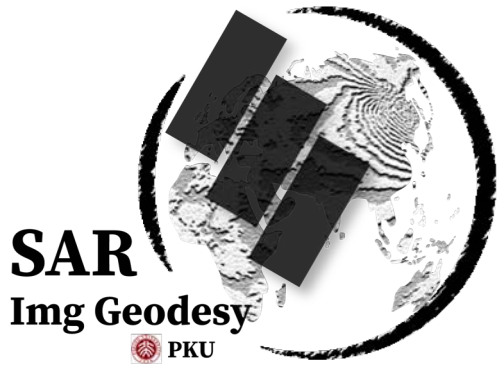




Deep learning facilitated local deformation monitoring with large-scale SAR interferometry

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<http://sarimggeodesy.github.io>

1. School of Earth and Space Sciences, Peking University
2. State Key Laboratory of Information Engineering in Surveying, Mapping, and Remote Sensing, Wuhan University
3. Department of Space Microwave Remote Sensing System, Aerospace Information Research Institute, Chinese Academy of Sciences

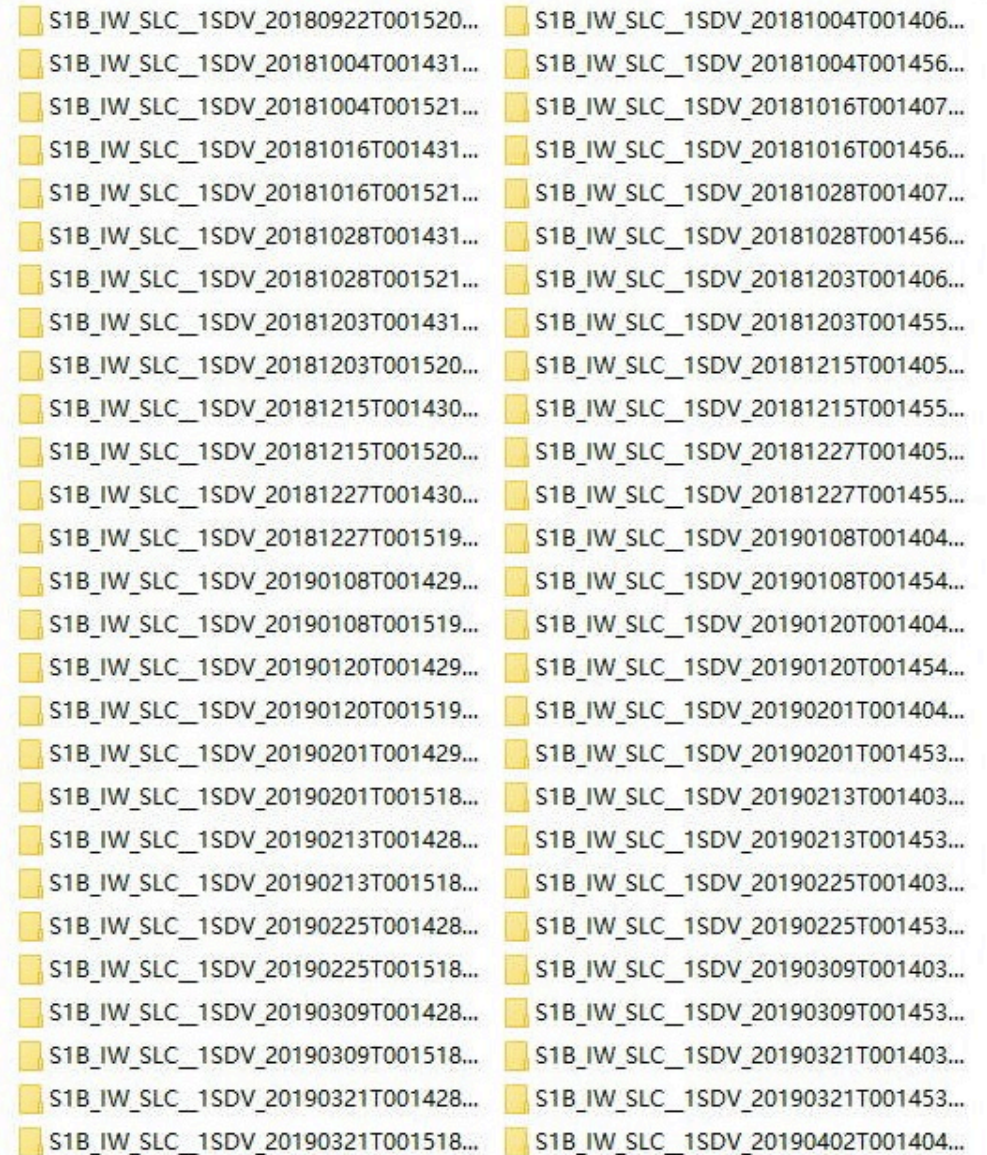
Big
Data

Large
Scale

AI

Big Data

- More satellites
- Shorter repeating time
- Higher resolution



S1B_IW_SLC_1SDV_20180922T001520... S1B_IW_SLC_1SDV_20181004T001406...
S1B_IW_SLC_1SDV_20181004T001431... S1B_IW_SLC_1SDV_20181004T001456...
S1B_IW_SLC_1SDV_20181004T001521... S1B_IW_SLC_1SDV_20181016T001407...
S1B_IW_SLC_1SDV_20181016T001431... S1B_IW_SLC_1SDV_20181016T001456...
S1B_IW_SLC_1SDV_20181016T001521... S1B_IW_SLC_1SDV_20181028T001407...
S1B_IW_SLC_1SDV_20181028T001431... S1B_IW_SLC_1SDV_20181028T001456...
S1B_IW_SLC_1SDV_20181028T001521... S1B_IW_SLC_1SDV_20181203T001406...
S1B_IW_SLC_1SDV_20181203T001431... S1B_IW_SLC_1SDV_20181203T001455...
S1B_IW_SLC_1SDV_20181203T001520... S1B_IW_SLC_1SDV_20181215T001405...
S1B_IW_SLC_1SDV_20181215T001430... S1B_IW_SLC_1SDV_20181215T001455...
S1B_IW_SLC_1SDV_20181215T001520... S1B_IW_SLC_1SDV_20181227T001405...
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S1B_IW_SLC_1SDV_20181227T001519... S1B_IW_SLC_1SDV_20190108T001404...
S1B_IW_SLC_1SDV_20190108T001429... S1B_IW_SLC_1SDV_20190108T001454...
S1B_IW_SLC_1SDV_20190108T001519... S1B_IW_SLC_1SDV_20190120T001404...
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S1B_IW_SLC_1SDV_20190201T001518... S1B_IW_SLC_1SDV_20190213T001403...
S1B_IW_SLC_1SDV_20190213T001428... S1B_IW_SLC_1SDV_20190213T001453...
S1B_IW_SLC_1SDV_20190213T001518... S1B_IW_SLC_1SDV_20190225T001403...
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S1B_IW_SLC_1SDV_20190321T001518... S1B_IW_SLC_1SDV_20190402T001404...

One track, 1362 images

Big Data

- Data management -> Database for images and results
- Parallelized algorithms -> Fully parallelized InSAR processor
- Distributed computing -> Build up IT infrastructures

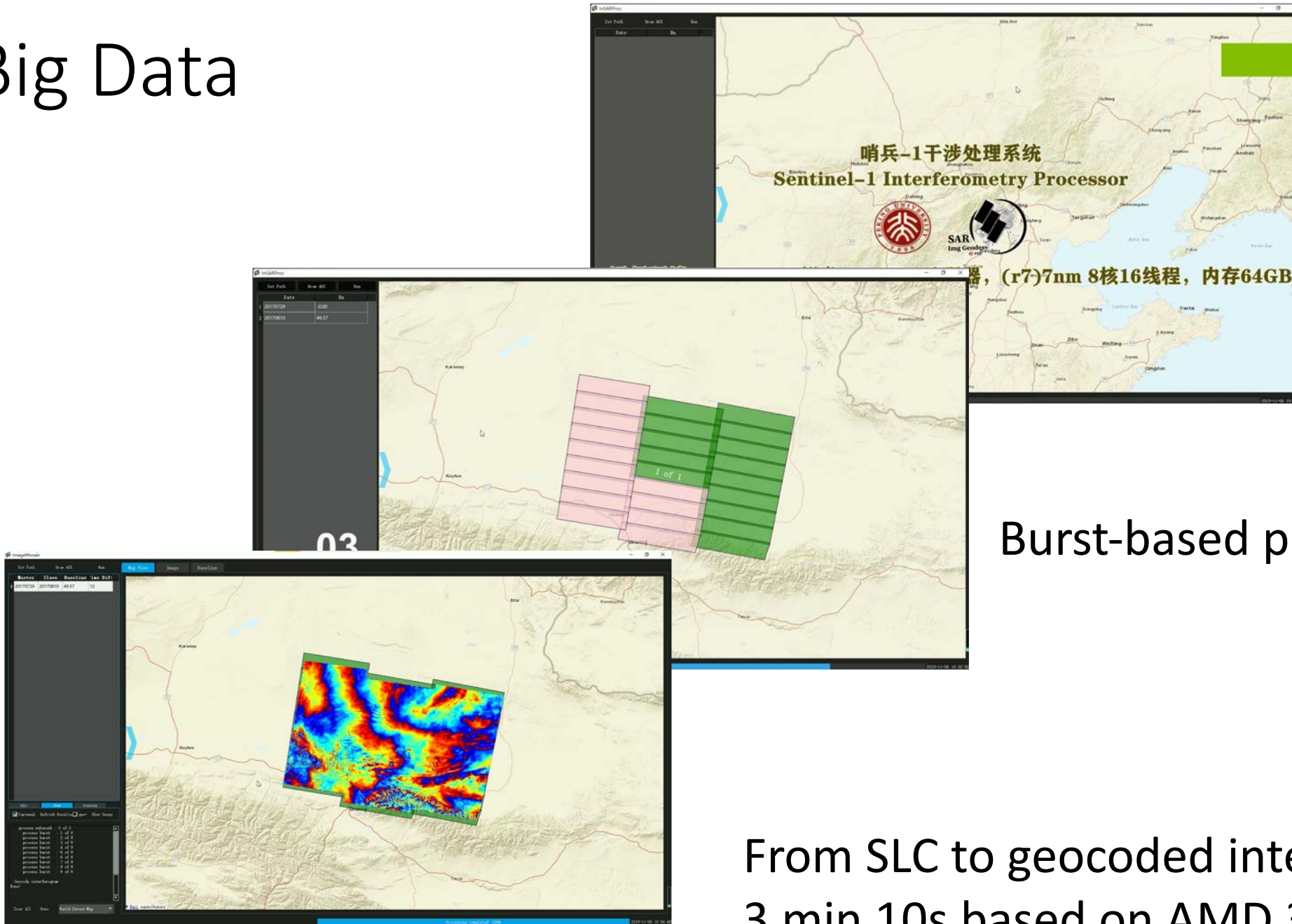
Big Data

CPU paralleled

Burst-based processor

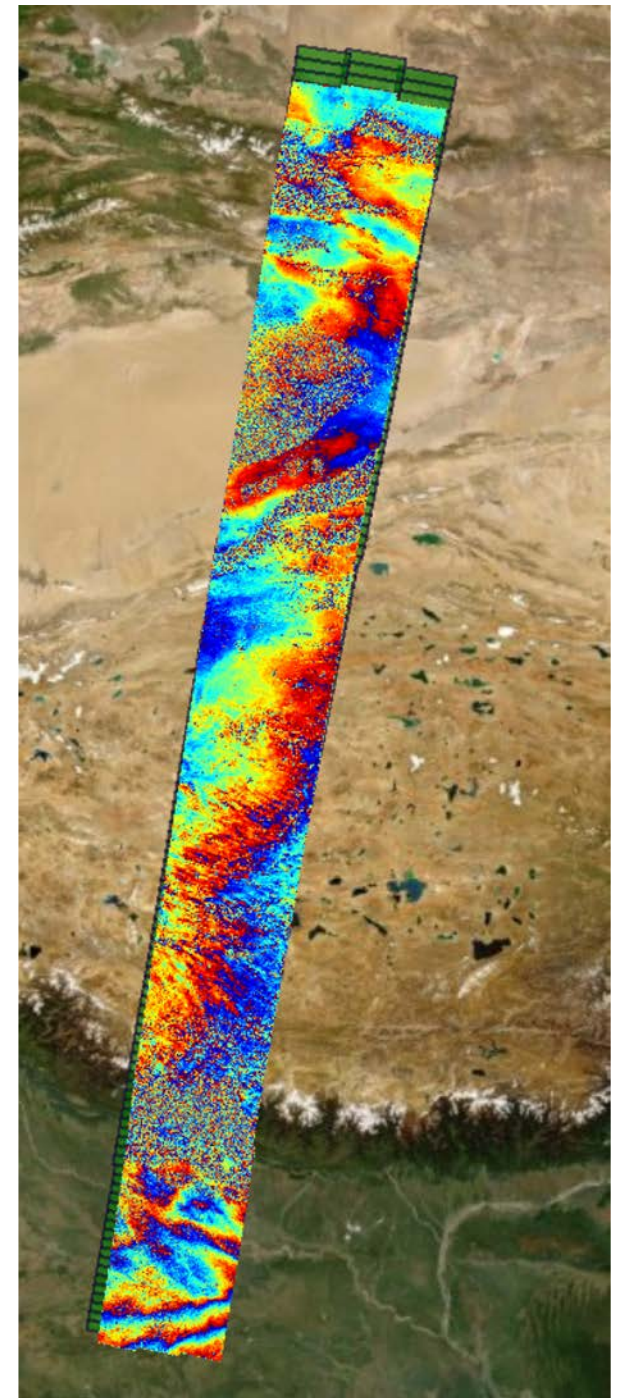
From SLC to geocoded interferogram
3 min 10s based on AMD 3700X, 8 cores

<https://sarimggeodesy.github.io/software/>



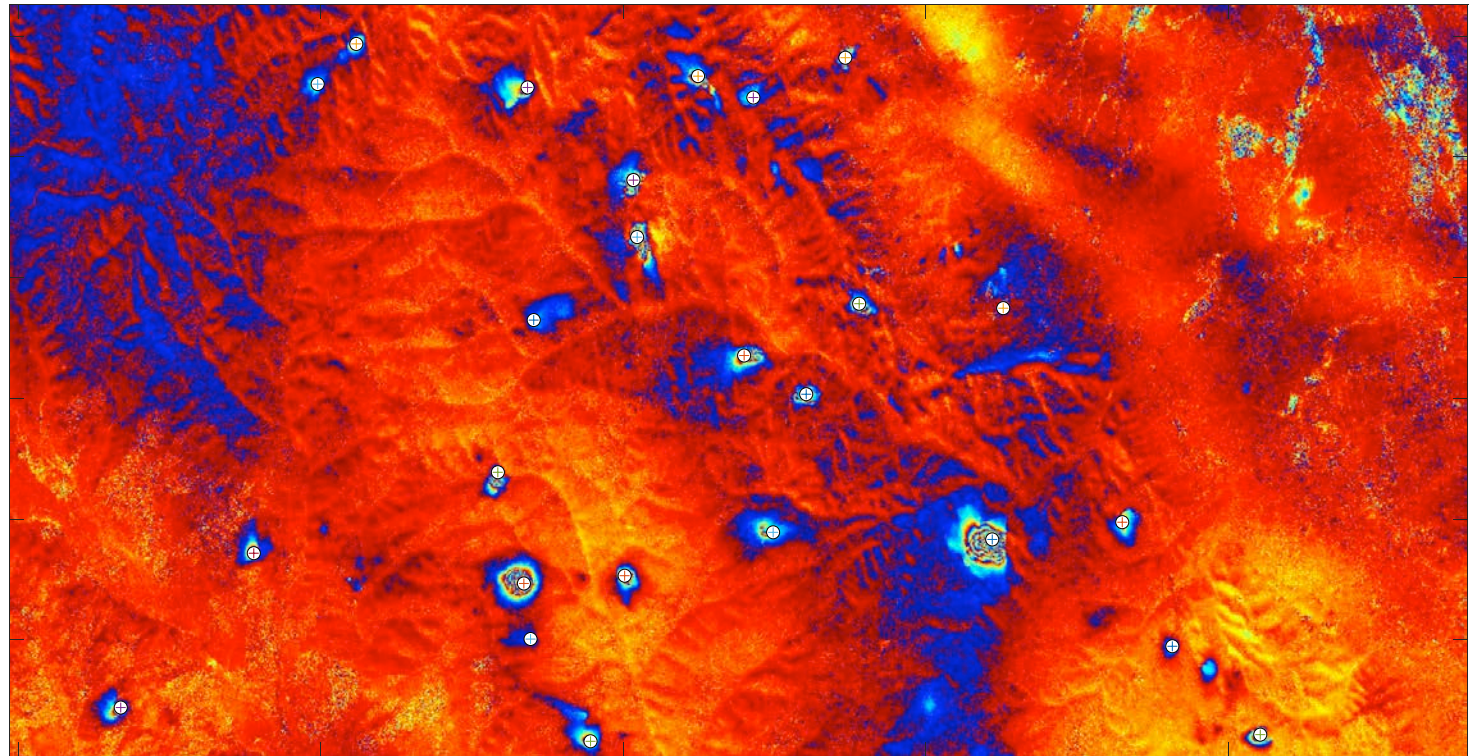
Large Scale

- Long-wavelength deformation
 - Tectonic motion
 - Coastal deformation
- Local deformation
 - Landslides
 - Mining subsidence
 - Sink holes



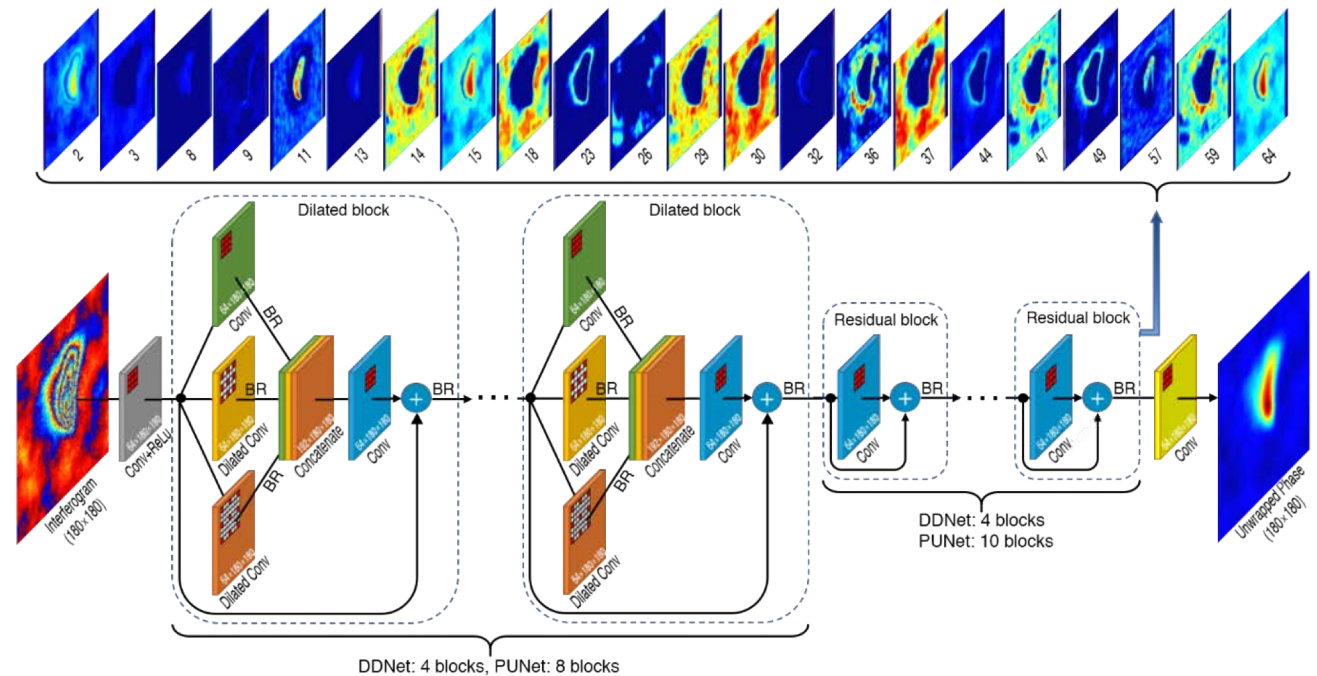
Large Scale- local deformation monitoring

- Prepare stack of interferograms efficiently
- Masking out decorrelation areas
- Detect local deformation
- Phase unwrapping
- Time-series analysis



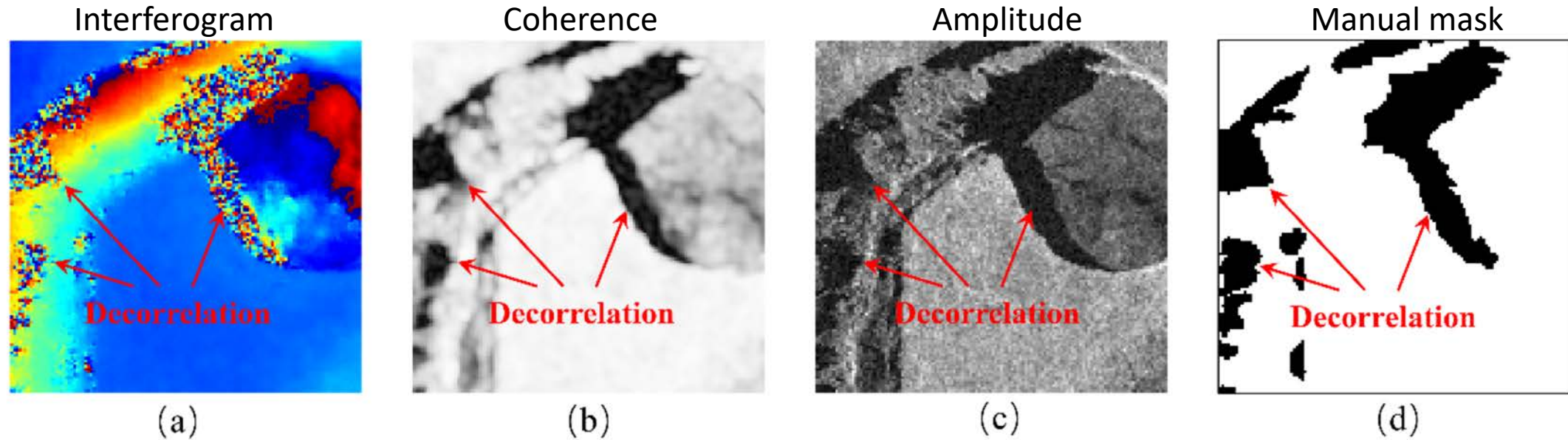
AI- Deep learning networks

- Masking
- Local deformation detection
 - Mining-induced subsidence
 - landslides
- Phase unwrapping



Architecture of our phase unwrapping network for localized mining-induced subsidence

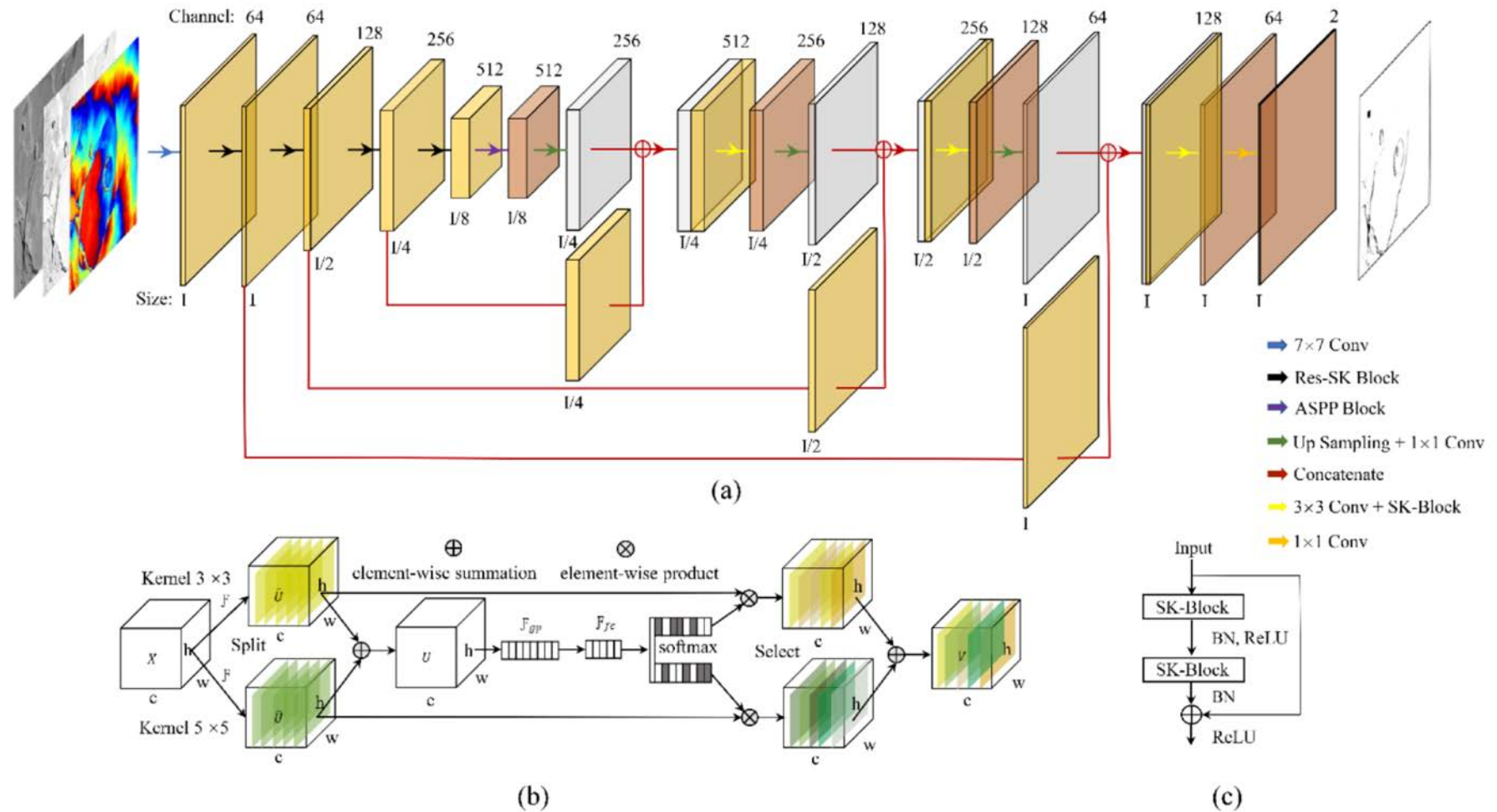
Masking



Input: Interferogram | Coherence map | Amplitude map

Training set: Manually labeled Masks

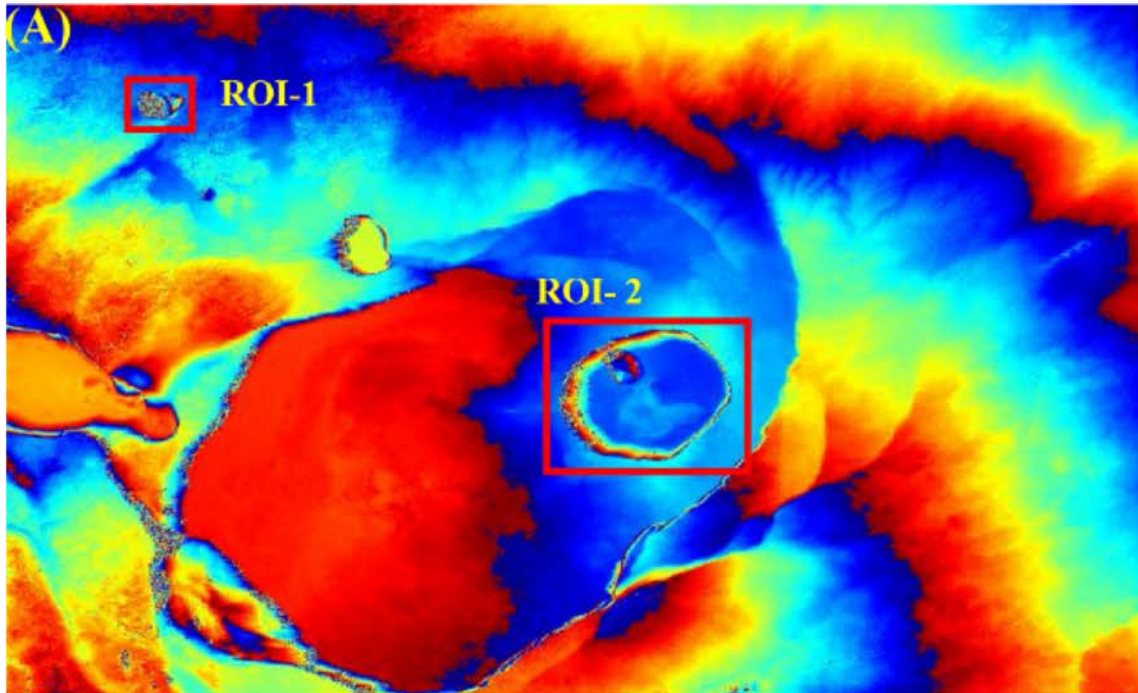
Masking



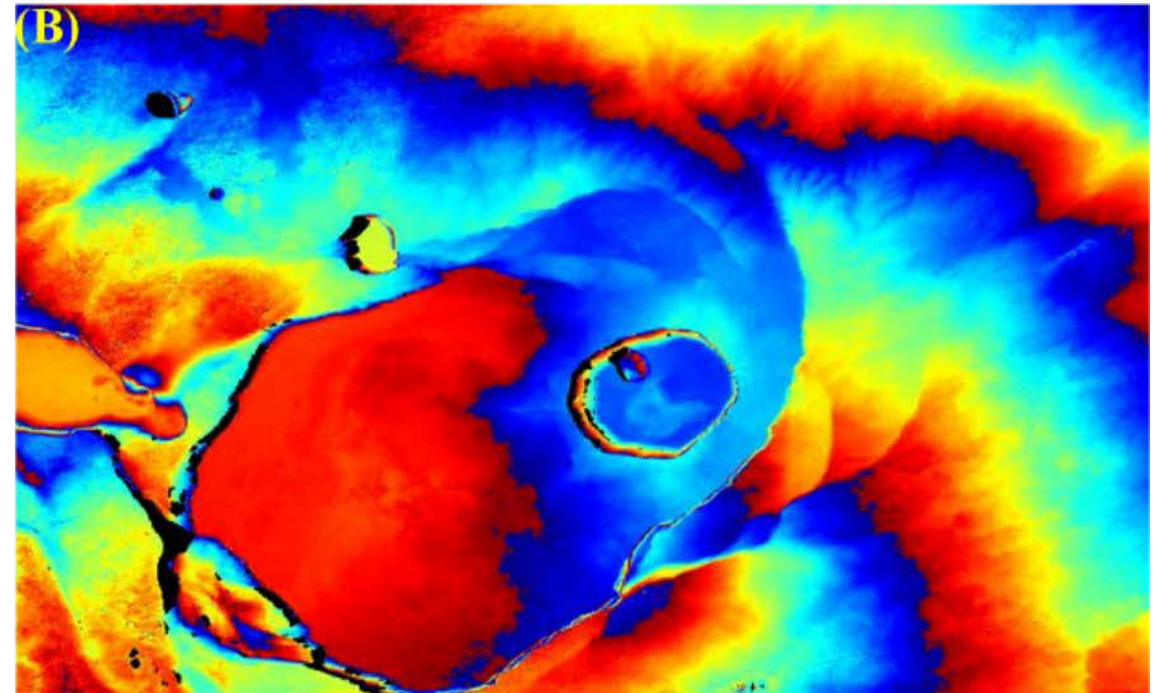
Based on Selective Kernel Res-Attention UNet

Masking

Apply to TanDEM-X interferogram: Kīlauea Volcano, Hawaii



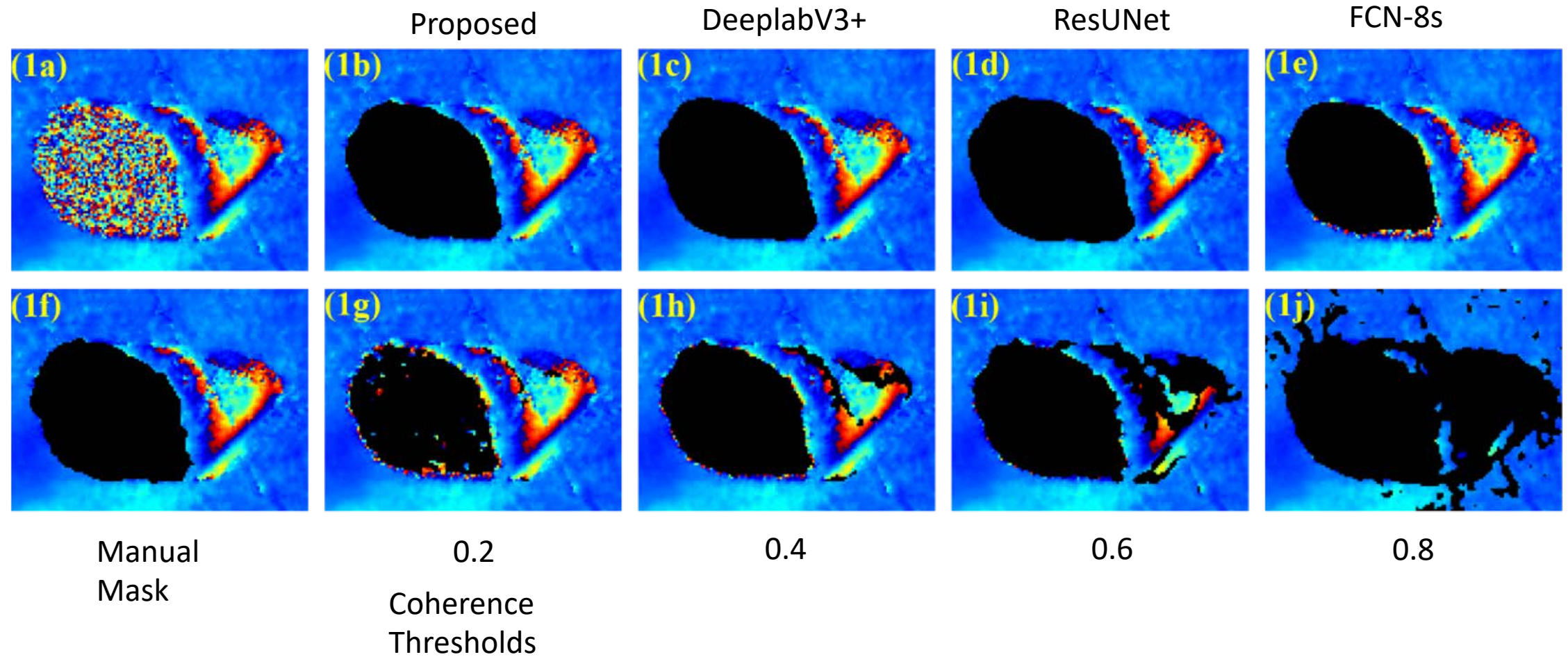
Original Interferogram



Masked Interferogram

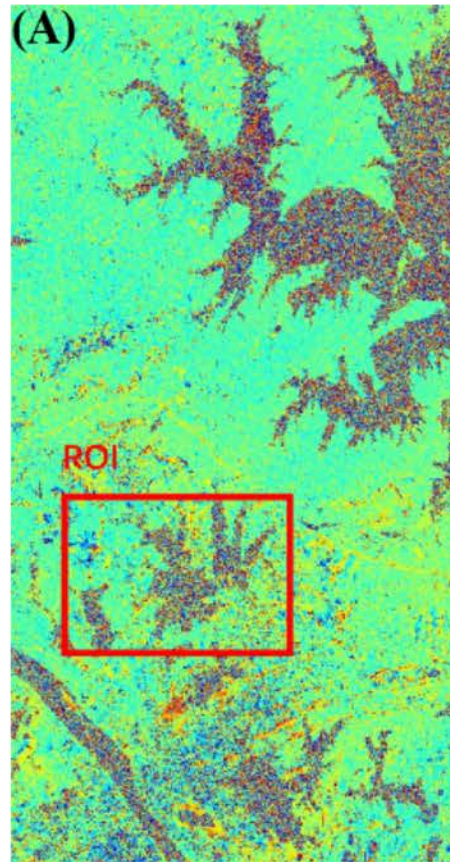
Masking

Apply to TanDEM-X interferogram: Kīlauea Volcano, Hawaii

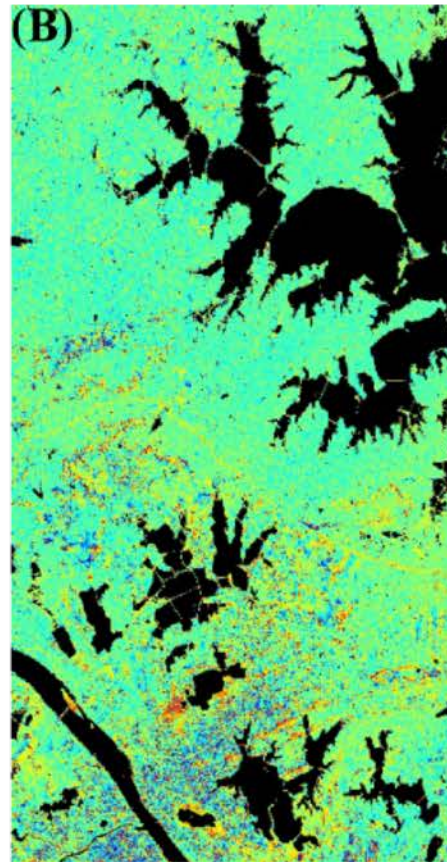


Masking

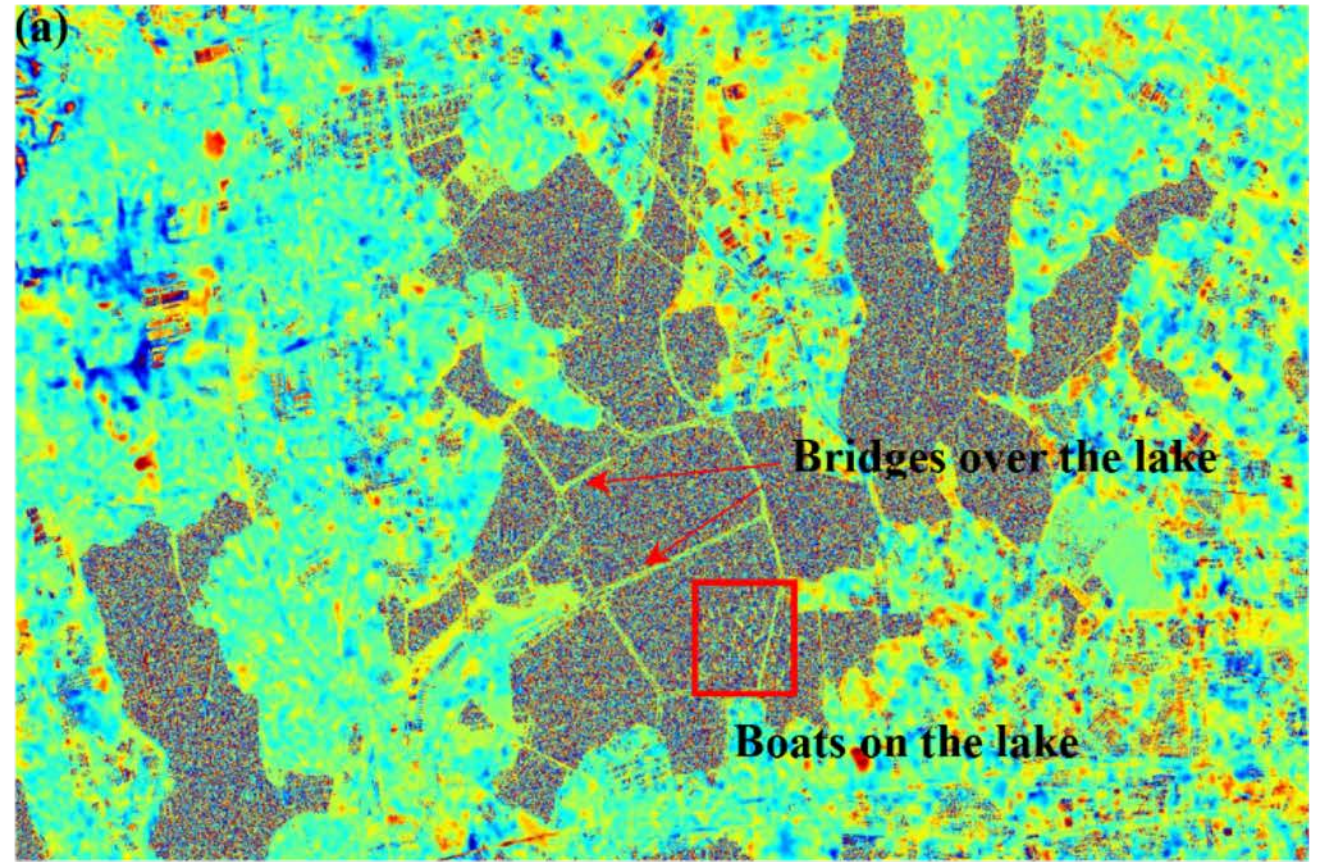
Apply to TanDEM-X interferogram: Wuhan, China



Original
Interferogram



Masked
Interferogram

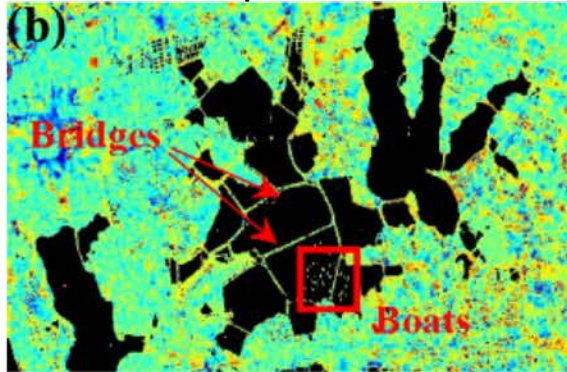


Enlarged lake area

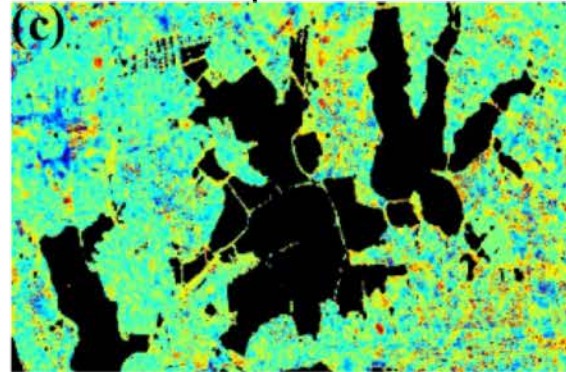
Masking

Apply to TanDEM-X interferogram: Wuhan, China

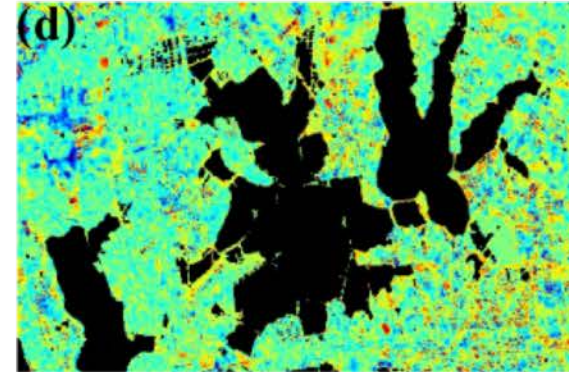
Proposed



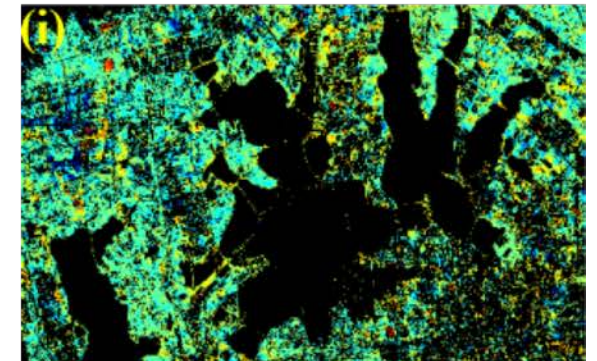
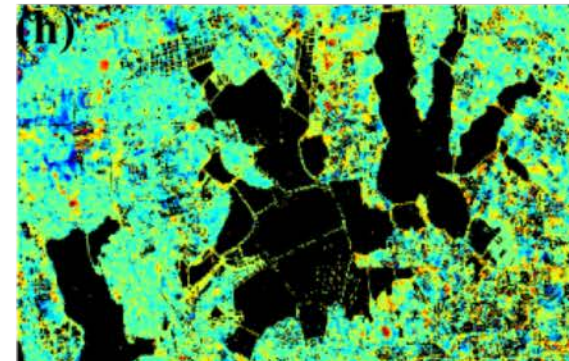
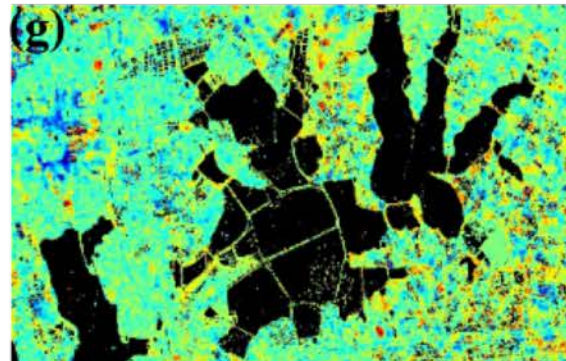
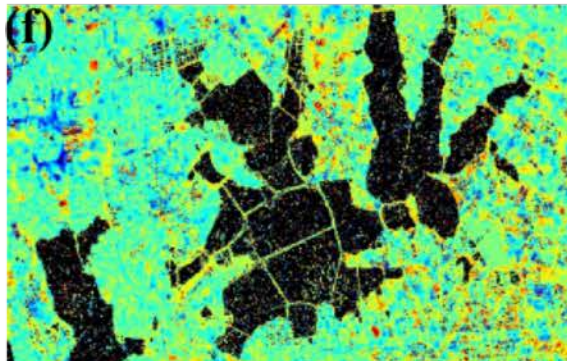
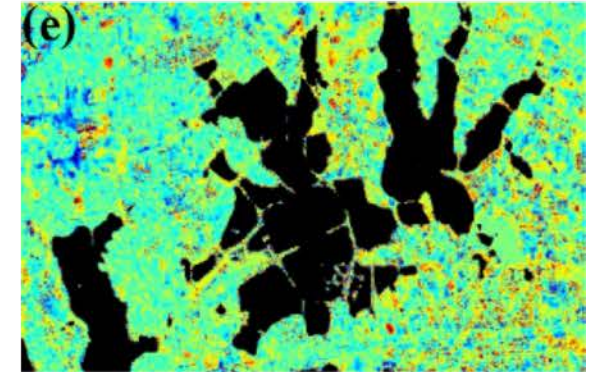
DeeplabV3+



ResUNet



FCN-8s



Coherence
Thresholds

0.2

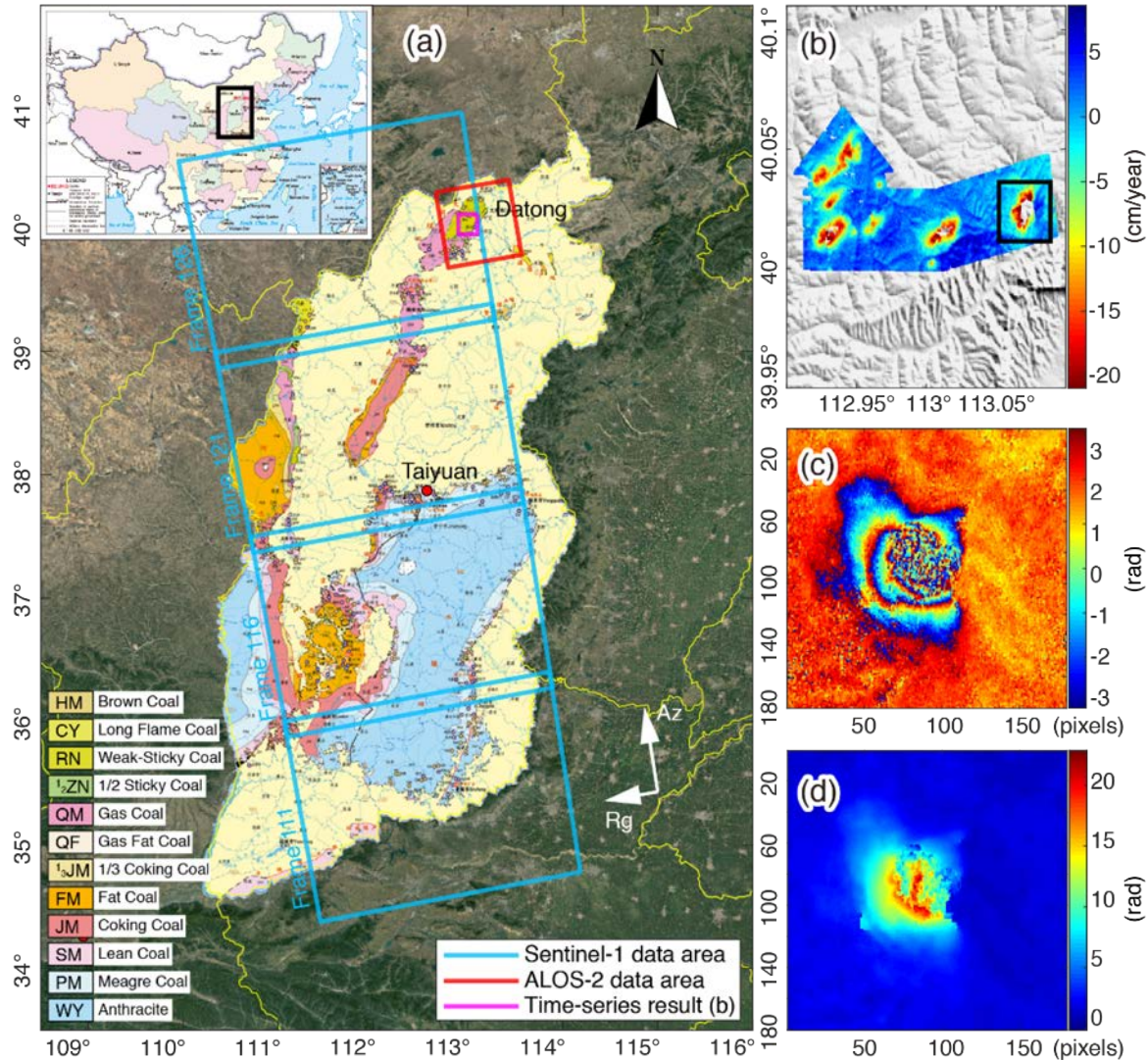
0.4

0.6

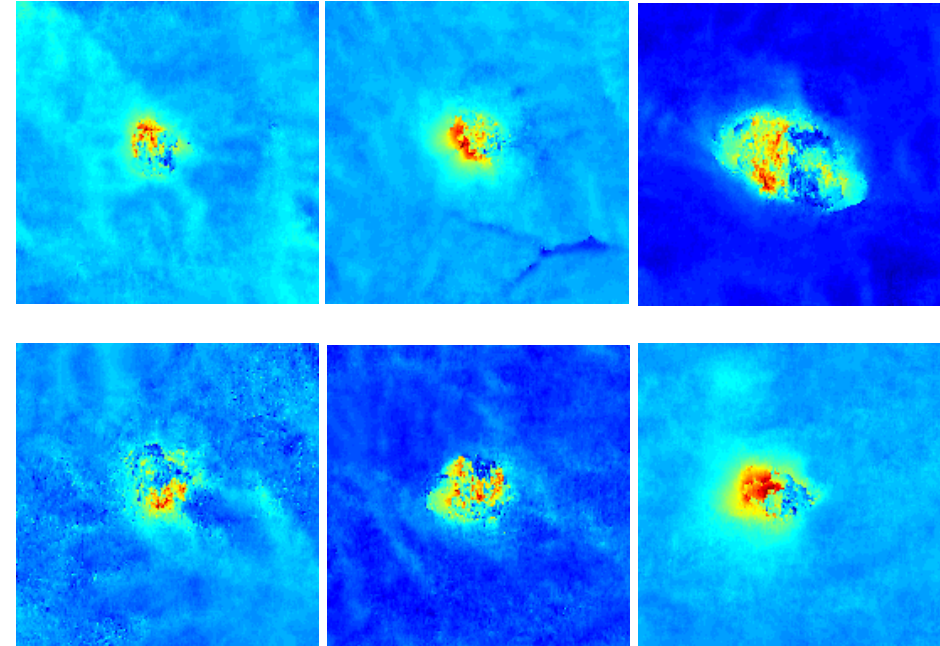
0.8

Mining Subsidence

Shanxi Province, China

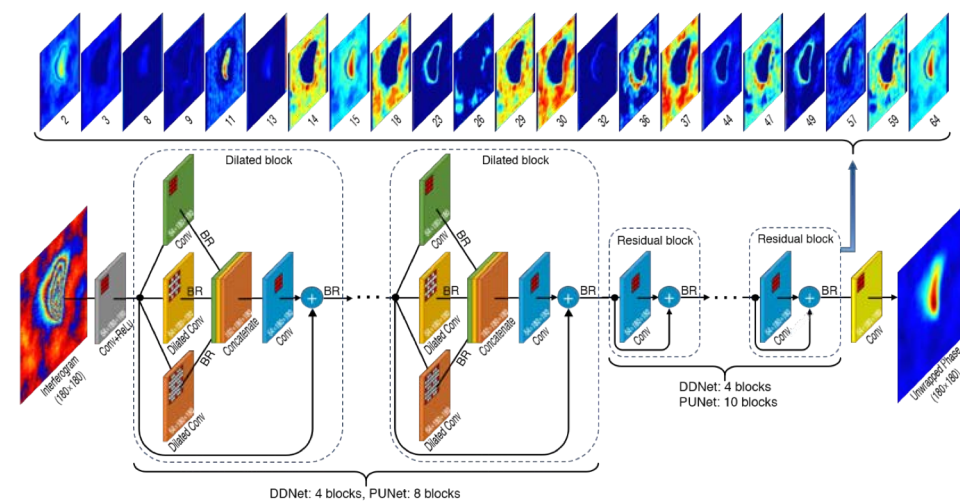


SNAPHU

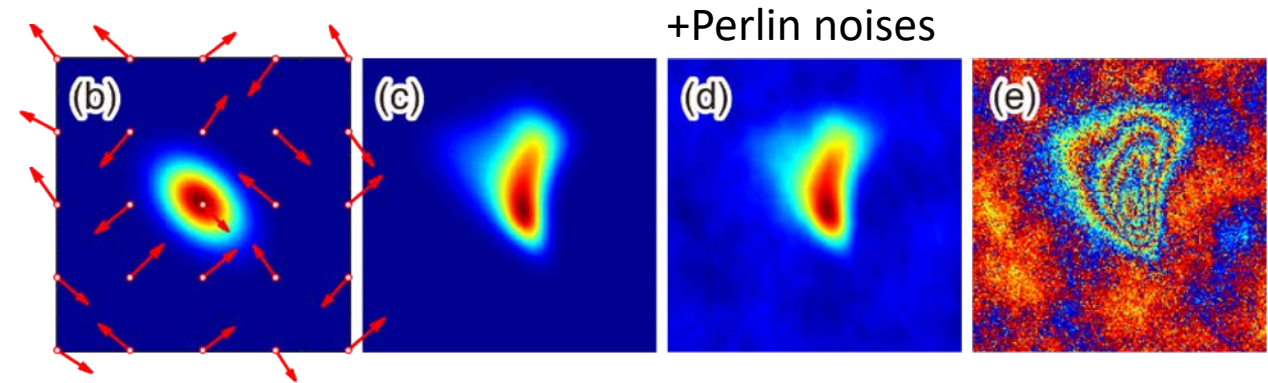


- 178,000 km²
- Large amount of mining-induced subsiding areas
- One year of Sentinel-1 images

Mining Subsidence

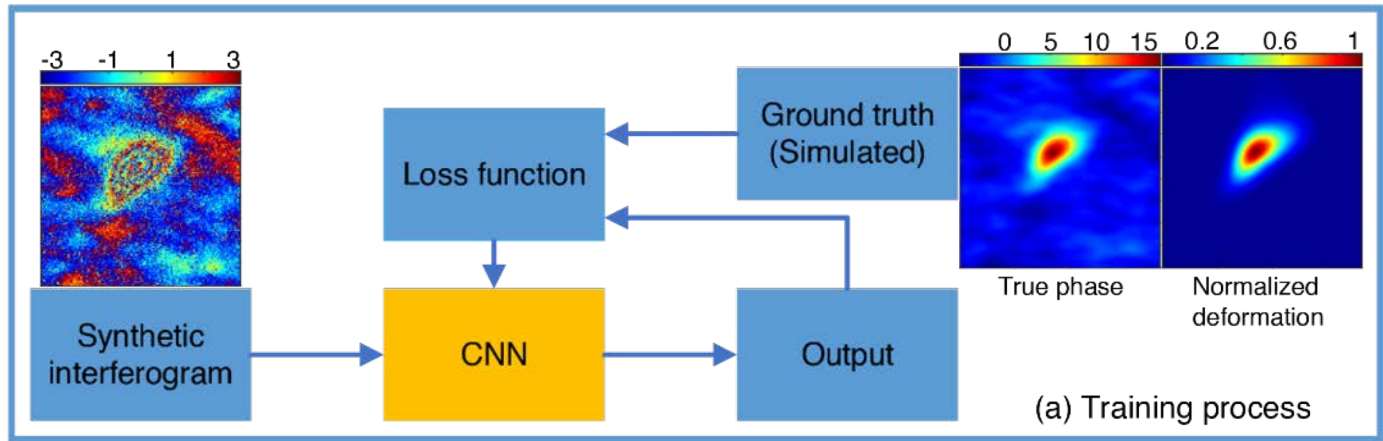


Network Structure

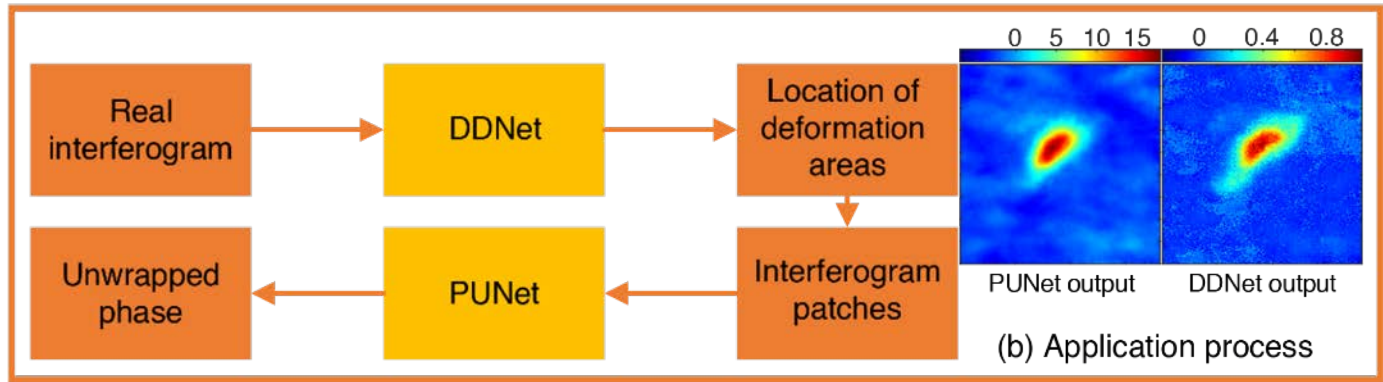


Distorted Gaussian Surface

+Decorrelation noises



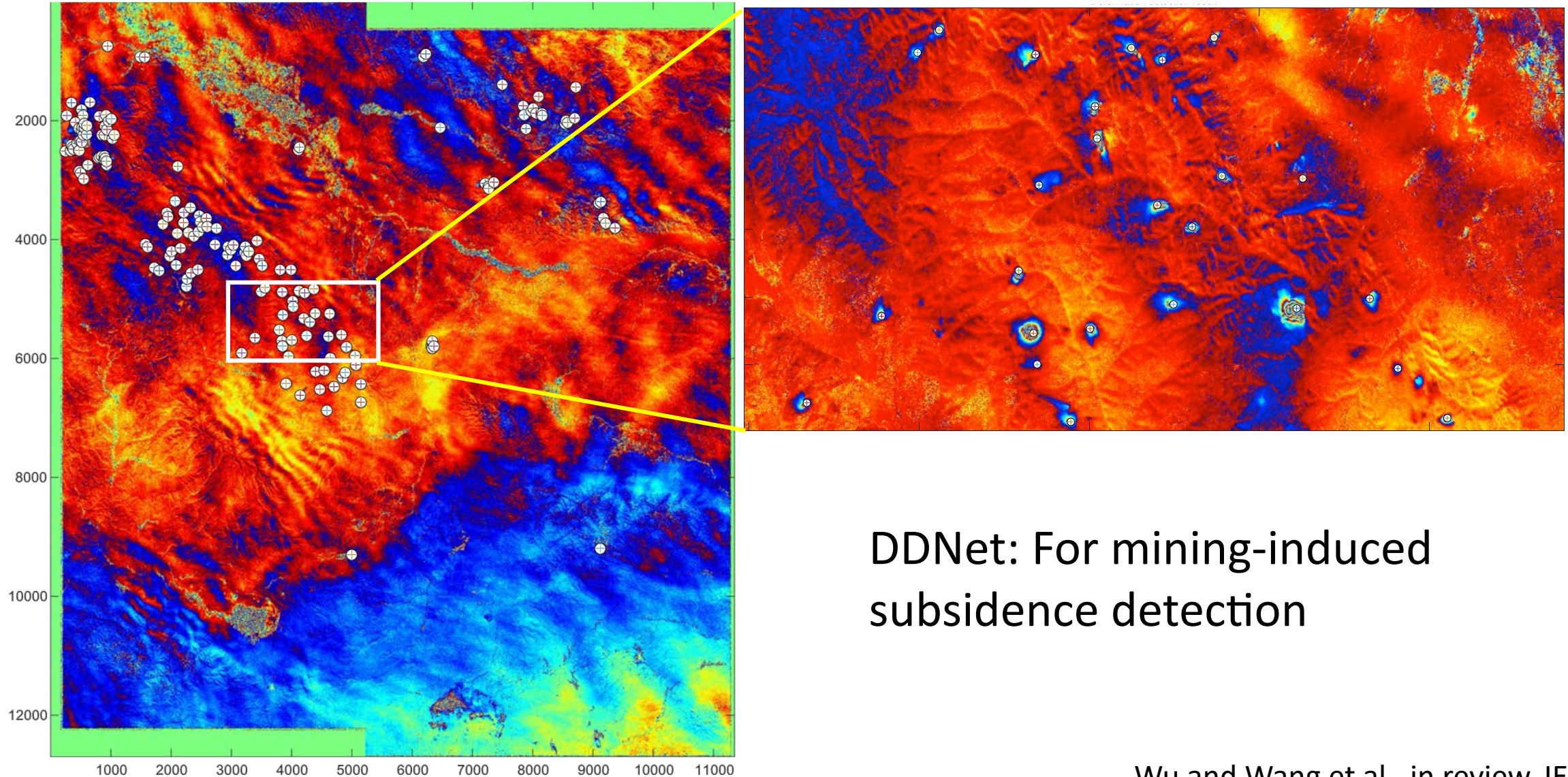
(a) Training process



(b) Application process

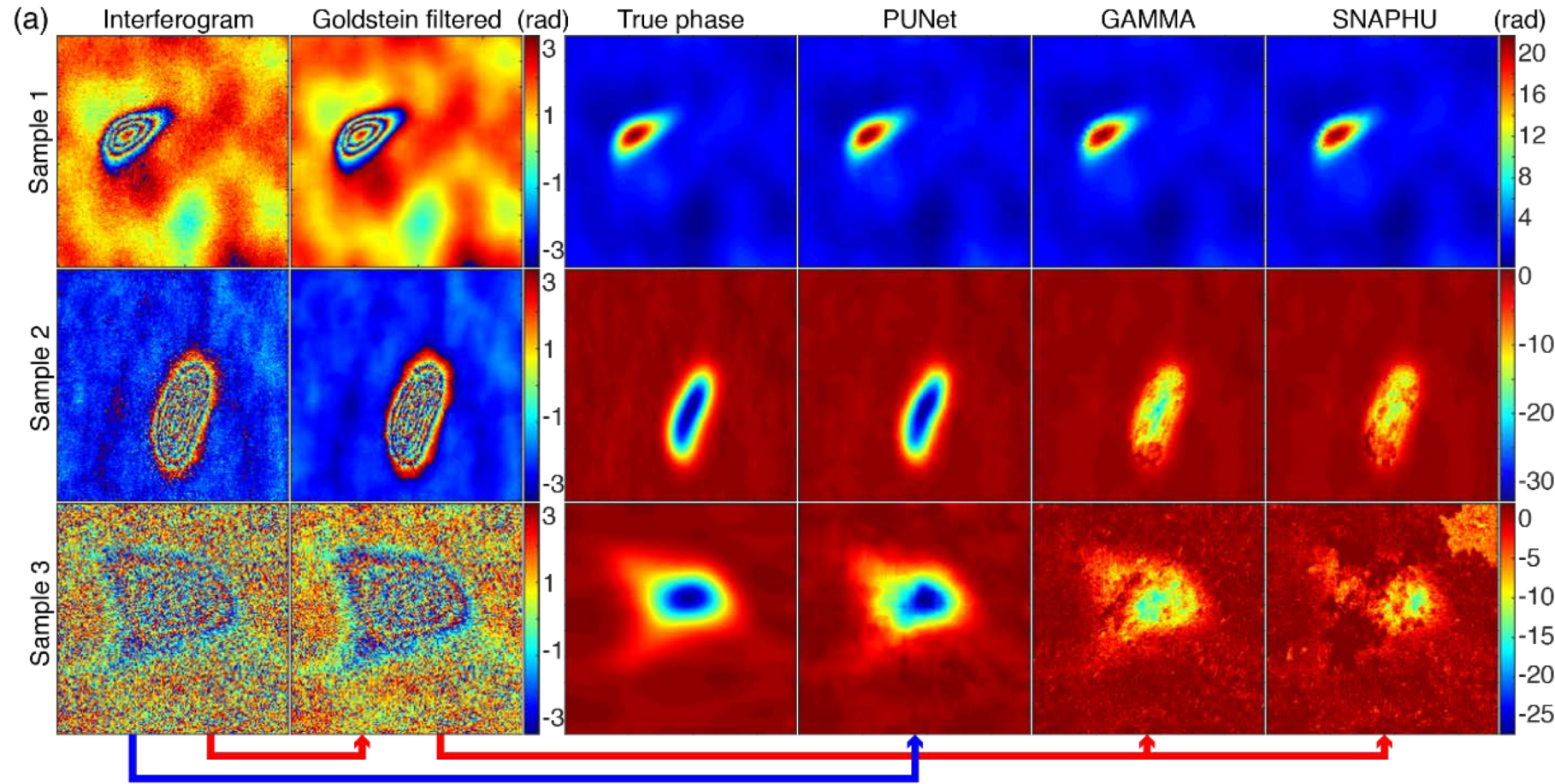
Simulated
interferograms as
training set

Mining Subsidence



DDNet: For mining-induced
subsidence detection

Mining Subsidence



PUNet: For local
phase unwrapping

Mining Subsidence

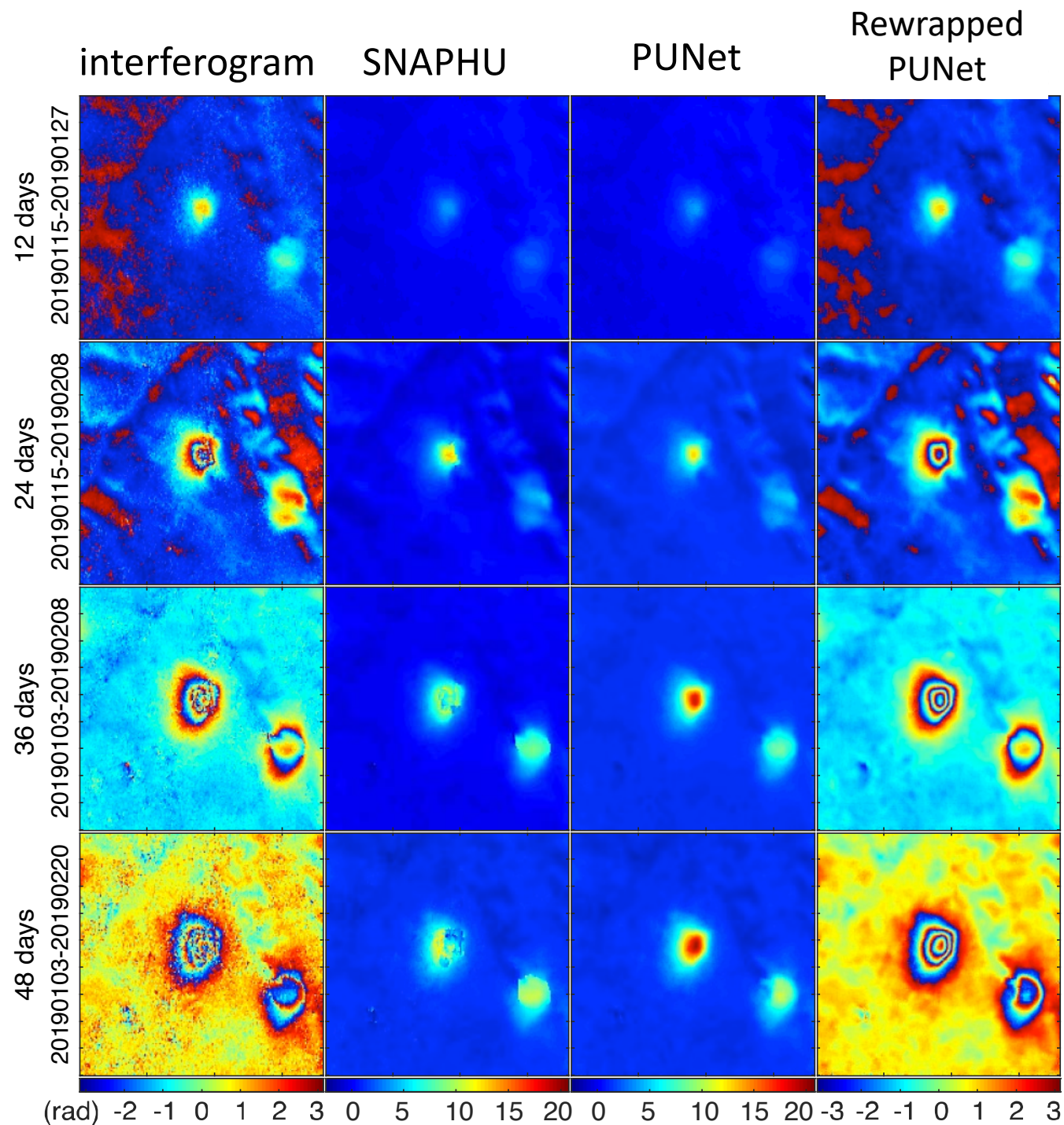
Validation on
Sentinel-1
interferograms

12-day →

24-day →

36-day →

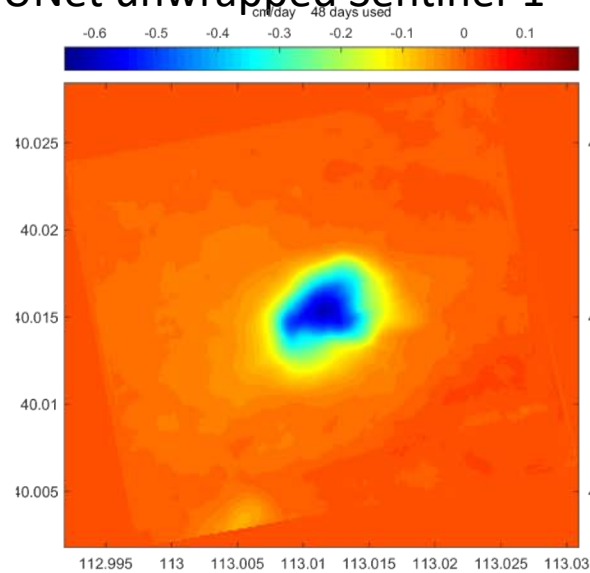
48-day →



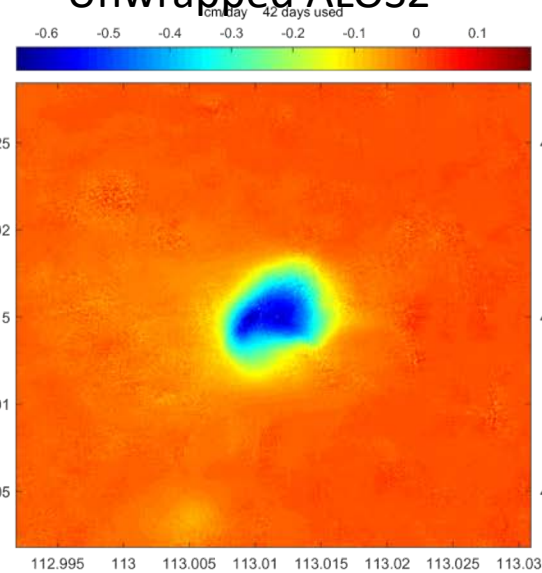
Mining Subsidence

Validation on real interferograms

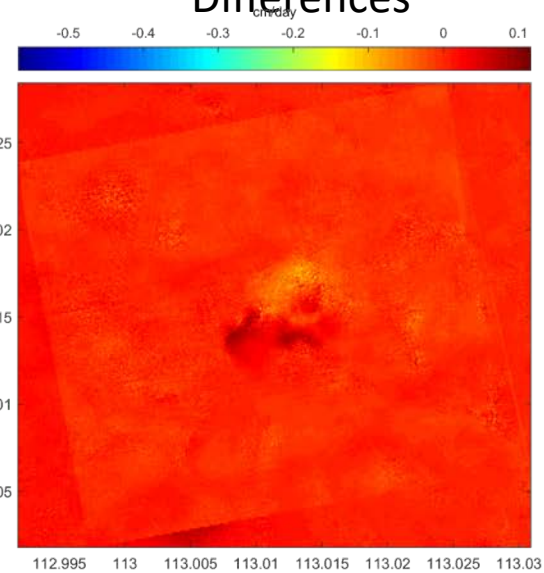
PUNet unwrapped Sentinel-1



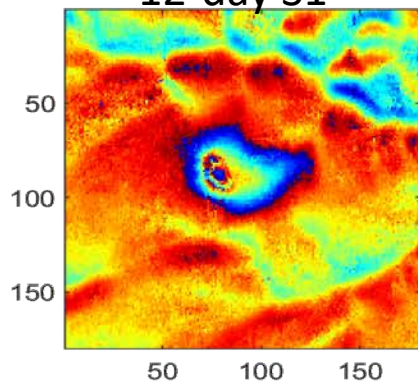
Unwrapped ALOS2



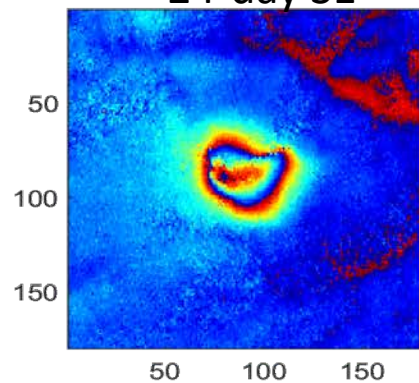
Differences



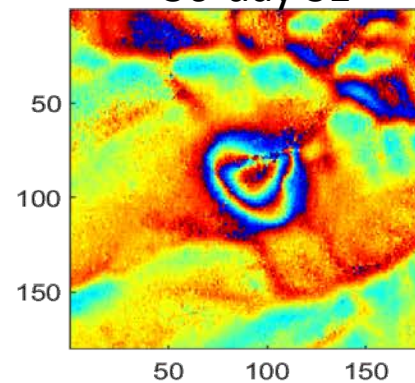
12-day S1



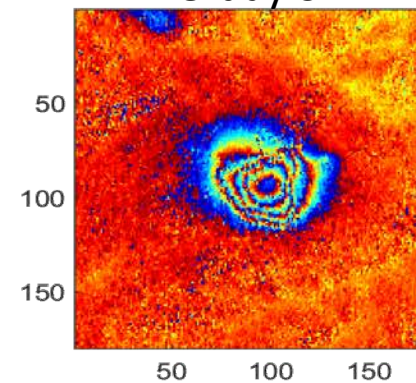
24-day S1



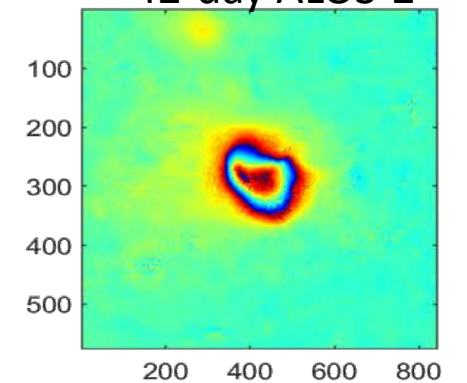
36-day S1



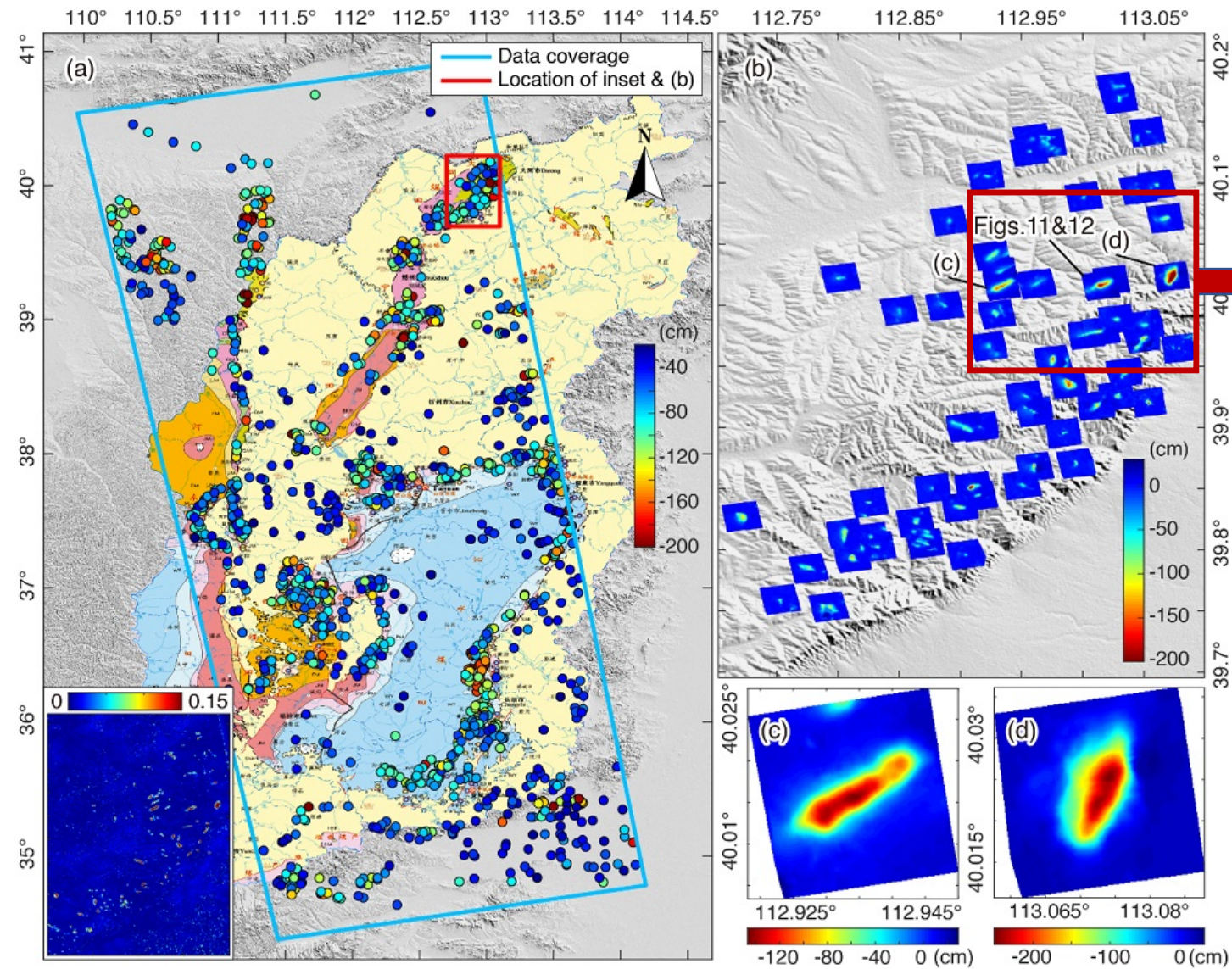
48-day S1



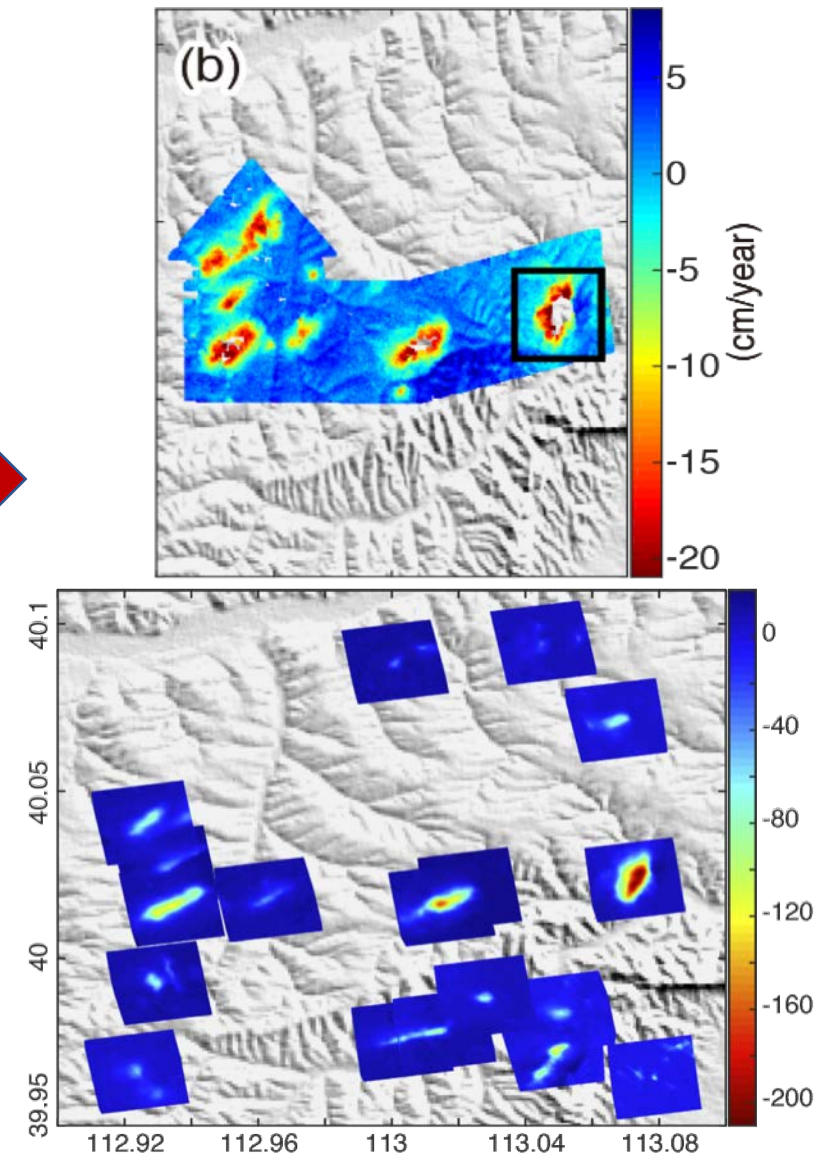
42-day ALOS-2



Mining Subsidence



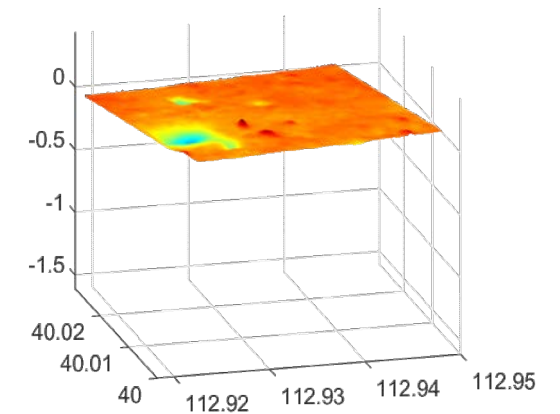
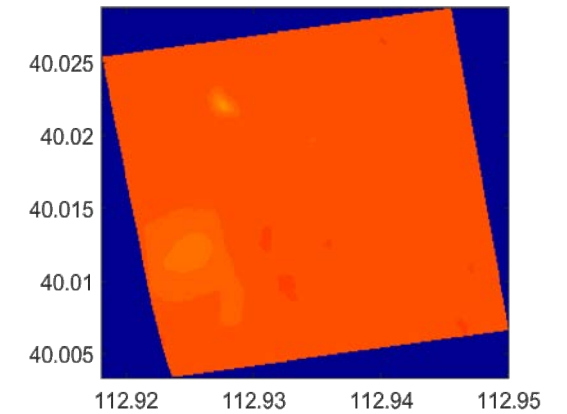
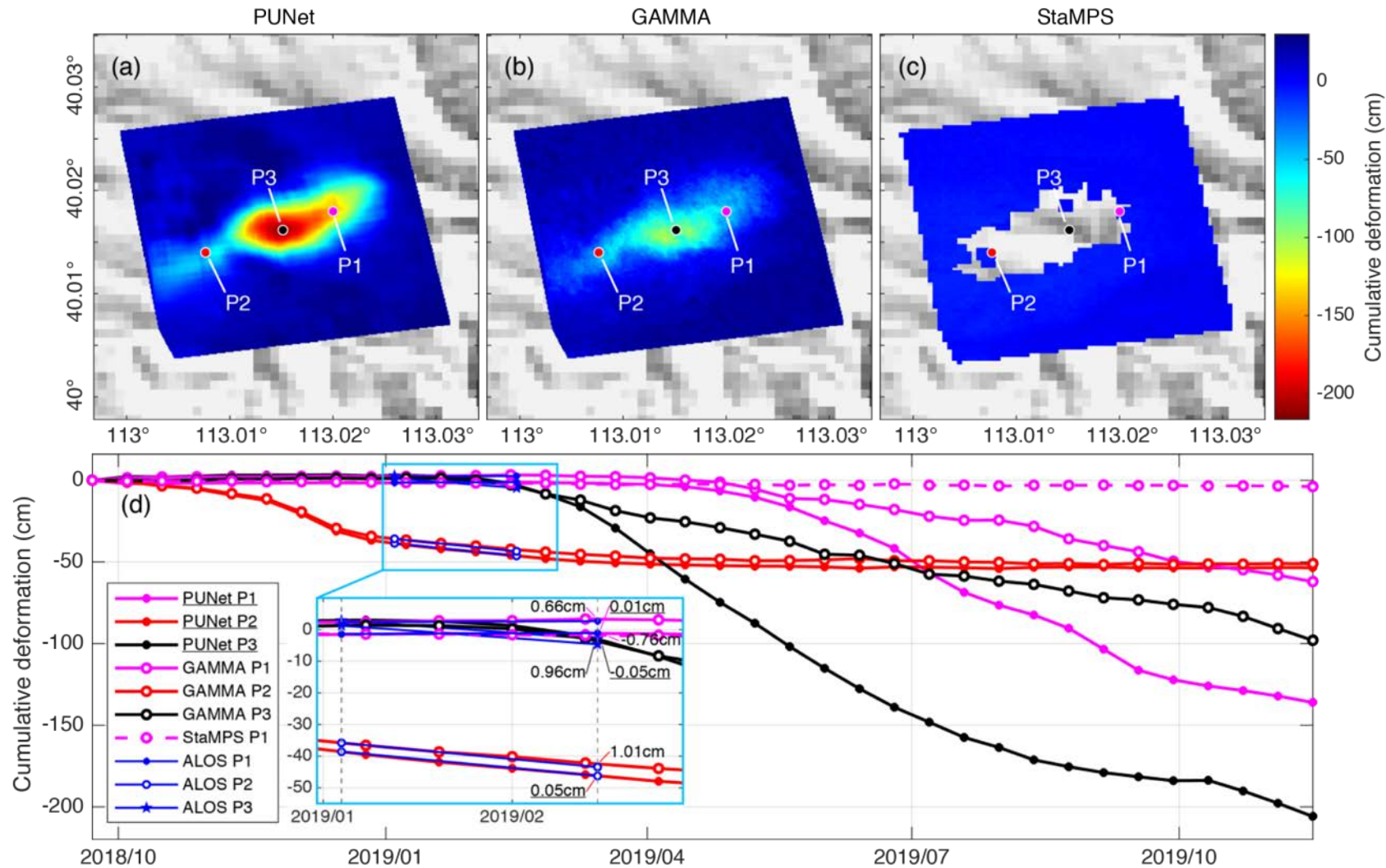
StaMPS | SNAPHU



Wu and Wang et al., in review, IEEE TGRS

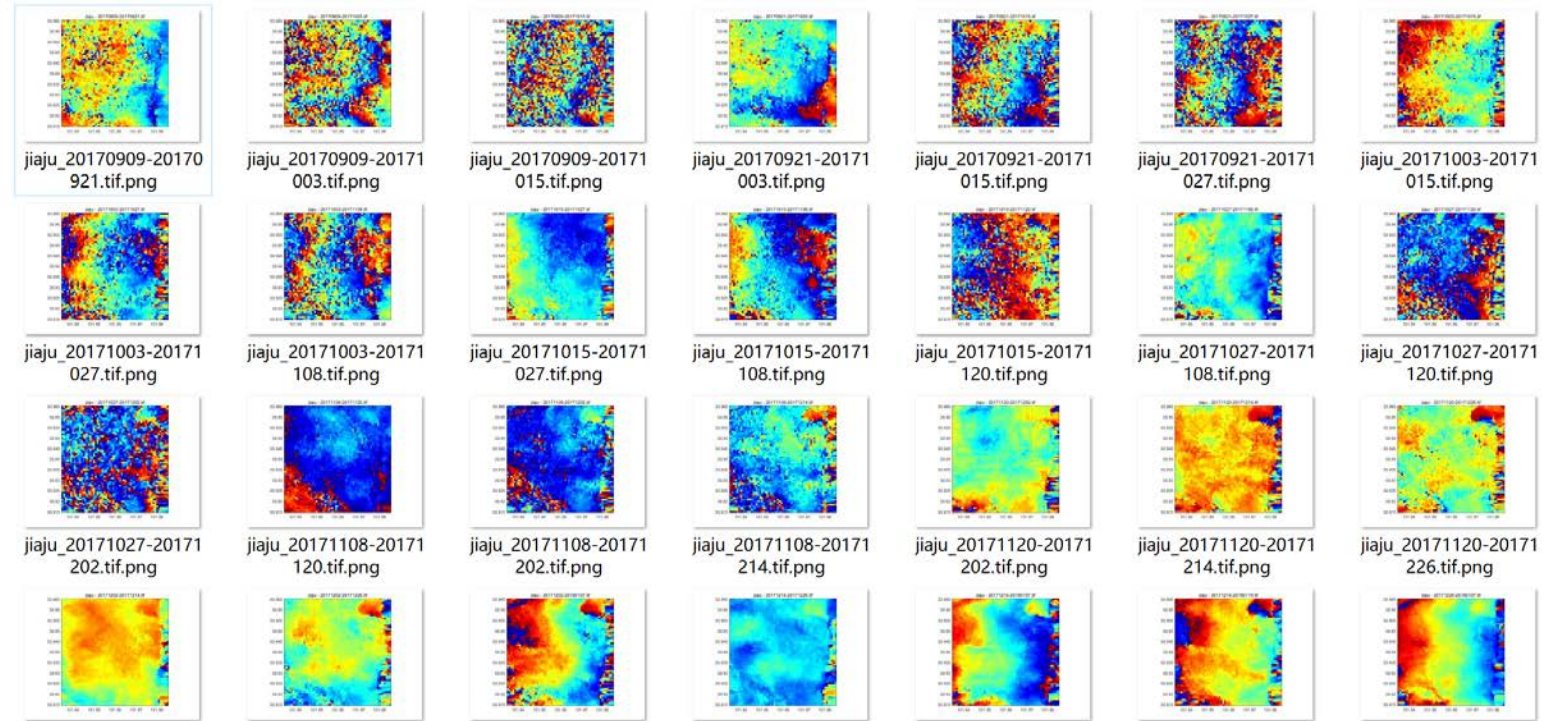
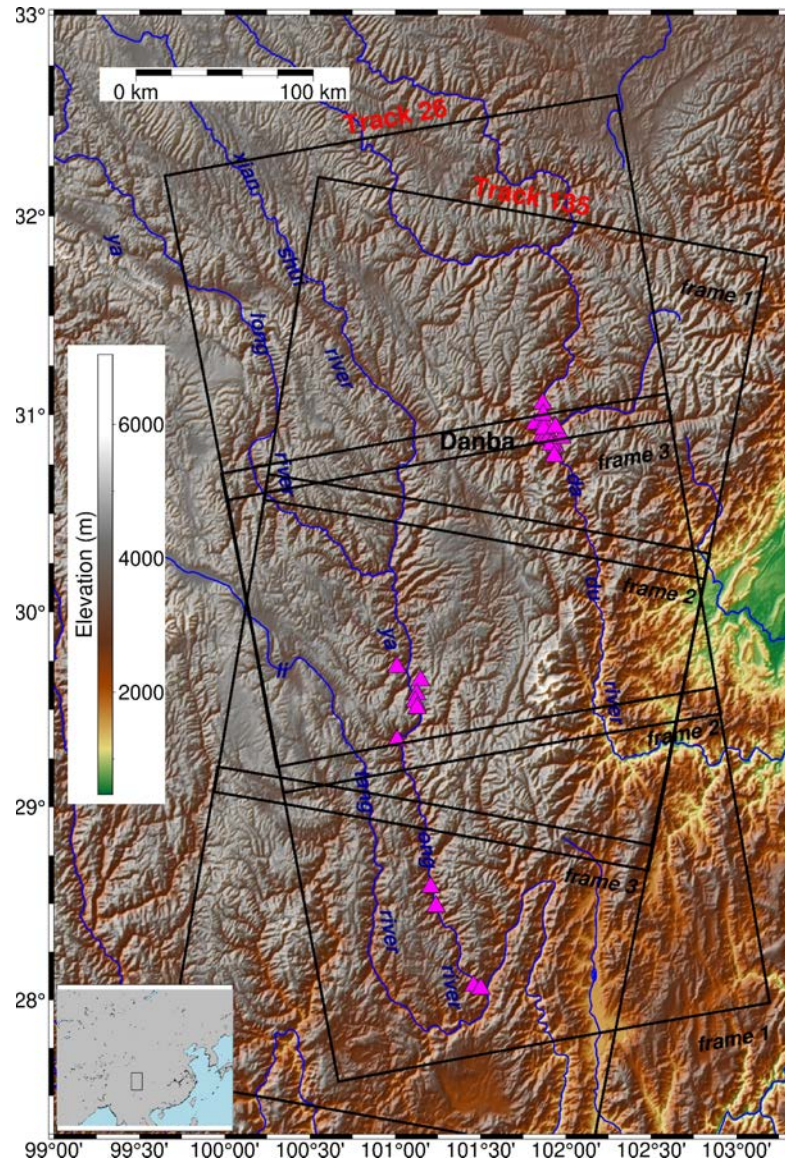
Mining Subsidence

Time-series



Active Landslides

Sichuan Province, China

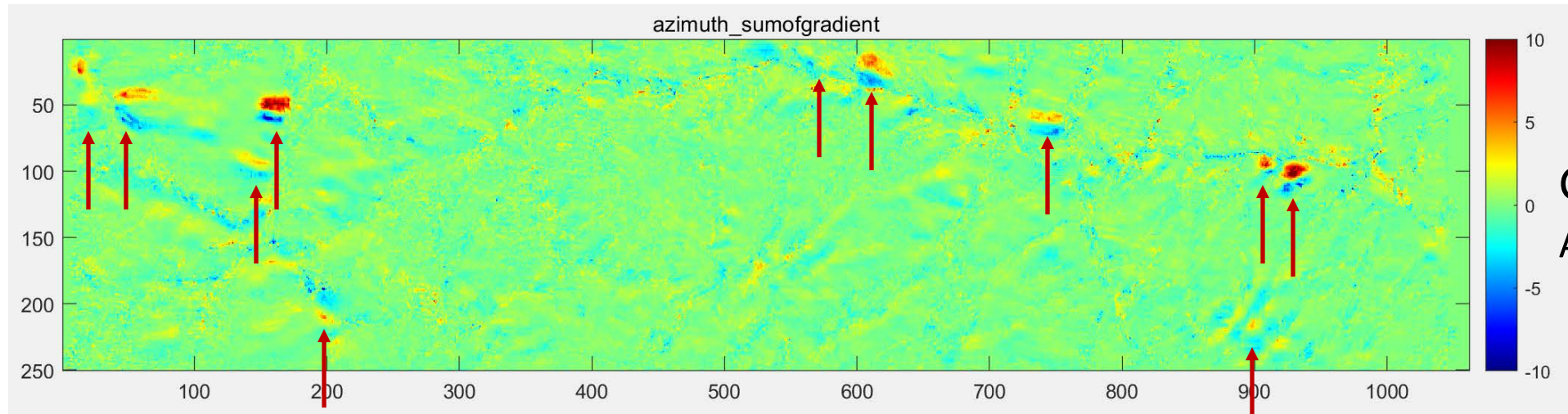


Local interferograms

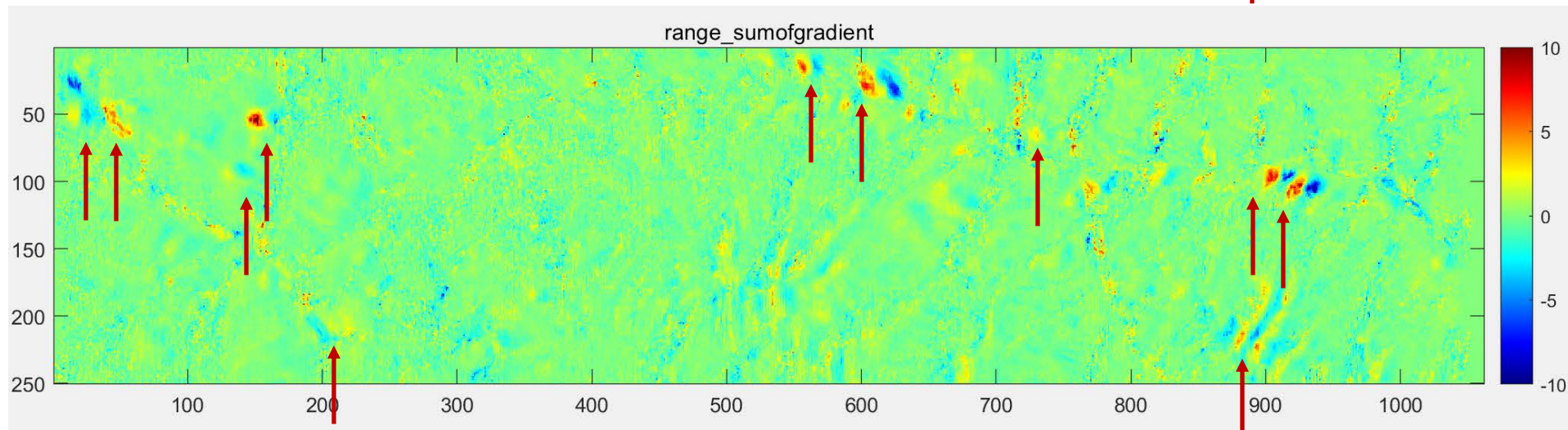
- Ascending + Descending
- 180,000 km²
- Thousands of potential landslides
- Five years of Sentinel-1 images

Active Landslides

Phase-gradient stacking



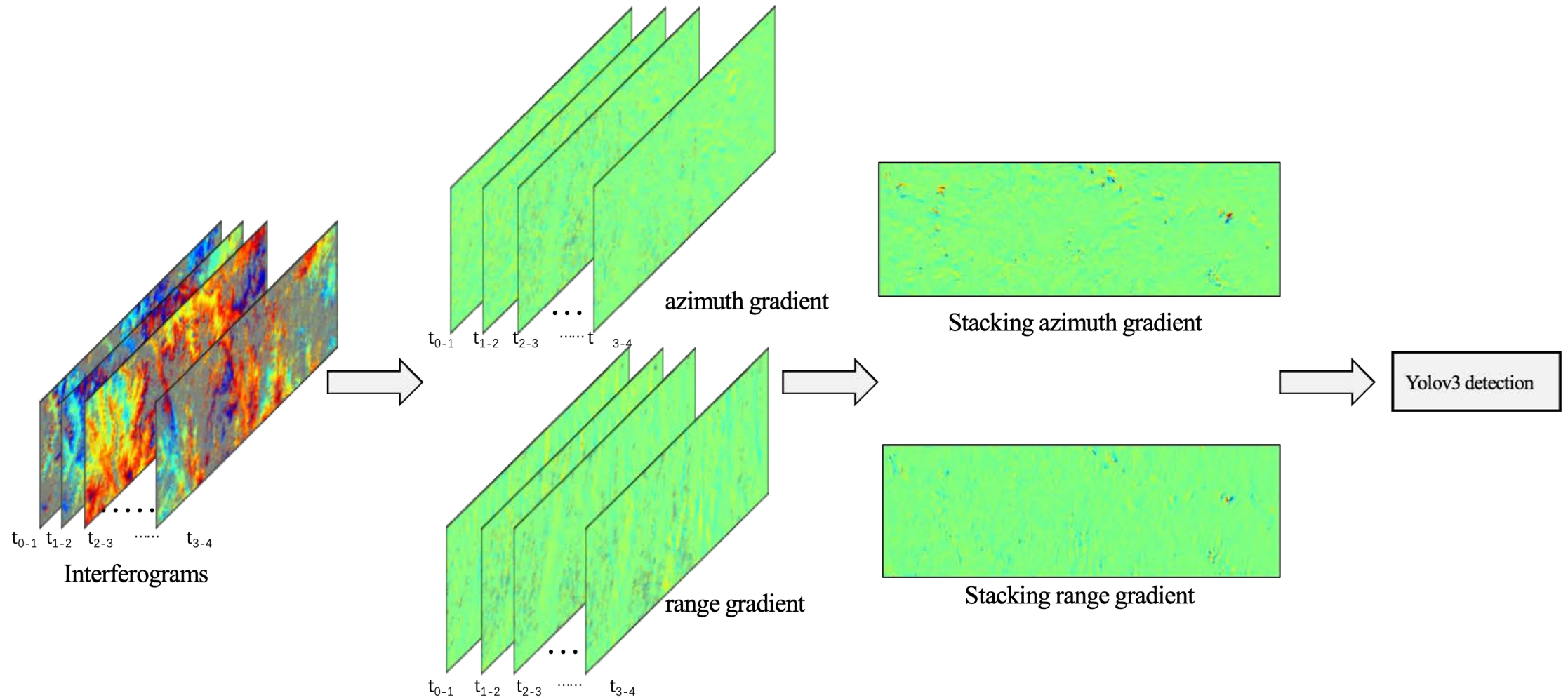
Gradient Stacking
Azimuth



Gradient Stacking
Range

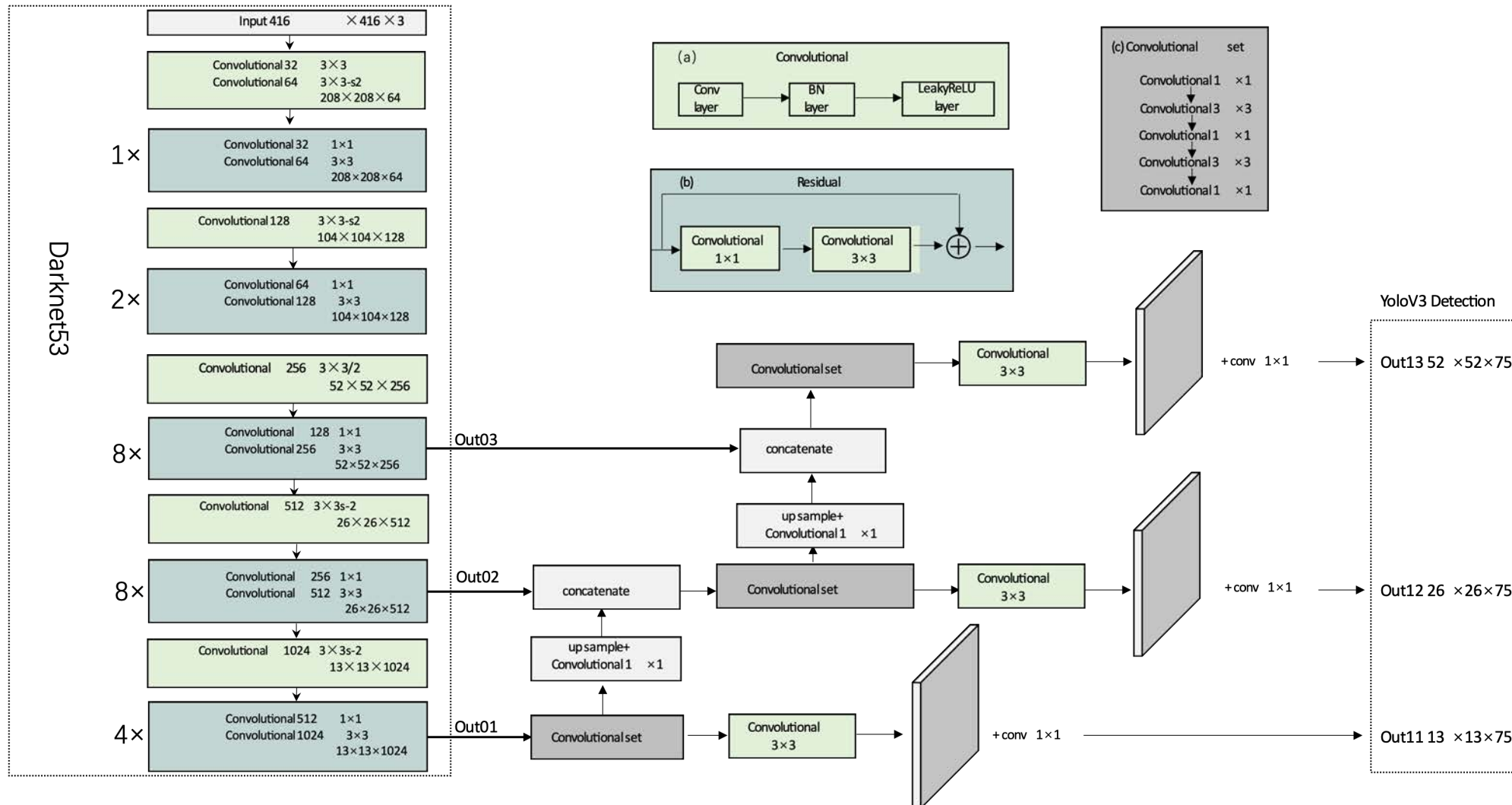
Active Landslides

Phase gradient stacking
+ deep-learning network

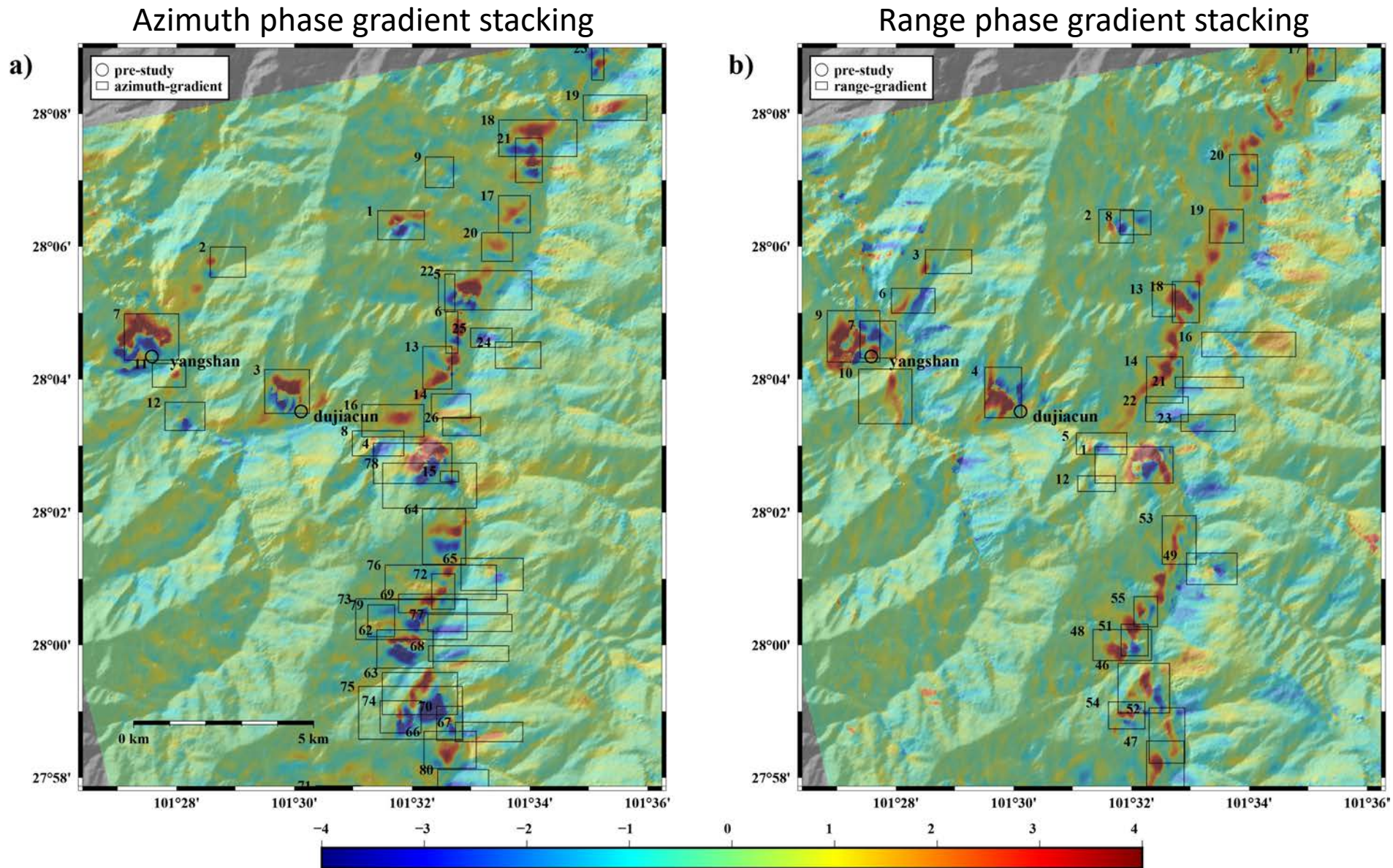


Active Landslides

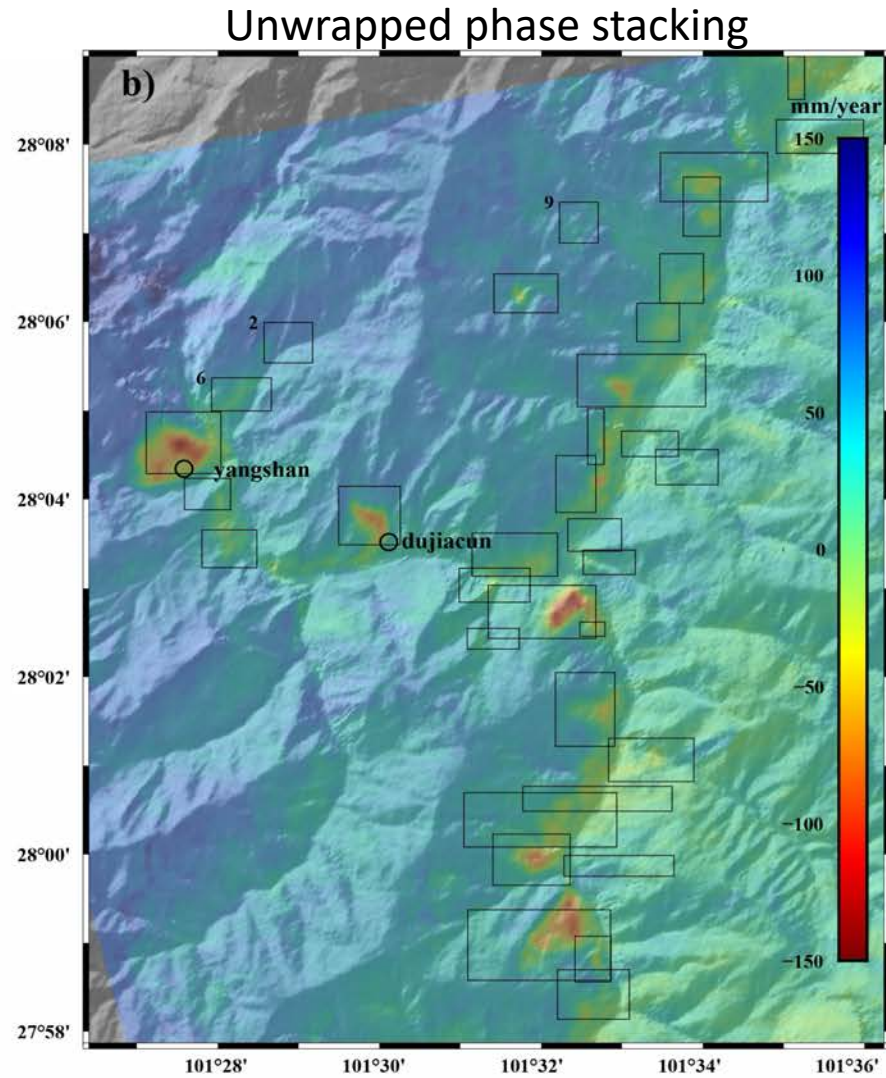
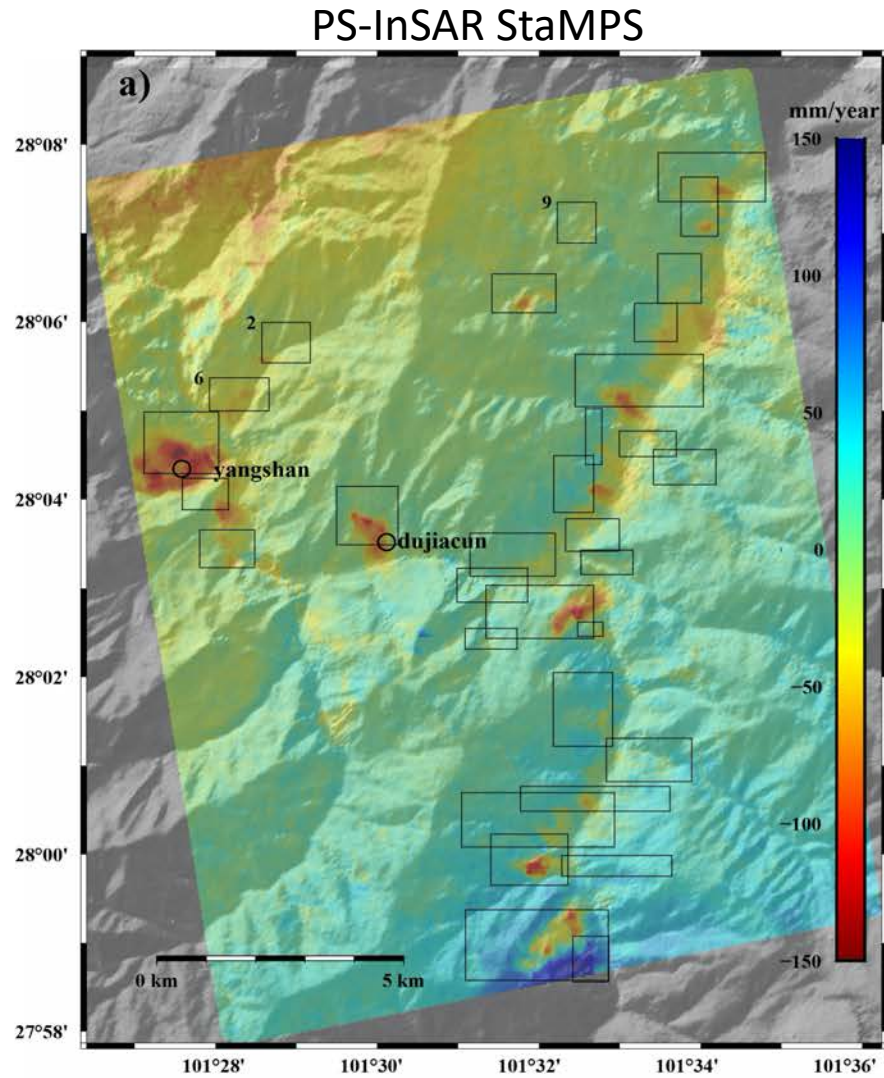
You Only Look Once (YOLOv3)



Active Landslides

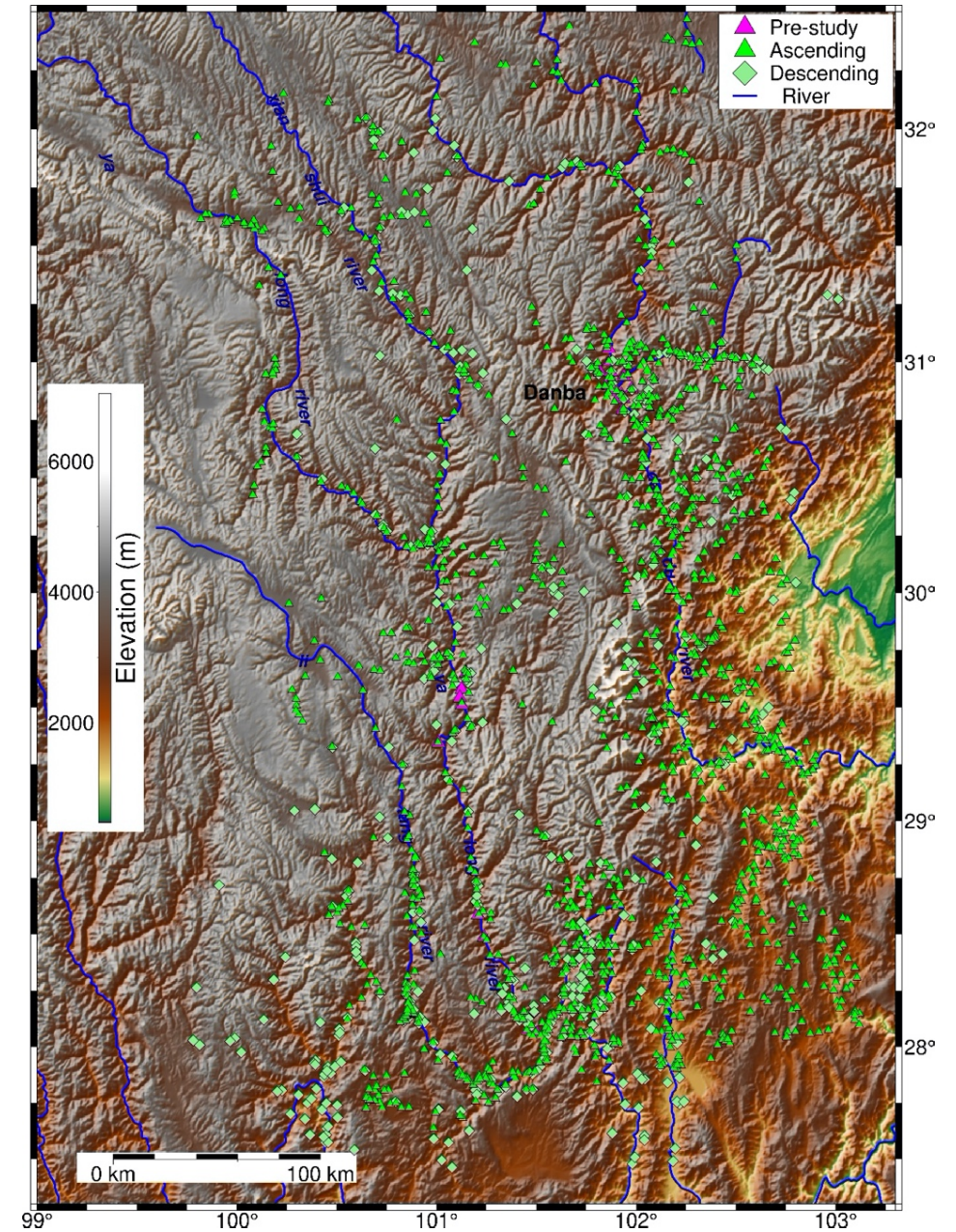


Active Landslides



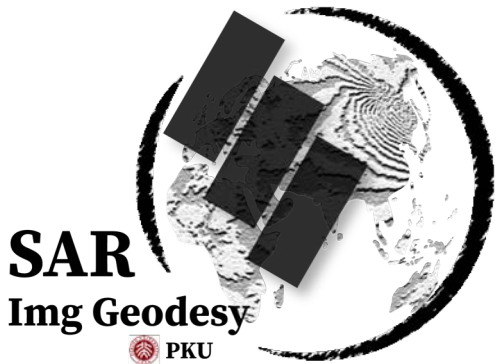
Active Landslides

- Sentinel-1 images acquired 2014-2020
- 145(A)+97(D) images in standard frame
- 349(A)+191(D) Interferograms within 36 days
- 180,000 km²
- 3797 of potential active landslides detected
- From SLC to detection result within 48h



Take home messages

- Fast InSAR processor is highly needed
- Detecting first, time-series processing later
- Deep learning is useful in large-scale SAR interferometry



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Assistant Professor

Thanks

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Email: wang.teng@pku.edu.cn

<http://sarimggeodesy.github.io>