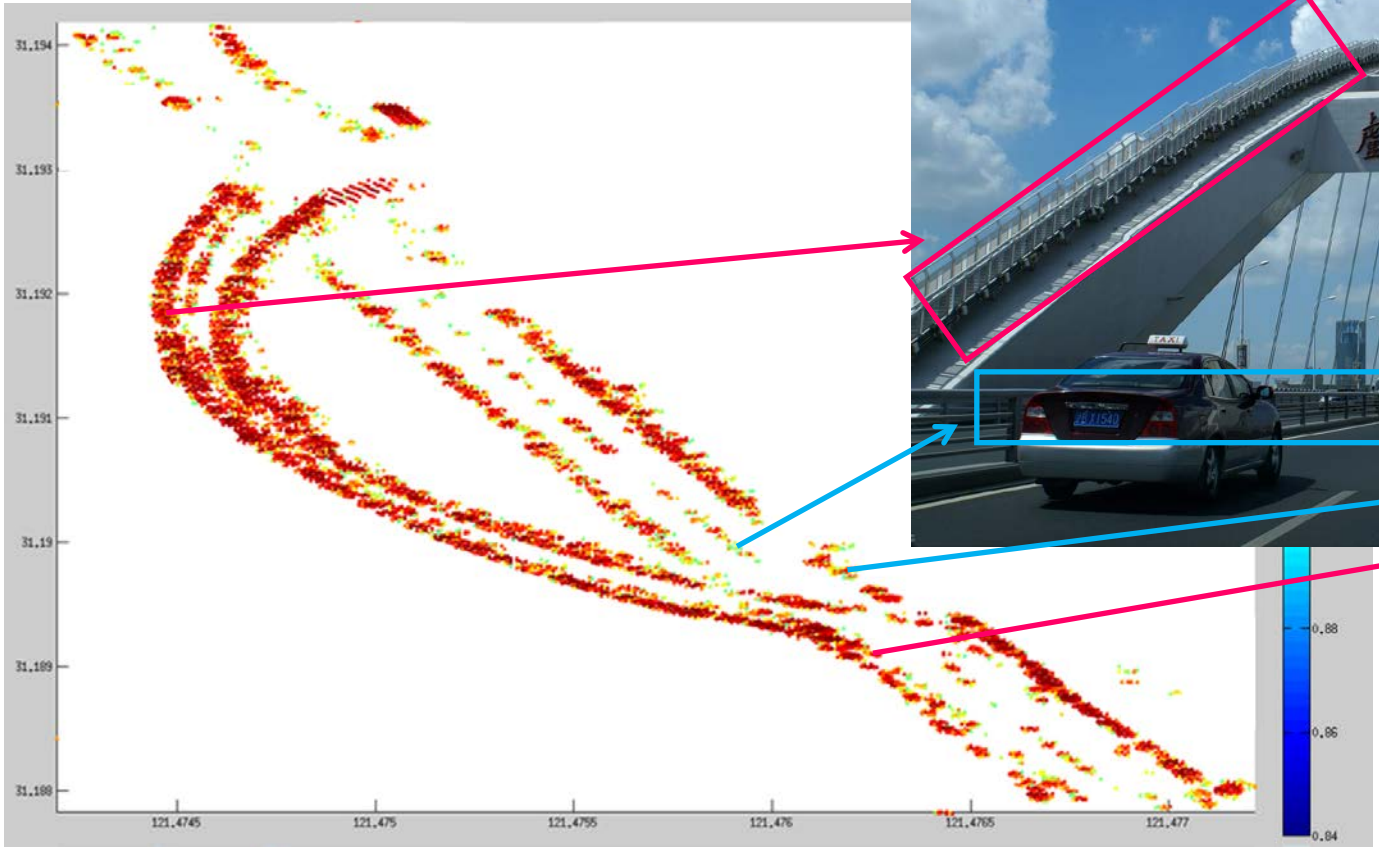


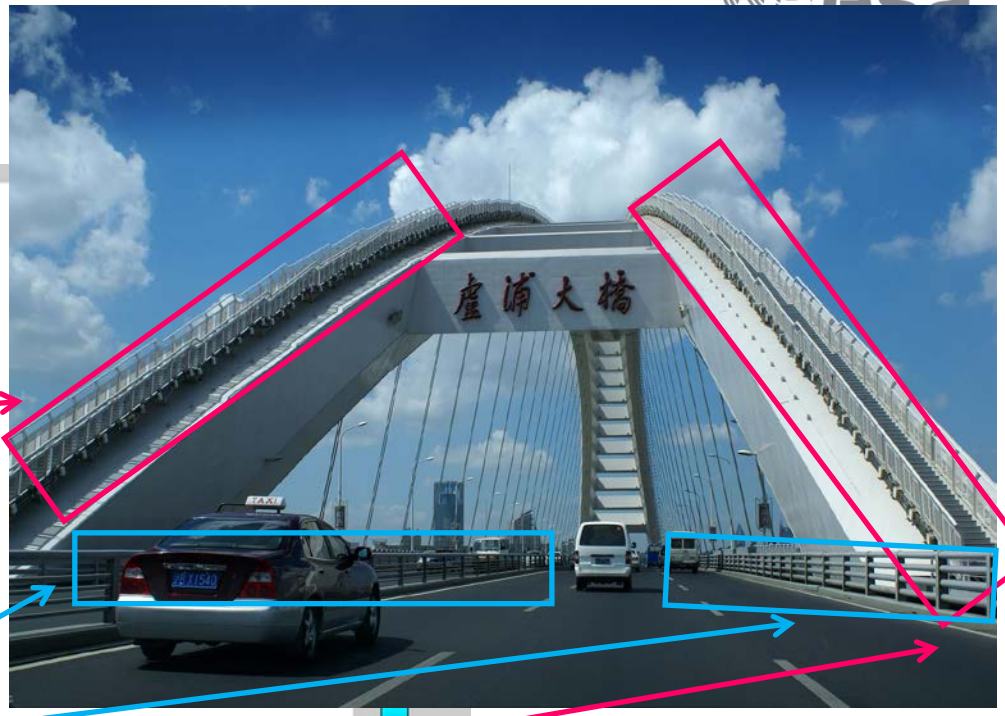
The same deformation patterns

Different incidence angles and acquisition dates lead to a little difference in LOS displacements

Lupu Bridge-Coherence

PTs Distribution



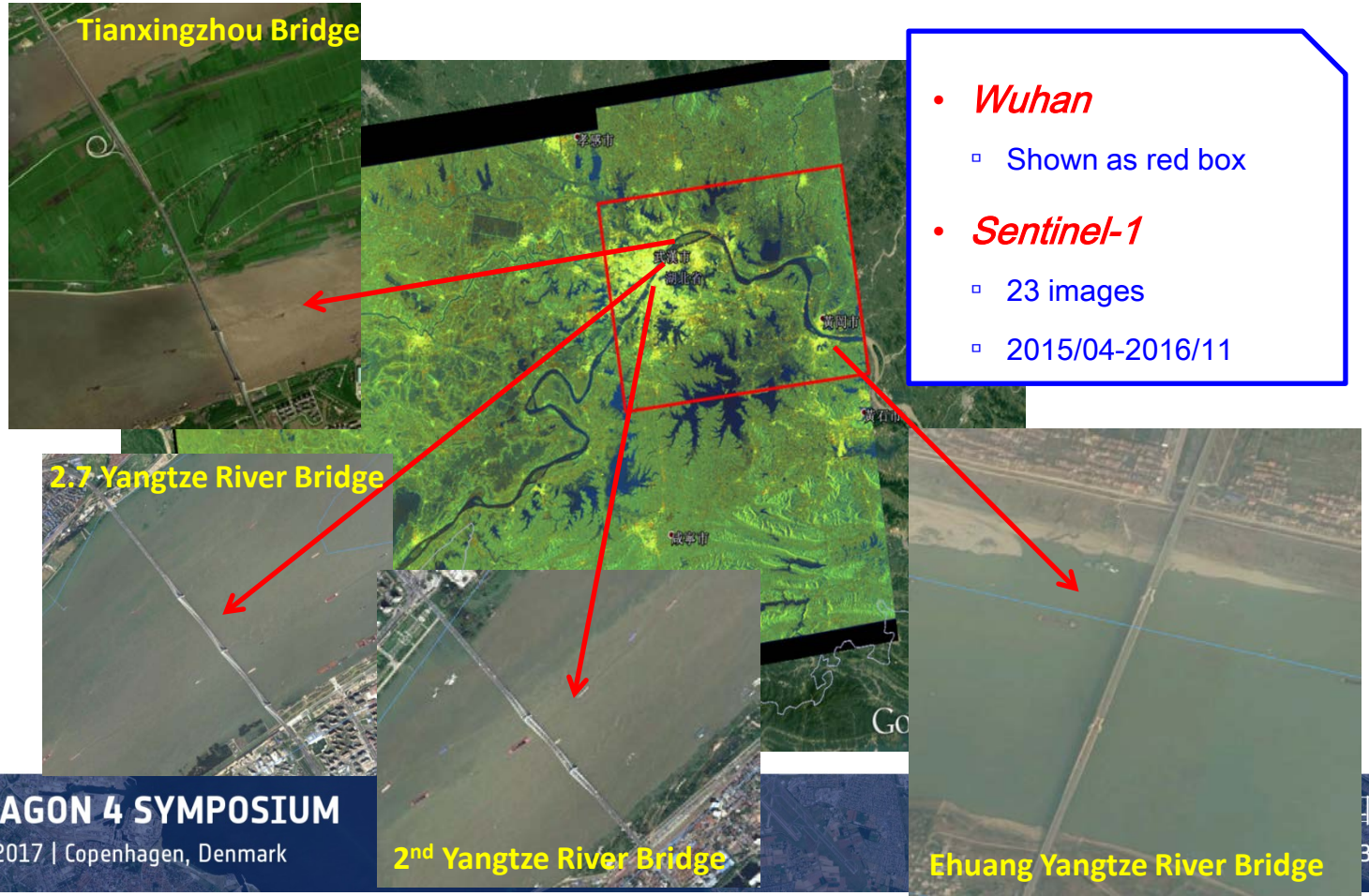


PTs on the Arch

PTs on the beam

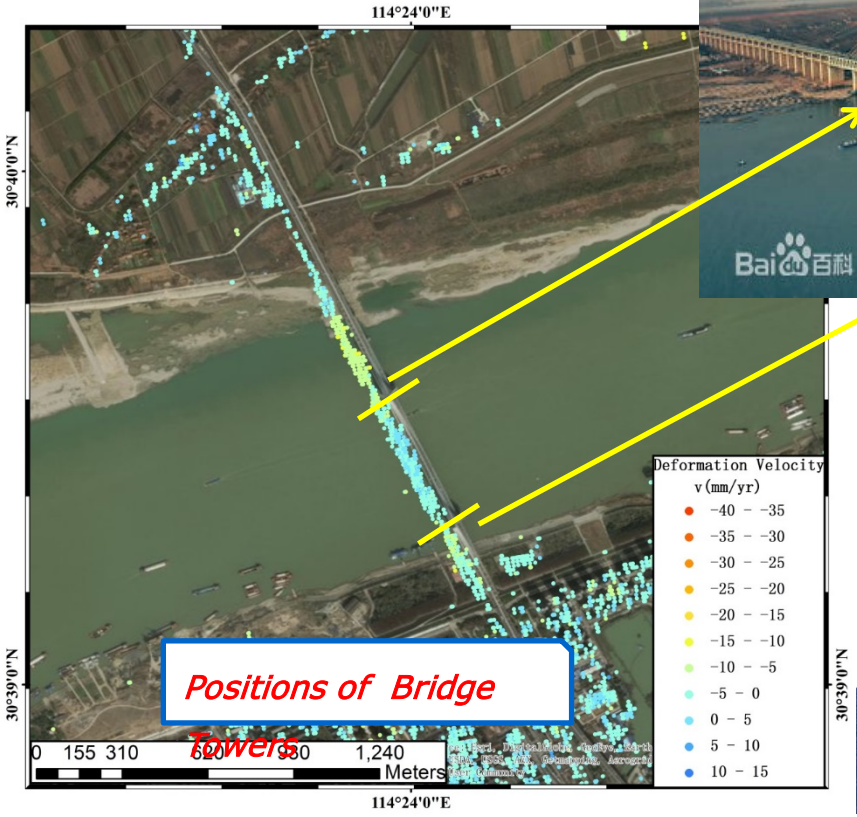
All from the railings

Data and Coverage，Wuhan



- *Wuhan*
  - Shown as red box
- *Sentinel-1*
  - 23 images
  - 2015/04-2016/11

Tianxingzhou Bridge Results



- *Wuhan*
  - Tianxingzhou Bridge
  - Built:2004/09-2008/09

Research activities & Results – Part III

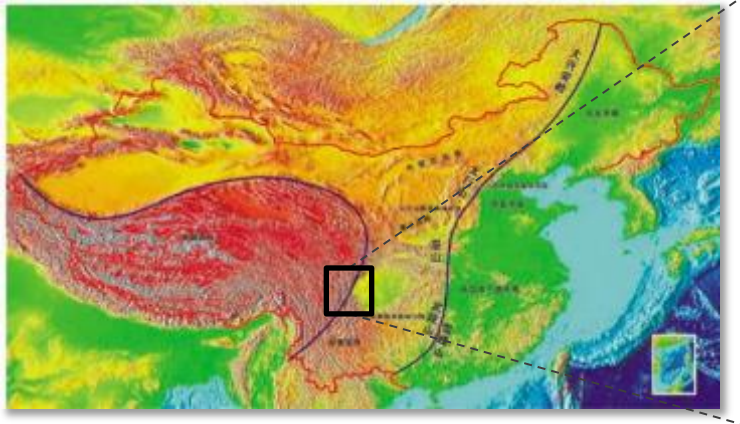
Landslide Displacement Monitoring by InSAR

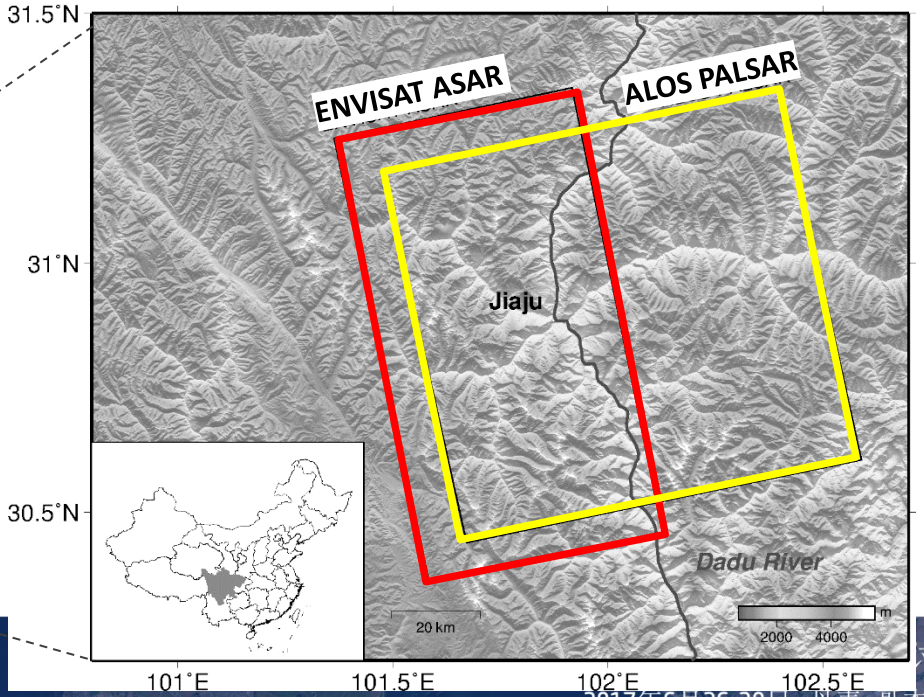
Analyses with Persistent and Distributed Scatterers

Case Study of Danba County, China

Study Area

- The zone of first step extending to second step of the China's three ladders
- The upper reach of Dadu River in Danba County, West of China
  - **Steep and forested terrains**
  - **Active tectonic movements**
  - **Frequent geological hazards**



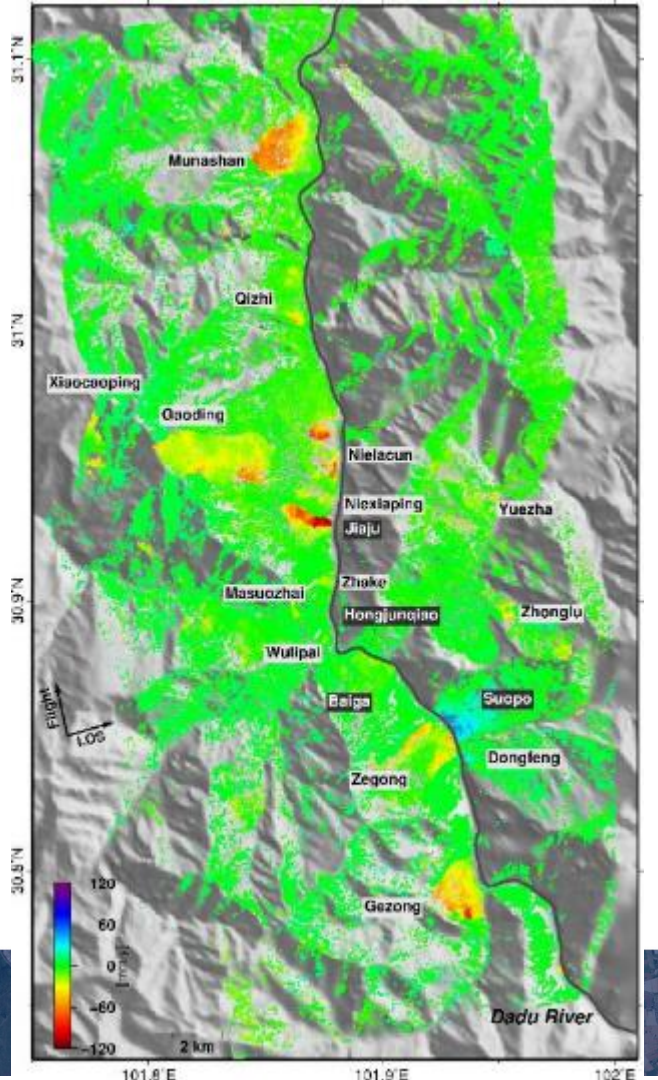


Wide-area landslides detection

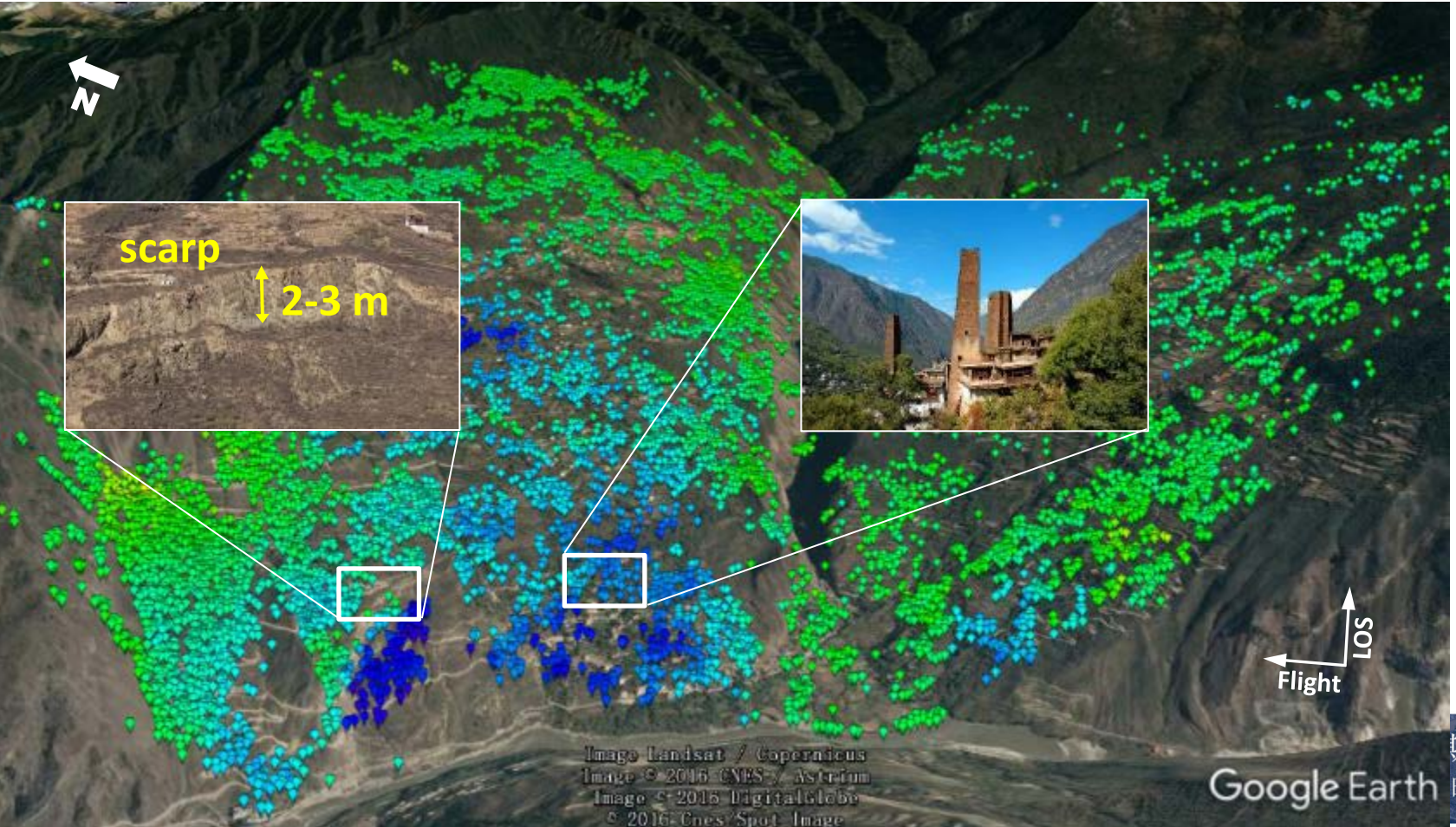
LOS deformation rate map derived by DSI from PALSAR (2006-2011)

- More than 4,000,000 measurement points (MPs) identified over an area of 1,000 km^2
- A spatial density of over 4,000 MPs/km^2
- 16 landslides detected along the Dadu River

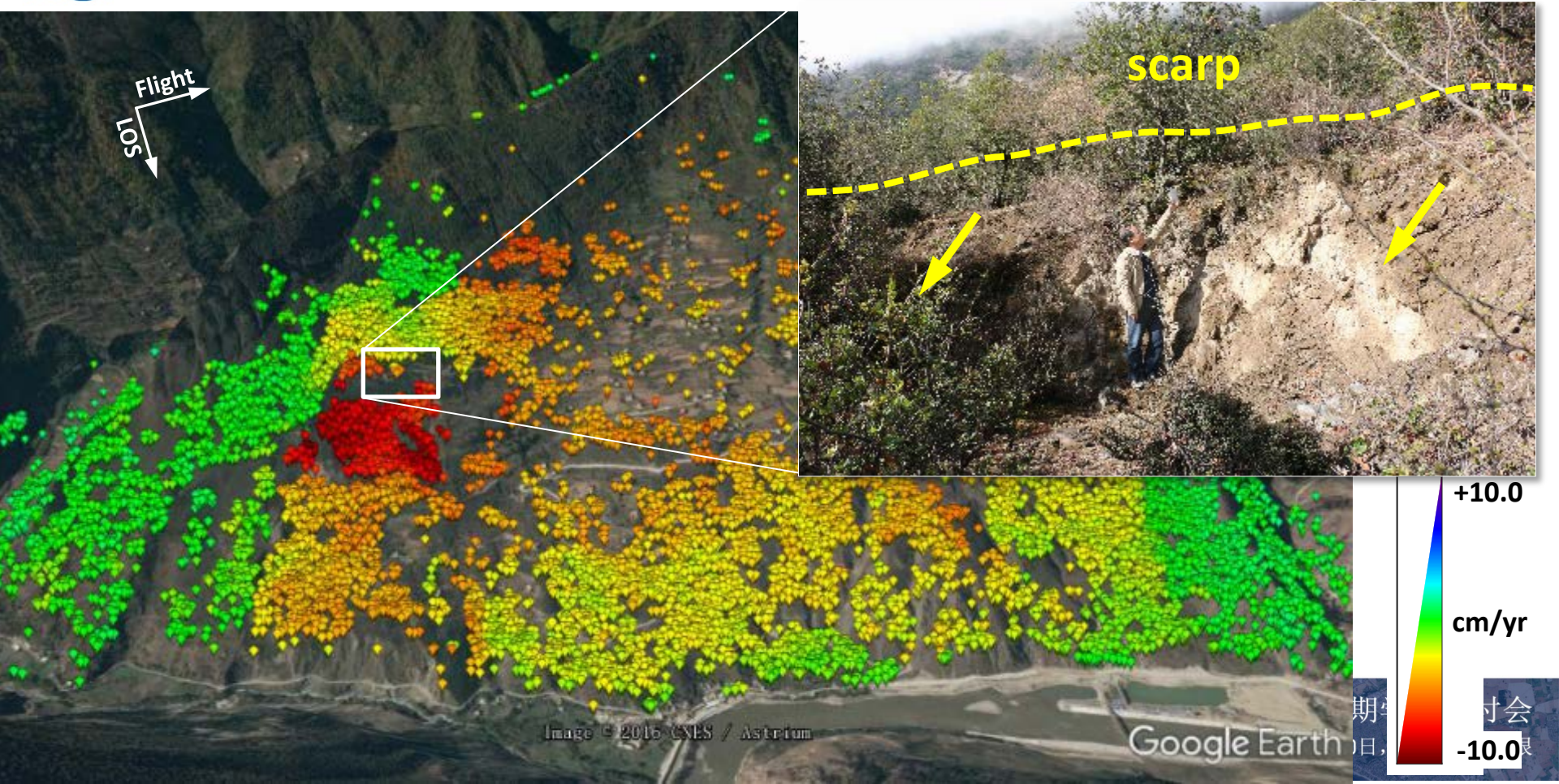
field survey



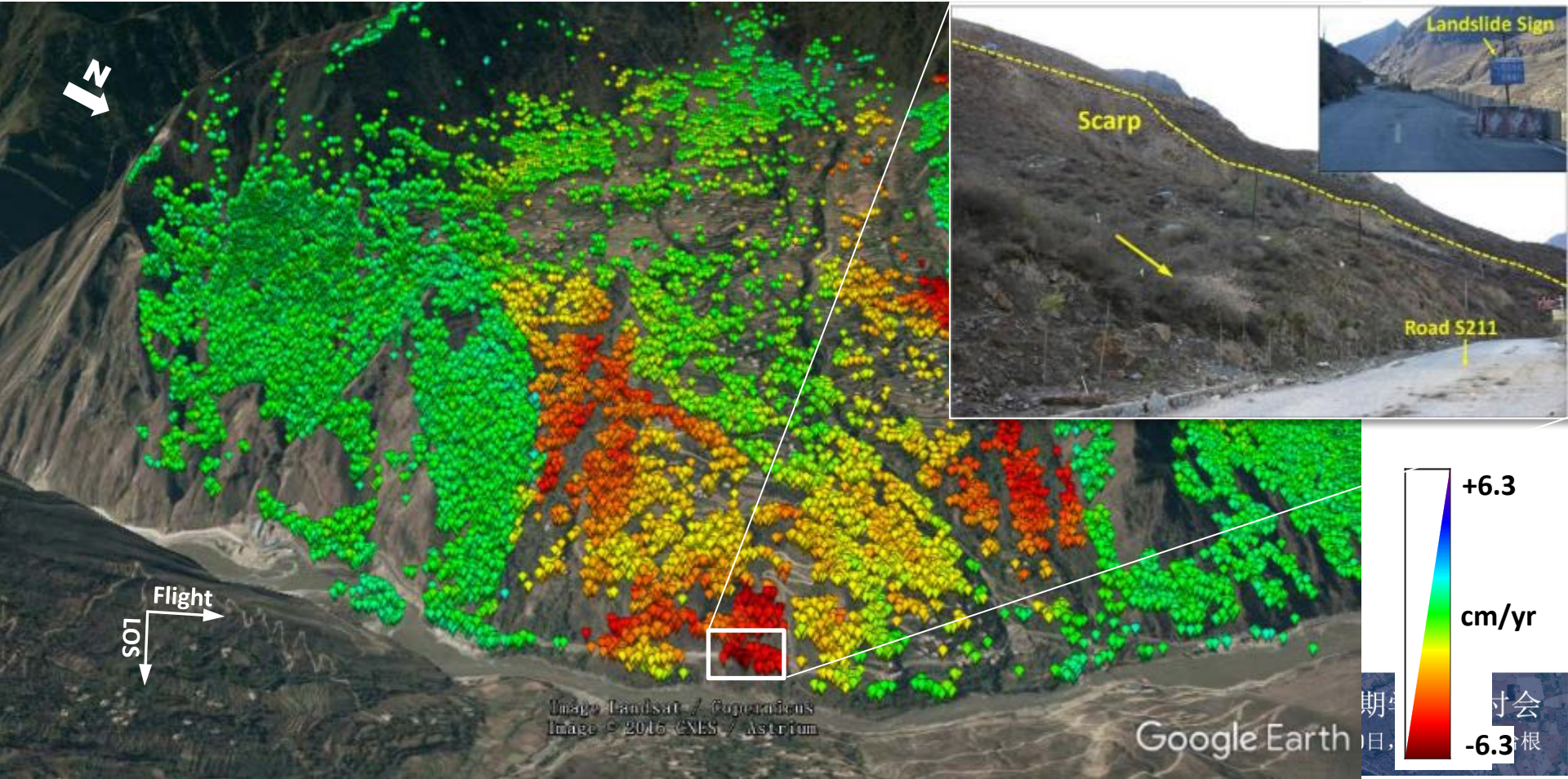
Results – Suopo landslide



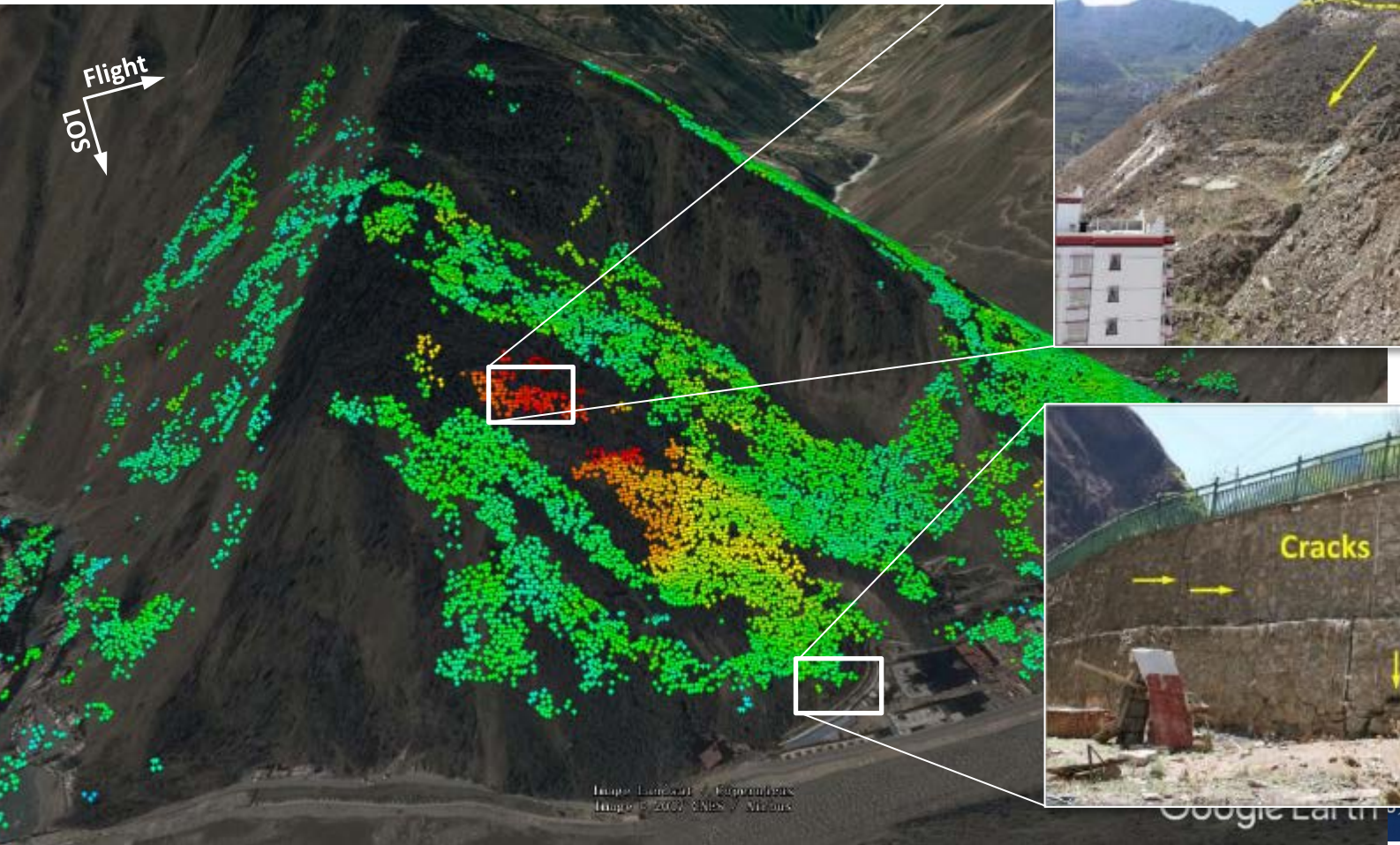
Results – Gezong landslide



Results – Zegong landslide



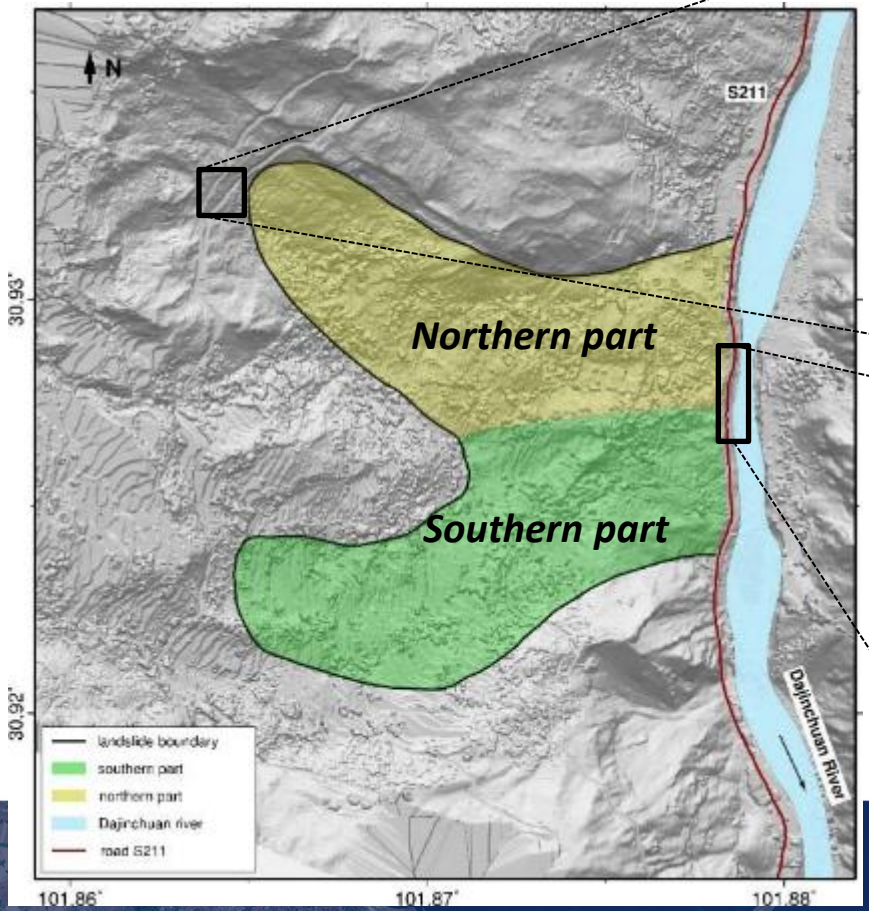
Results – Wulipai landslide

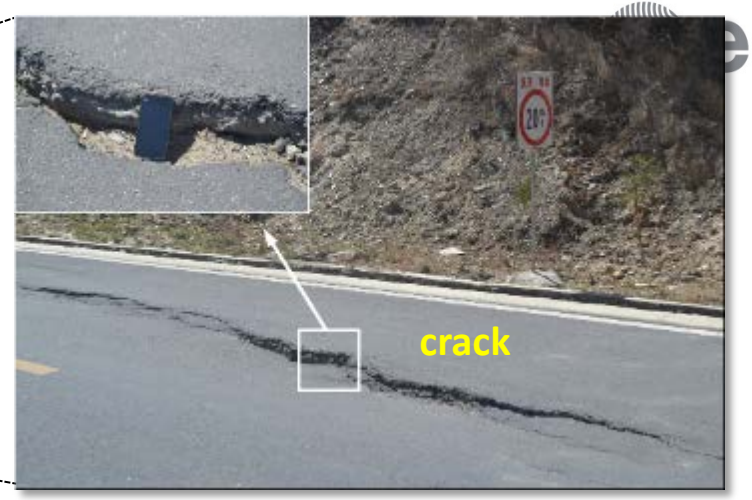


Jiaju Village

- A well-known Tibetan style village
- One of the most beautiful villages in China

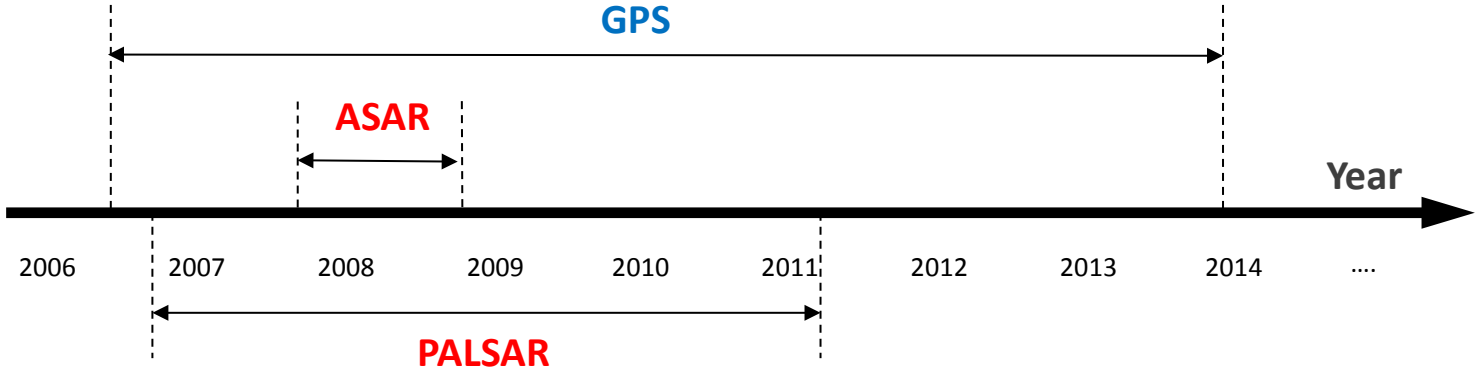
Study Area - Jiaju landslide





- Two
- Roa

Data



SAR images:

- L-band ALOS PALSAR: Ascending, 19 images, Dec-2006 - Jan-2011
- C-band ENVISAT ASAR: Ascending, 9 images, Aug-2007 - Jun-2008

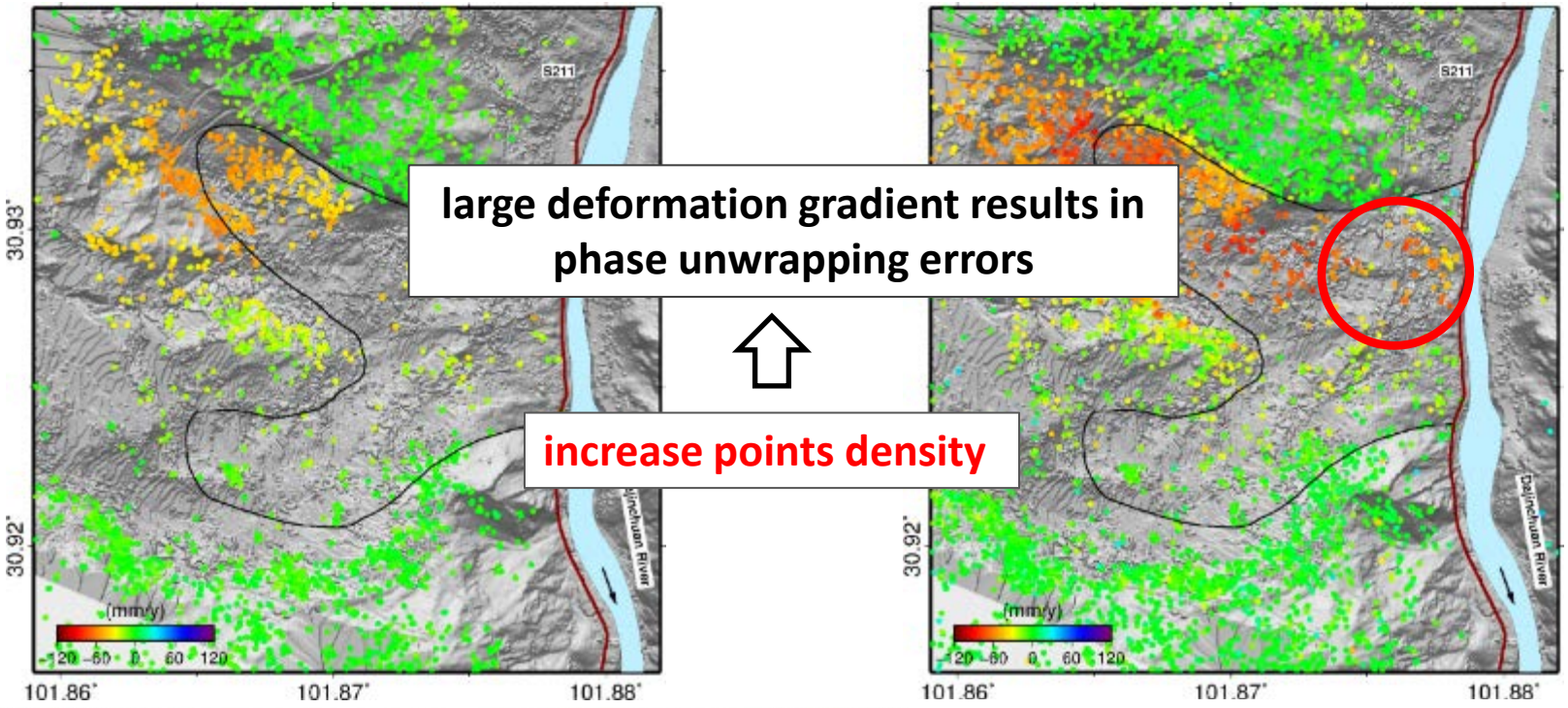
GPS observations for Jiaju landslide:

- 20 monitoring + 2 reference stations
- Trimble 5700 GPS receivers
- Aug-2006 – Dec-2013

Challenges of conventional time series InSAR

PSI

SBAS



large deformation gradient results in phase unwrapping errors

increase points density

rural area, very few PS points

more points but still underestimation according to the GPS measurements

Method - DSI

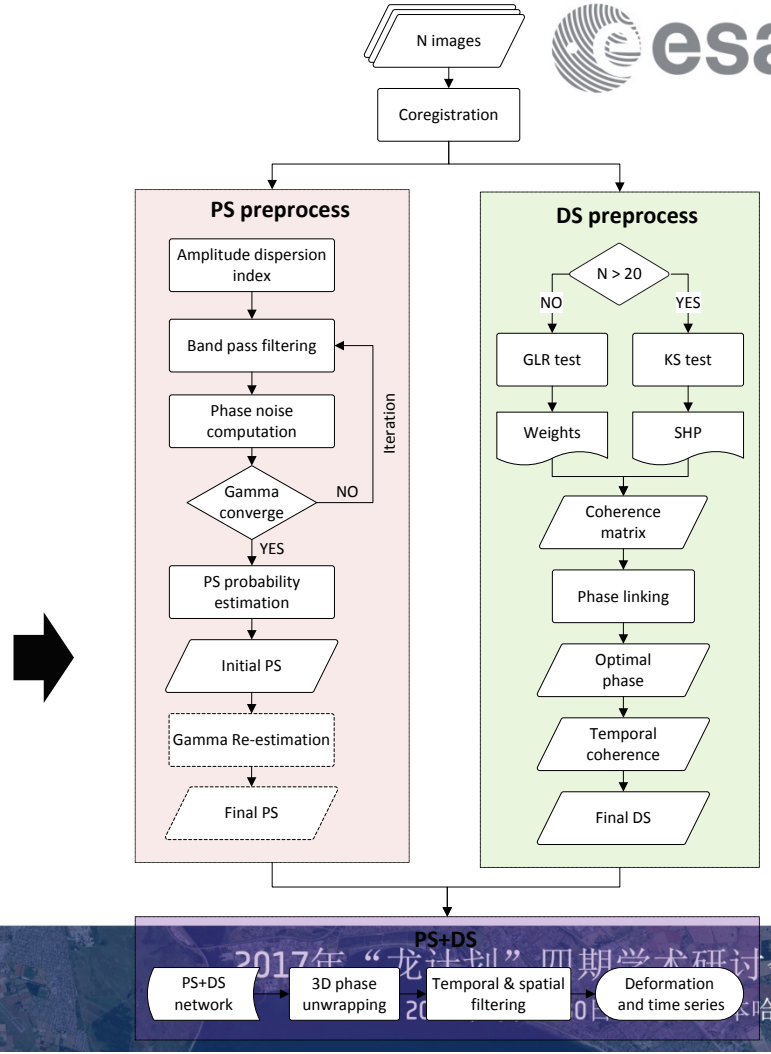
DSI method:

Persistent Scatterers (PS) +
Distributed Scatterers (DS)

(1) PS preprocessing:
StaMPS/PSInSAR

(2) DS preprocessing

(3) Combination analysis of PS and DS
standard time series analysis



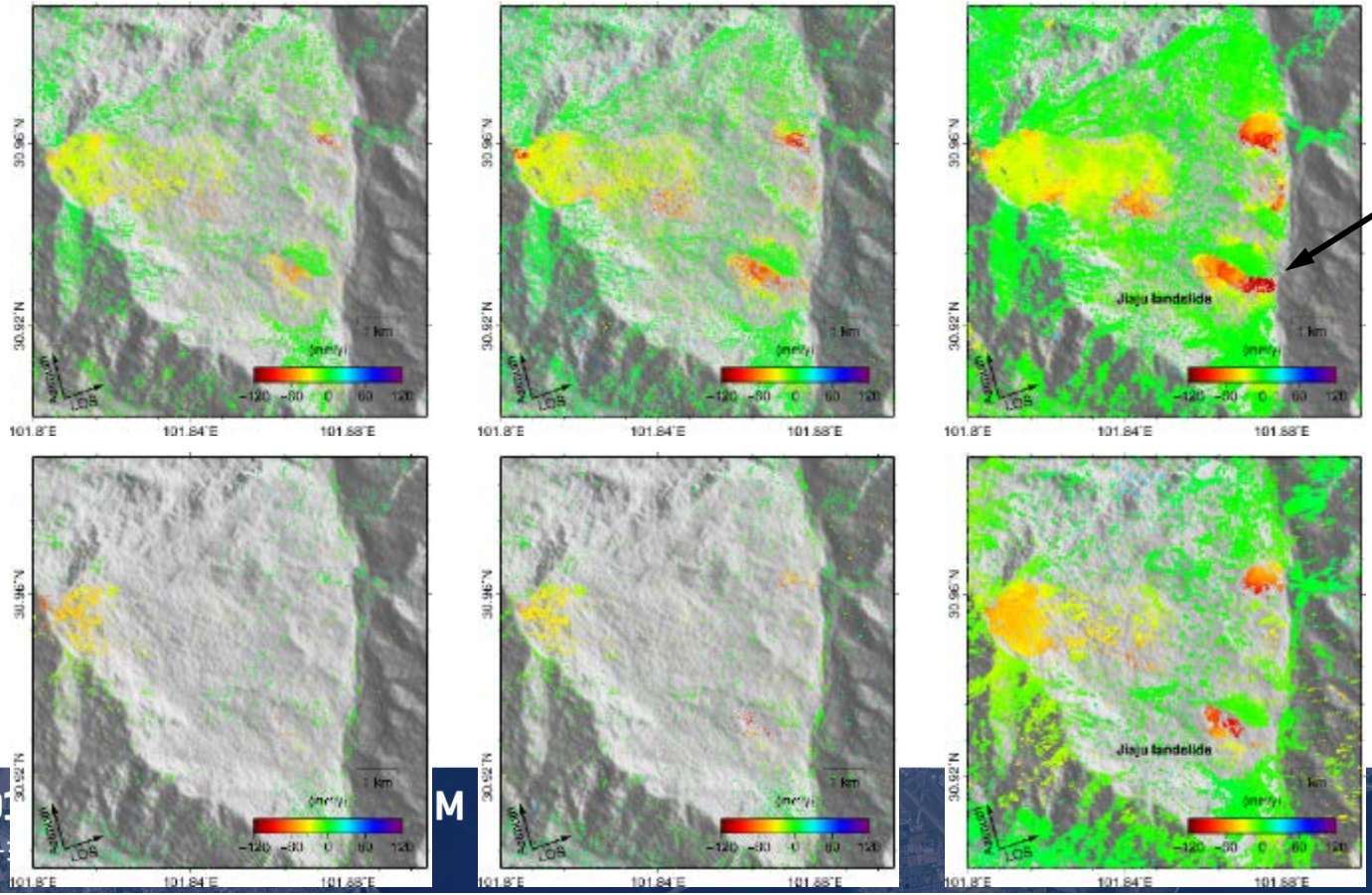
Ferretti et al, 2011, IEEE TGRS
Pariizzi, 2011, IEEE GRSL
Monti Guarnieri et al, 2008, IEEE TGRS

LOS Deformation rate

PSI | SBAS | DSI

PALSAR

ASAR



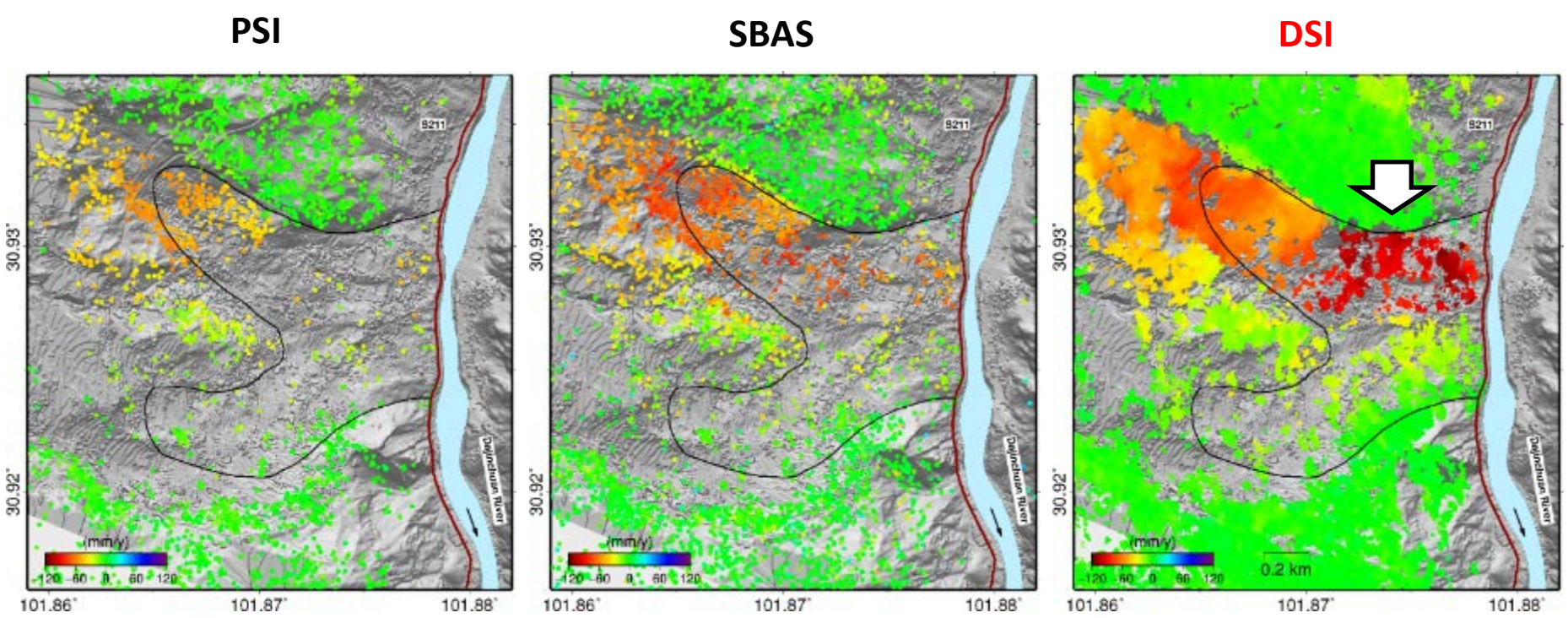
Jiaju landslide

	Spatial density (MPs/km²)	
	PALSAR	ASAR
PSI	323	44
SBAS	498	107
DSI	4,973	1,093

PSI & SBAS: StaMPS

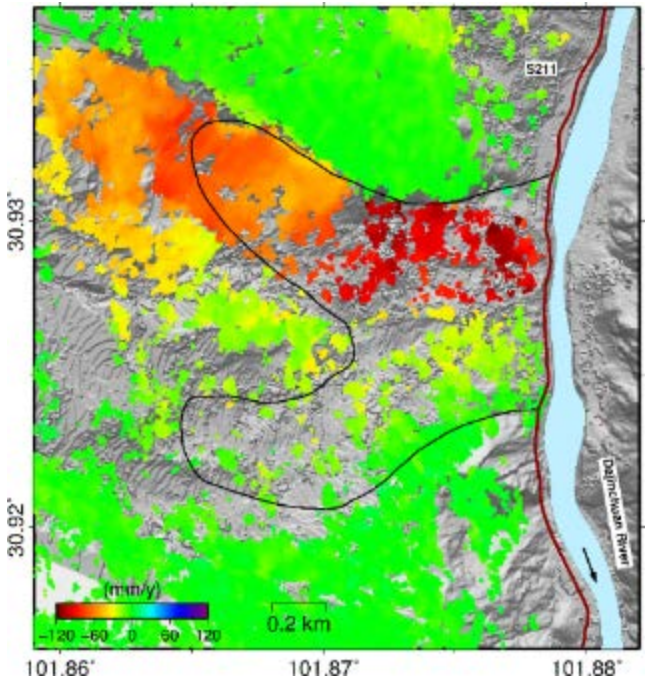
Jiaju landslide

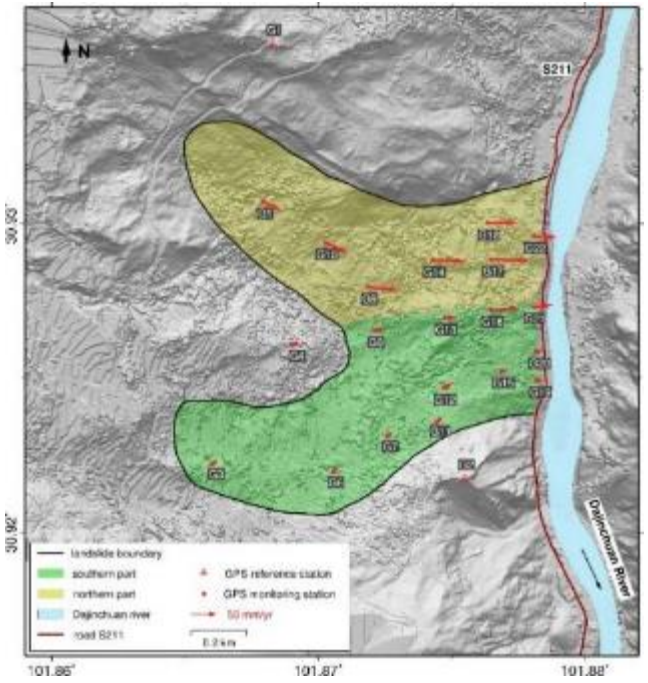
Results from PALSAR dataset



Evaluation of DSI

Validation with GPS measurements





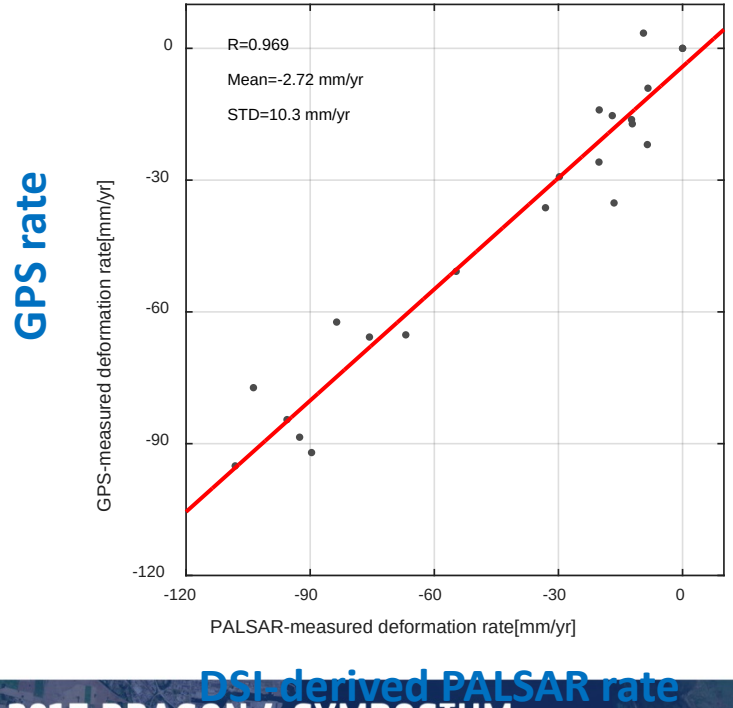
- The northern part (120 mm/yr) moved much faster than the southern part
- The foot moved faster than the head
- InSAR results agree well with GPS results

DSI derived PALSAR rate

GPS rate

Evaluation of DSI

Validation with GPS measurements



- The correlation between DSI-derived PALSAR rate and GPS rate on the GPS stations is **0.96**
- The mean difference is **-2.7** mm/yr
- The STD of the differences is **10.9** mm/yr

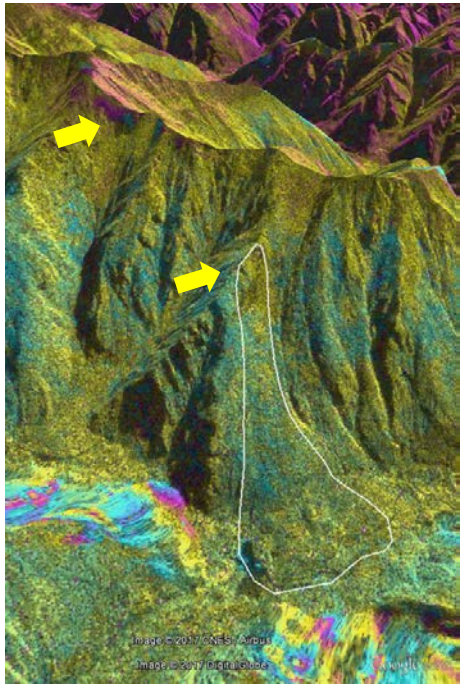
A Large landslide happened in Mao County on the morning of 2017-06-24

More than 100 people are missing

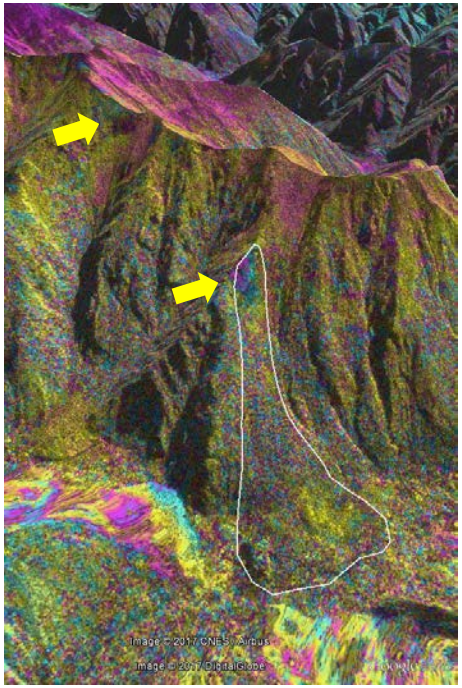
D-InSAR results from ALOS-2 PALSAR-2 data

ALOS-2 PALSAR-2 descending

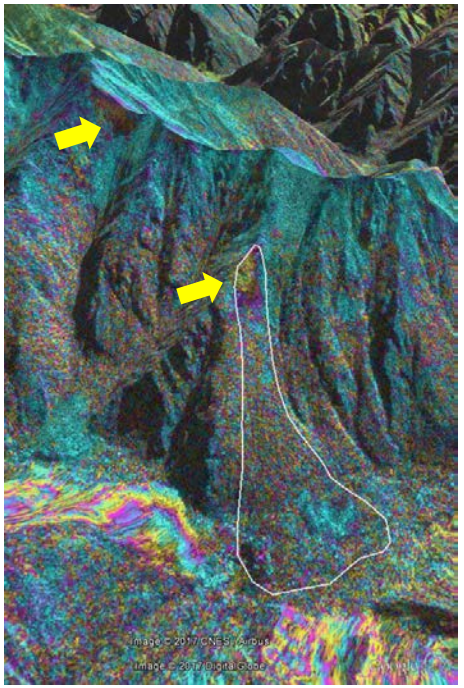
20150606-20150620
14 days, Bp:108m



20150606-20170617
742 days, Bp:91m

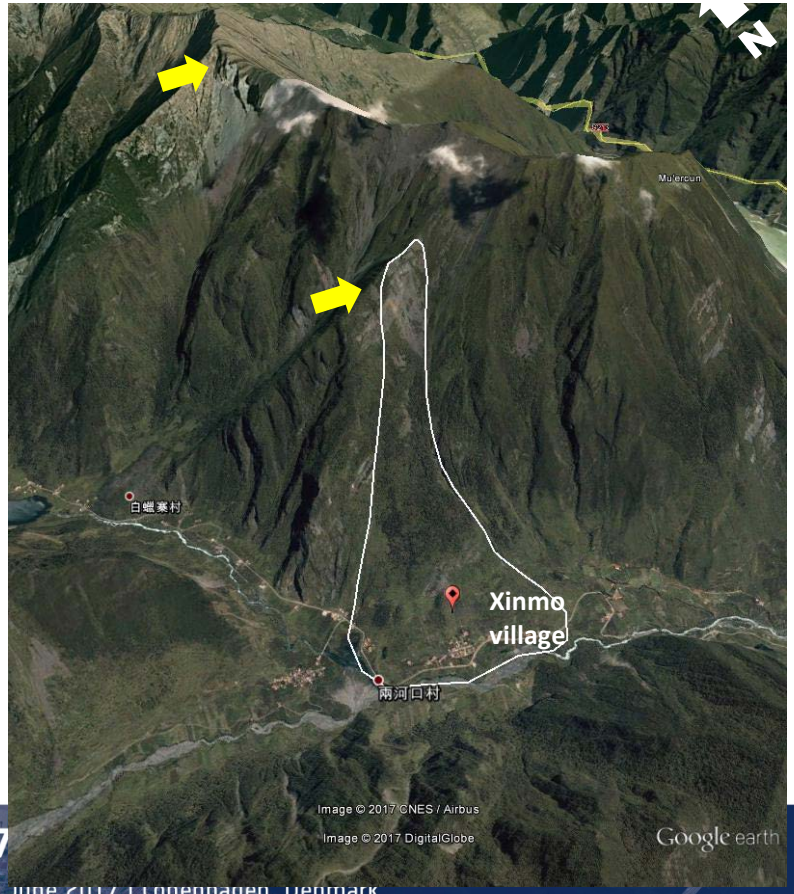


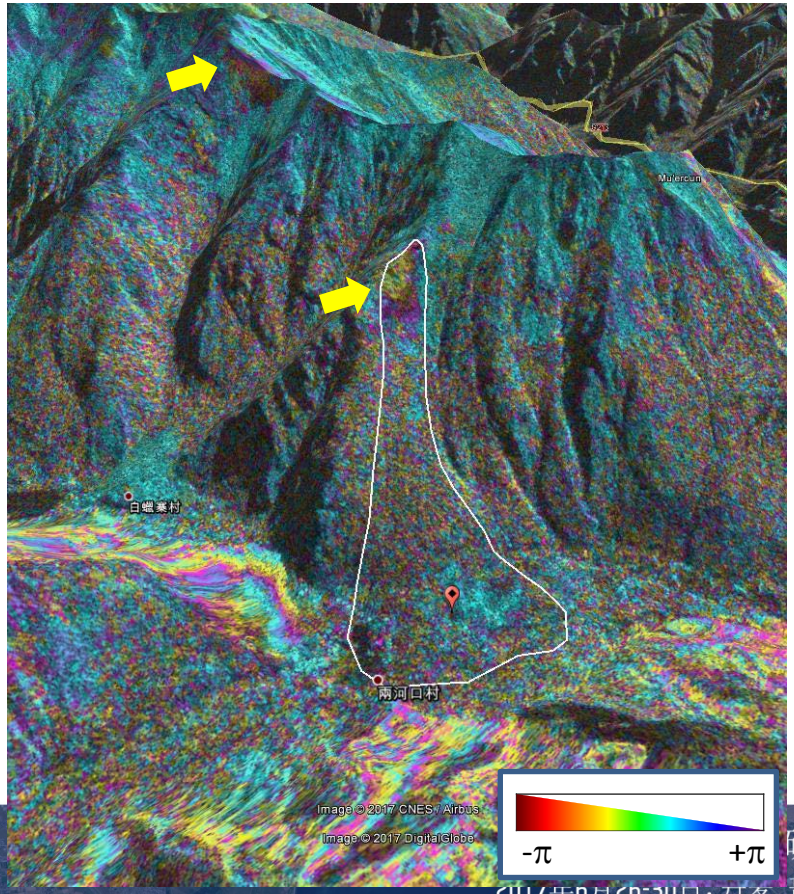
20150620-20170617
728 days, Bp:199m



ALOS-2 PALSAR-2 descending

20150620-20170617

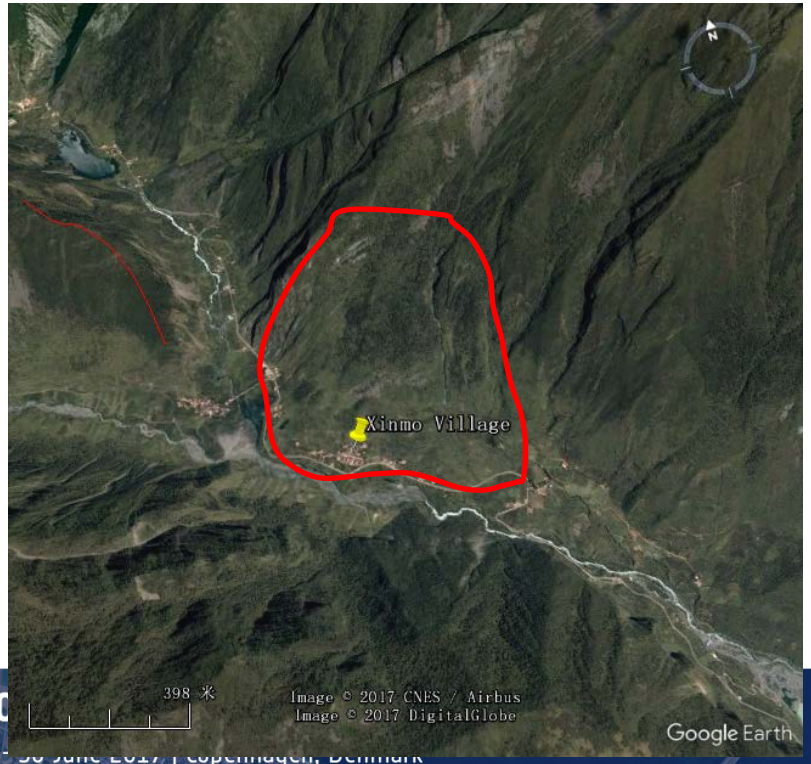




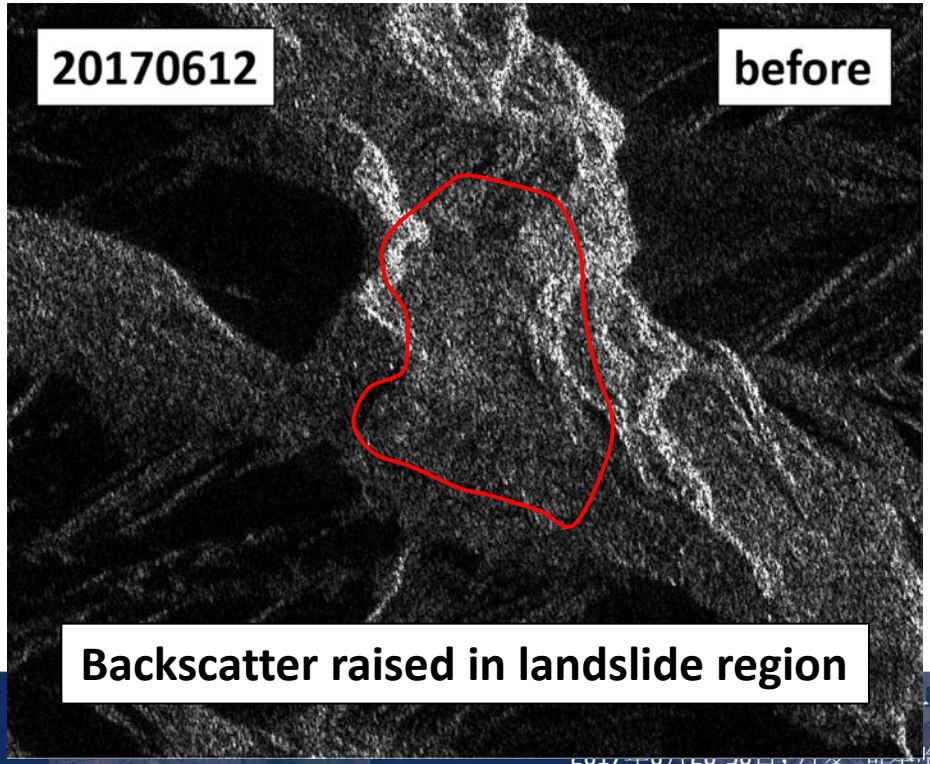
D-InSAR results for Sentinel-1 data

Sentinel-1 ascending

Google Earth™ image

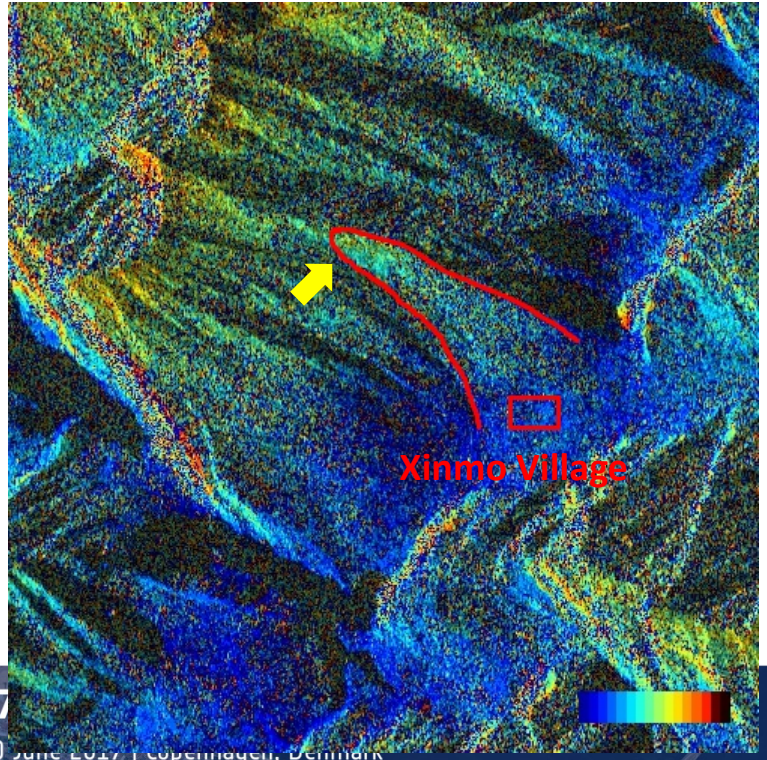


Amplitude change

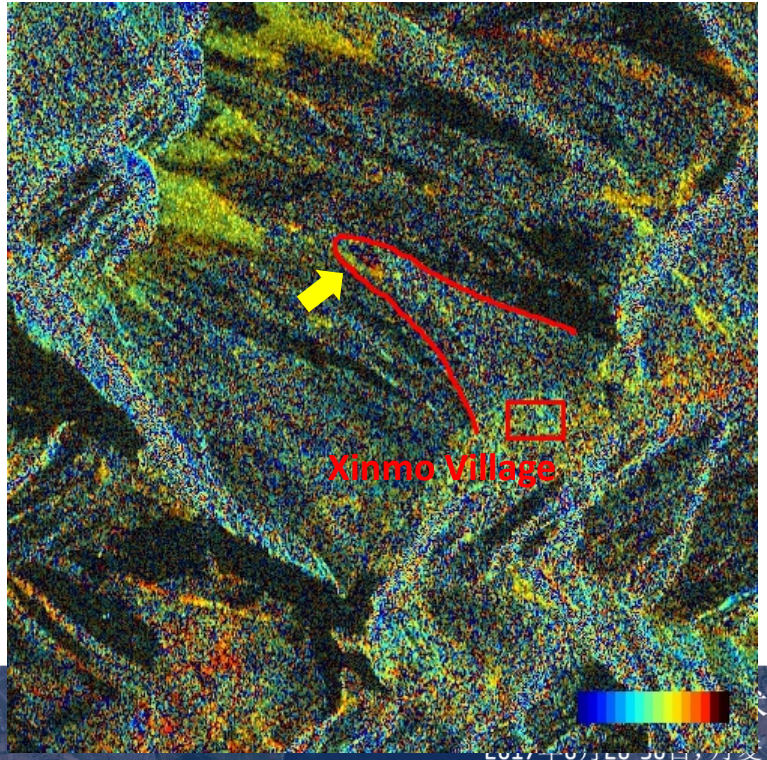


Sentinel-1 descending

20170315-20170327



20170607-20170619



Summary for monitoring landslides

- DSI can detect wide-area landslides and monitor local-scale landslides with high precision.

- More points are detected by DSI than PSI and SBAS.

- DSI and L-band SAR data are more suitable for landslide monitoring in vegetated terrains.

Conclusion

- High-resolution stereoSAR was used to improve the quality of InSAR DEM in vegetated hilly areas.
- HR&MR SAR data stacks were applied for monitoring urban subsidence and infrastructures. The results from Sentinel-1 data were effective for observing the bridge deformation.
- DS-InSAR was used with PS-InSAR for monitoring landslide stability. The preliminary InSAR results are promising in steep & vegetated mountainous areas.

Thanks !

Bird viewing Mount Song, China