An Improved Atmospheric Delay Correction Method for Active Landslides Detection

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Background

- Synthetic aperture radar interferometry (InSAR) is an effective tool for investigating wide-area active landslides.
- Traditional atmospheric delay correction methods are hampered by low spatial-temporal resolution or model selection.
- Stacking-InSAR, a fast deformation inversion technology, can be used to remove the low-quality signals.
- Here, we propose an improved method based on the multivariable moving-window empirical model (MMEM) for landslides detection.

1. Study area and datasets

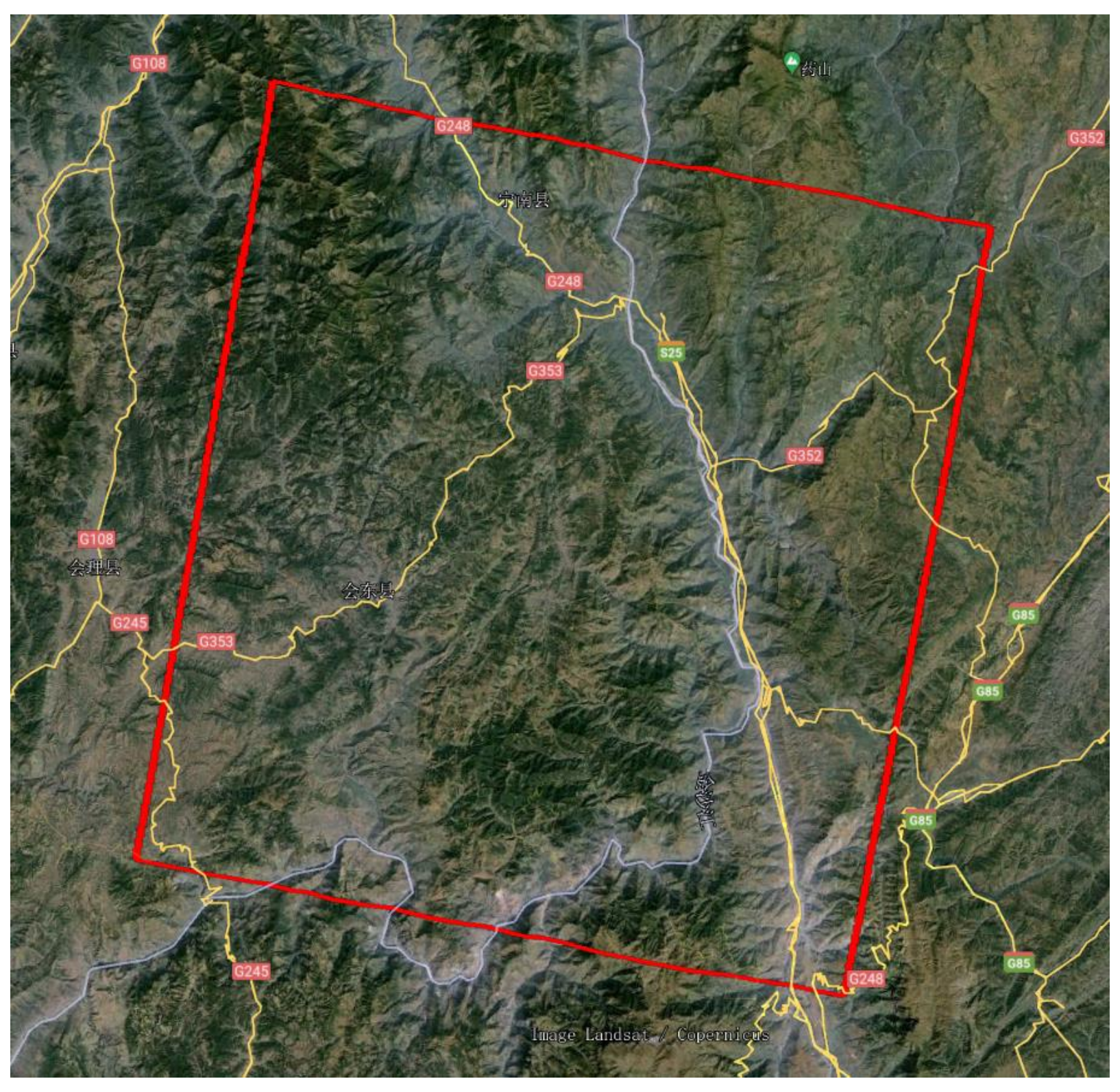


Figure 1 The location of the study area.

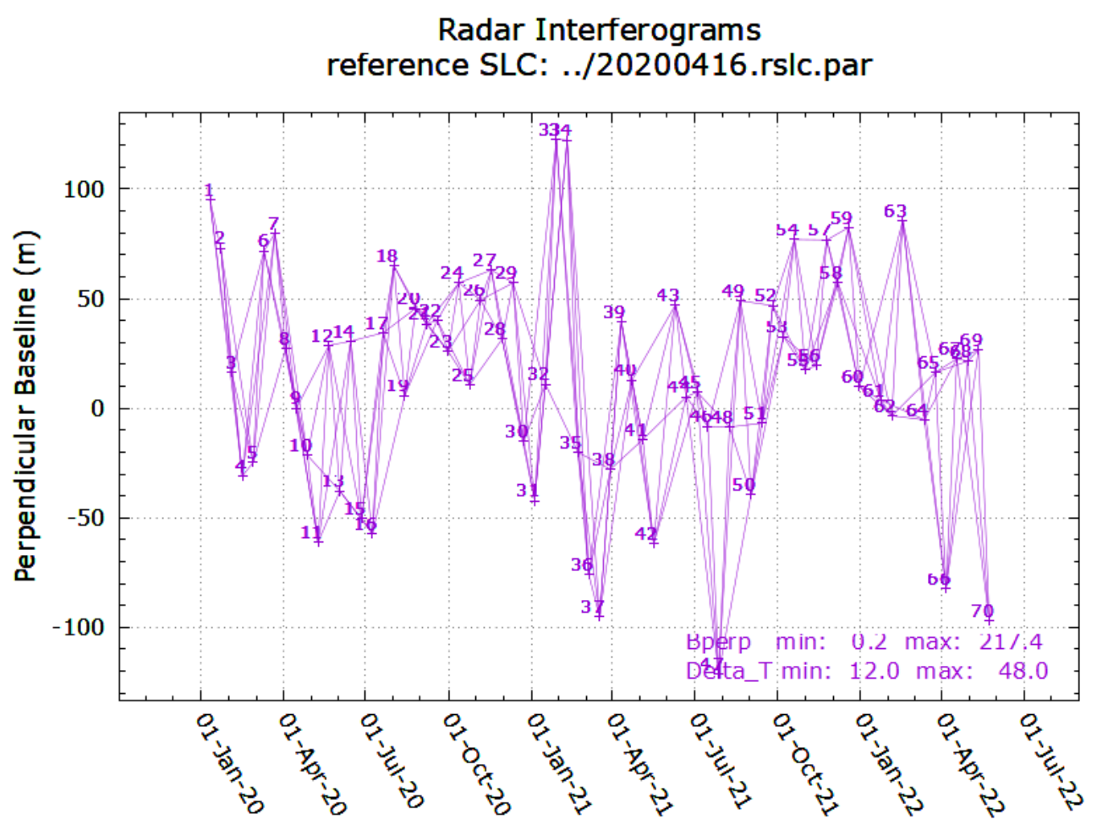


Figure 2 Spatial-temporal baselines of interferogram pairs.

The terrain of the area where Wudongde hydropower station located is high in the south and low in the north, with large terrain undulations, belonging to karst terrain, covering an area of 8405 km^2.

Key steps of SBAS-InSAR:

1. The main image is 2021/01/05.
2. The other image is registered and resampled with the main image.
3. Multilooking operation is used to remove speckle noise.
4. 95 interferograms are obtained.

3. Performance Evaluation

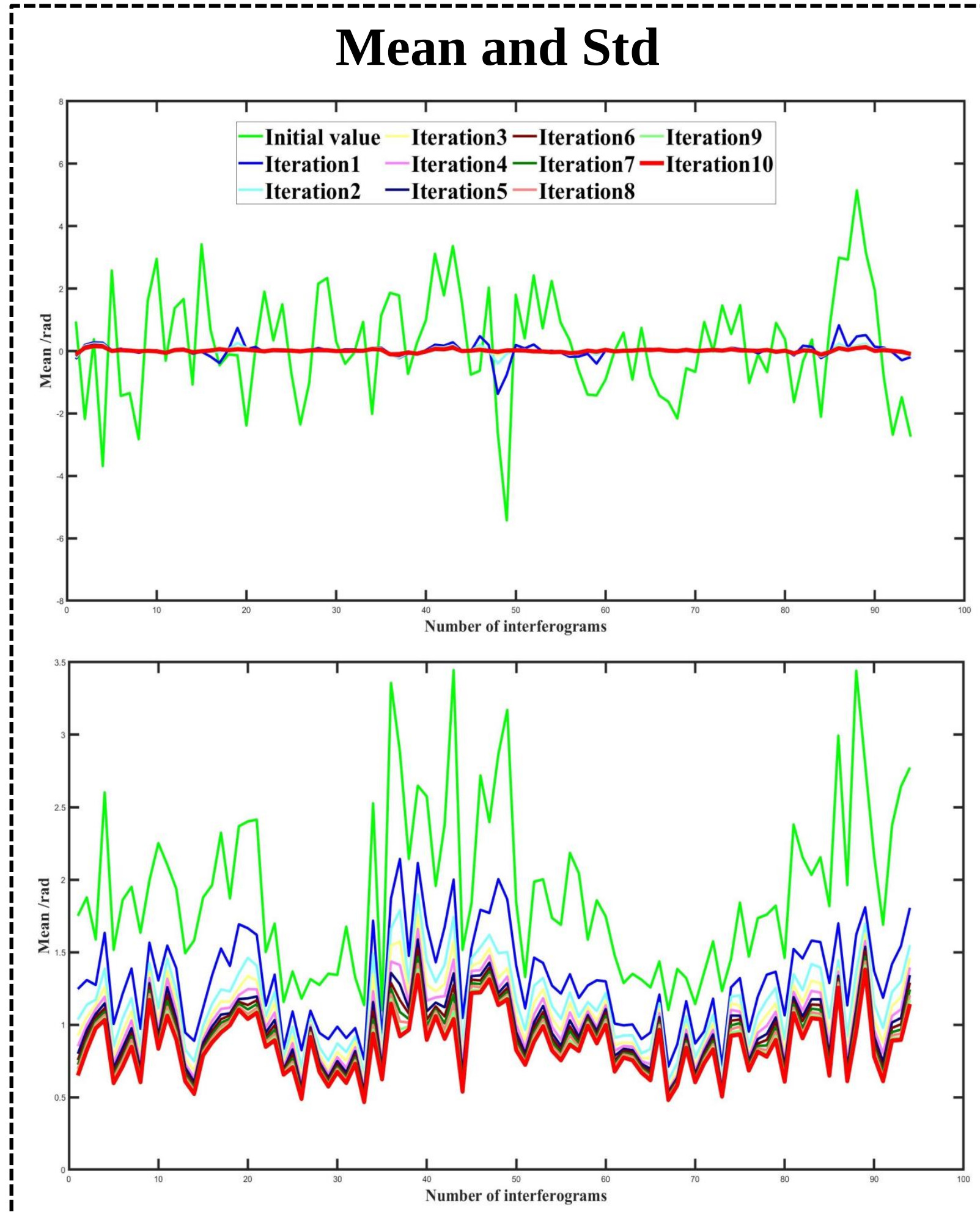


Figure 5 The iterative statistics of the Mean and Std. The red line is the result of the last correction.

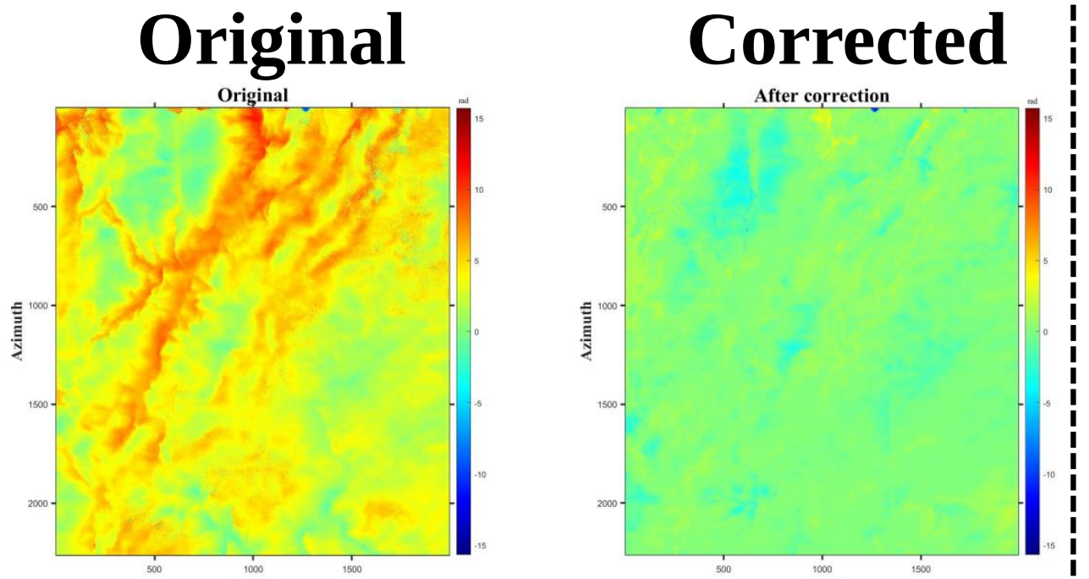


Figure 6 2020/04/28-2020/05/10.

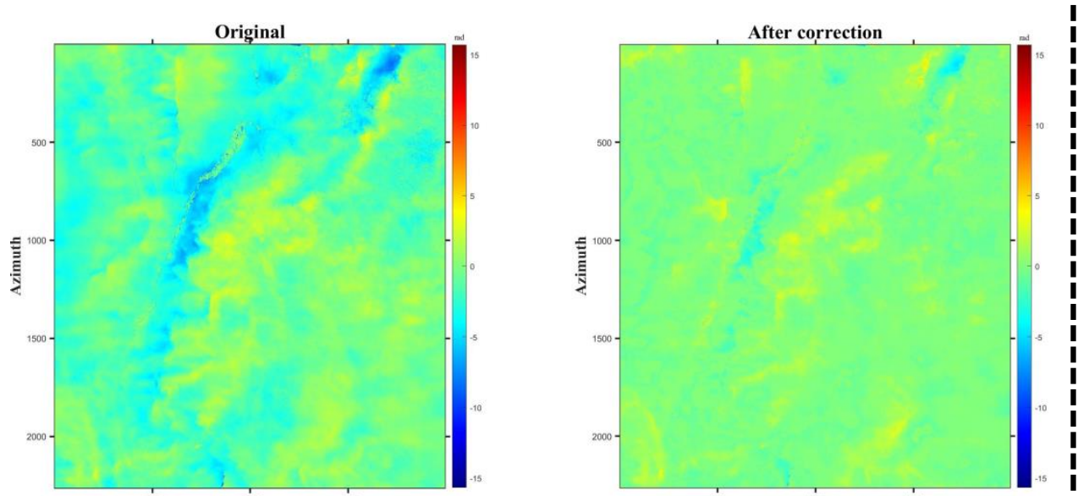


Figure 7 2021/12/31-2022/01/24.

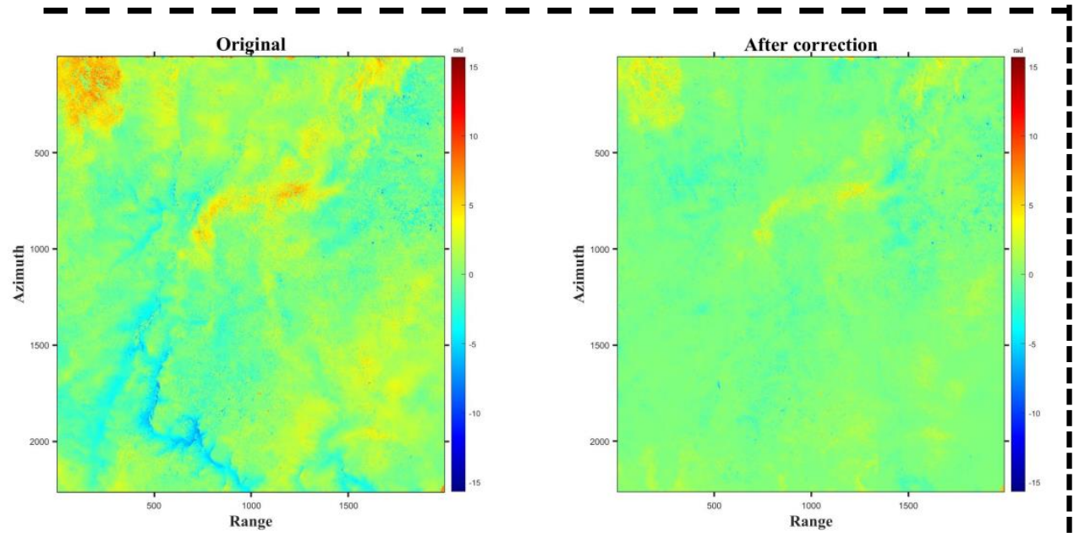
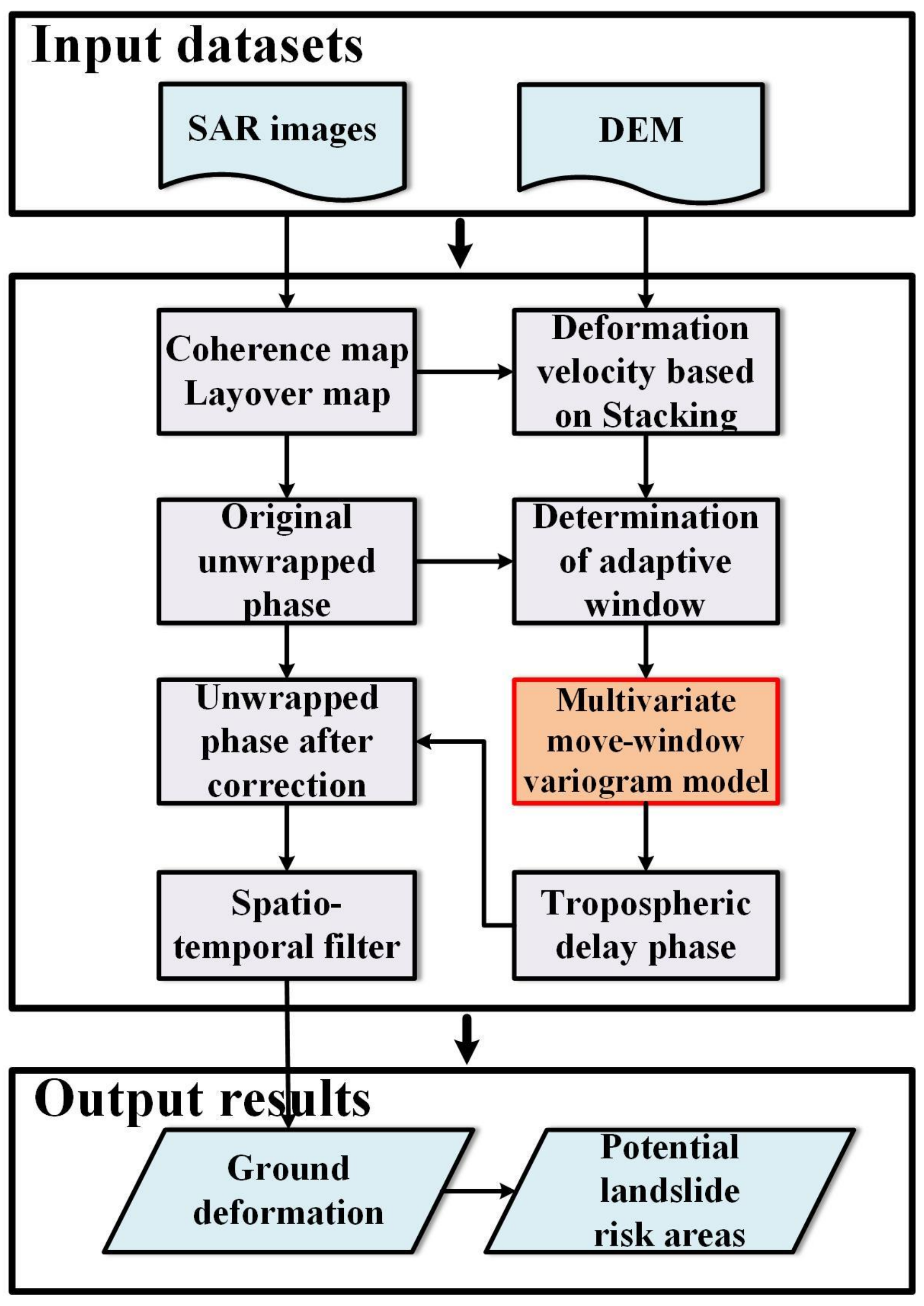


Figure 8 2022/02/05-2022/03/25.

The experimental results showed that the standard deviation (Std) of the phase, after being corrected by MMEM, decreased by 55.25% compared to the initial values, reducing from 1.9078 to 0.8538. The interferogram with the highest reduction is 2022/03/13-2022/04/06, reaching 72.32%.

2. Methodology



Input datasets

SAR images

DEM

Coherence map Layover map

Deformation velocity based on Stacking

Original unwrapped phase

Determination of adaptive window

Unwrapped phase after correction

Multivariate move-window variogram model

Spatio-temporal filter

Tropospheric delay phase

Output results

Ground deformation

Potential landslide risk areas

Figure 3 Workflow of the proposed method.

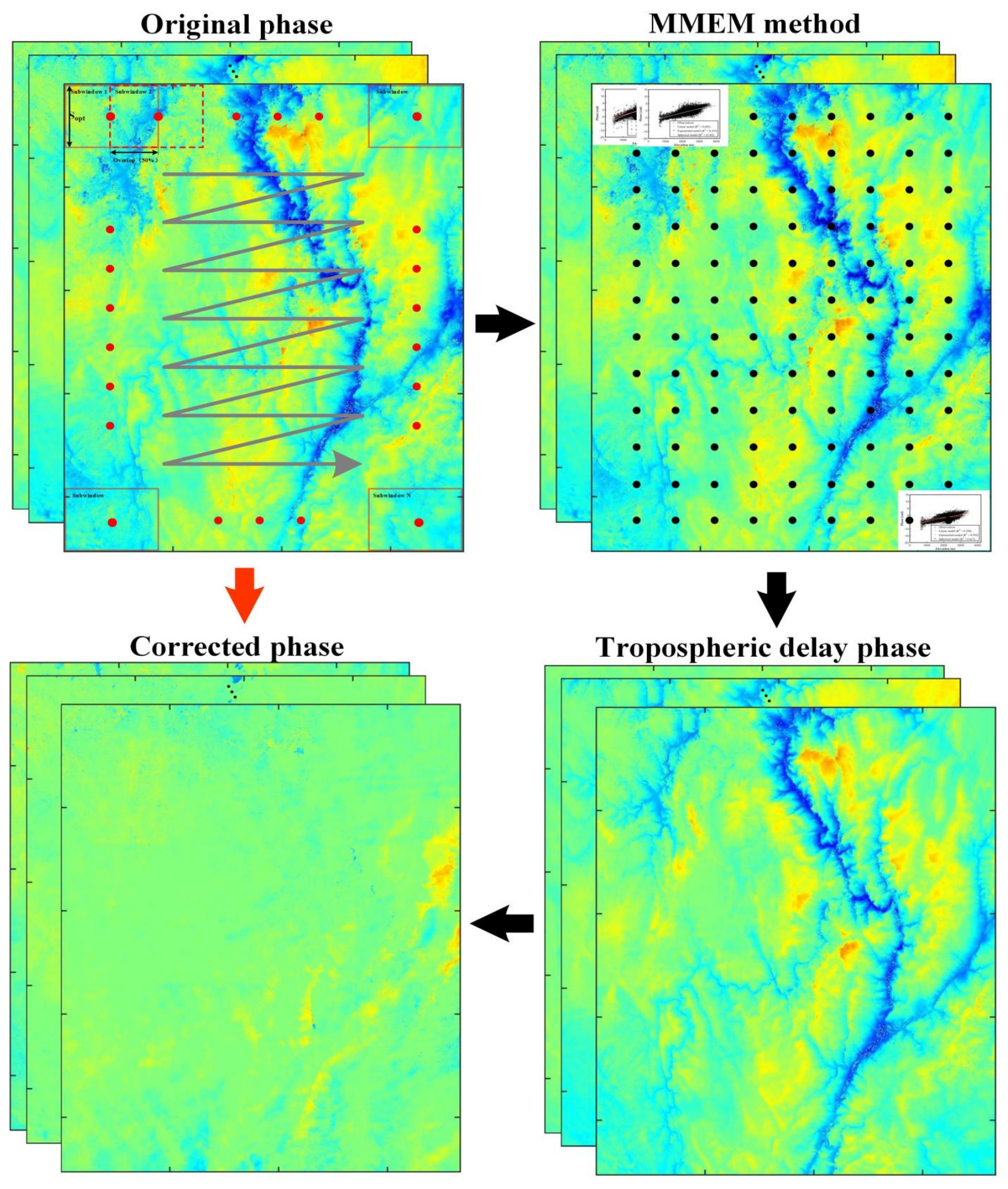


Figure 4 Schematic presentation of the proposed method.

Multivariable variogram models:

$$X = \operatorname{argmin}\left\{F\left(\phi_{S(n)} - \widehat{\phi}_{S(n)}\right)\right\}$$

$$= \operatorname{argmin}\left\{\sum_{i=1}^{k}\left[\begin{matrix}\phi^{i}_{S(n)}\\ \phi^{i}_{S(n)}\\ \phi^{i}_{S(n)}\\ \vdots\end{matrix} - \left(\begin{matrix}x_1\cdot h_{S(n)}+x_2\\ x_3\cdot x_4^{h_{S(n)}\cdot x_5}+x_6\\ x_7\cdot h^2_{S(n)}+x_8\cdot h_{S(n)}+x_9\\ \vdots\end{matrix}\right)\right]^2\right\}$$

MMEM of the *k*th iteration:

$$\begin{aligned}\varphi^{j}_{i,k+1} &= \varphi^{j}_{i,k} - w^{j}_{i,k}\cdot\widehat{\varphi}^{j}_{i,k}\\ &= \varphi^{j}_{i,k} - w^{j}_{i,k}\cdot\underset{\widehat{\varphi}}{\operatorname{argmax}}\left[R\left(\widehat{\varphi}^{j}_{i,k},\varphi^{j}_{i,k}\right)\right]\\ &= \varphi^{j}_{i,k} - w^{j}_{i,k}\cdot\underset{\widehat{\varphi}}{\operatorname{argmax}}\left(h^{j}_{i}\otimes X^{j}_{i,k}\right)\\ &= \varphi^{j}_{i,k} - w^{j}_{i,k}\cdot\underset{\widehat{\varphi}}{\operatorname{argmax}}\left\{h^{j}_{i}\otimes\underset{X}{\operatorname{argmin}}\left[F(X)\right]\right\}\end{aligned}$$

$$w^{j}_{i,k} = \begin{cases}1 & if: abs(v^{j}_{i,k}) \le v_{thr}\\ abs\left[abs(v^{j}_{i,k}) - v_{thr} + 1\right]^{\gamma} & if: abs(v^{j}_{i,k}) > v_{thr}\\ 0 & else\end{cases}$$

4. Experimental result

A total of 44 landslides were identified in the study area and 18 of which pose a threat to surrounding villages. Red solid polygons represent the boundaries of risky zones.

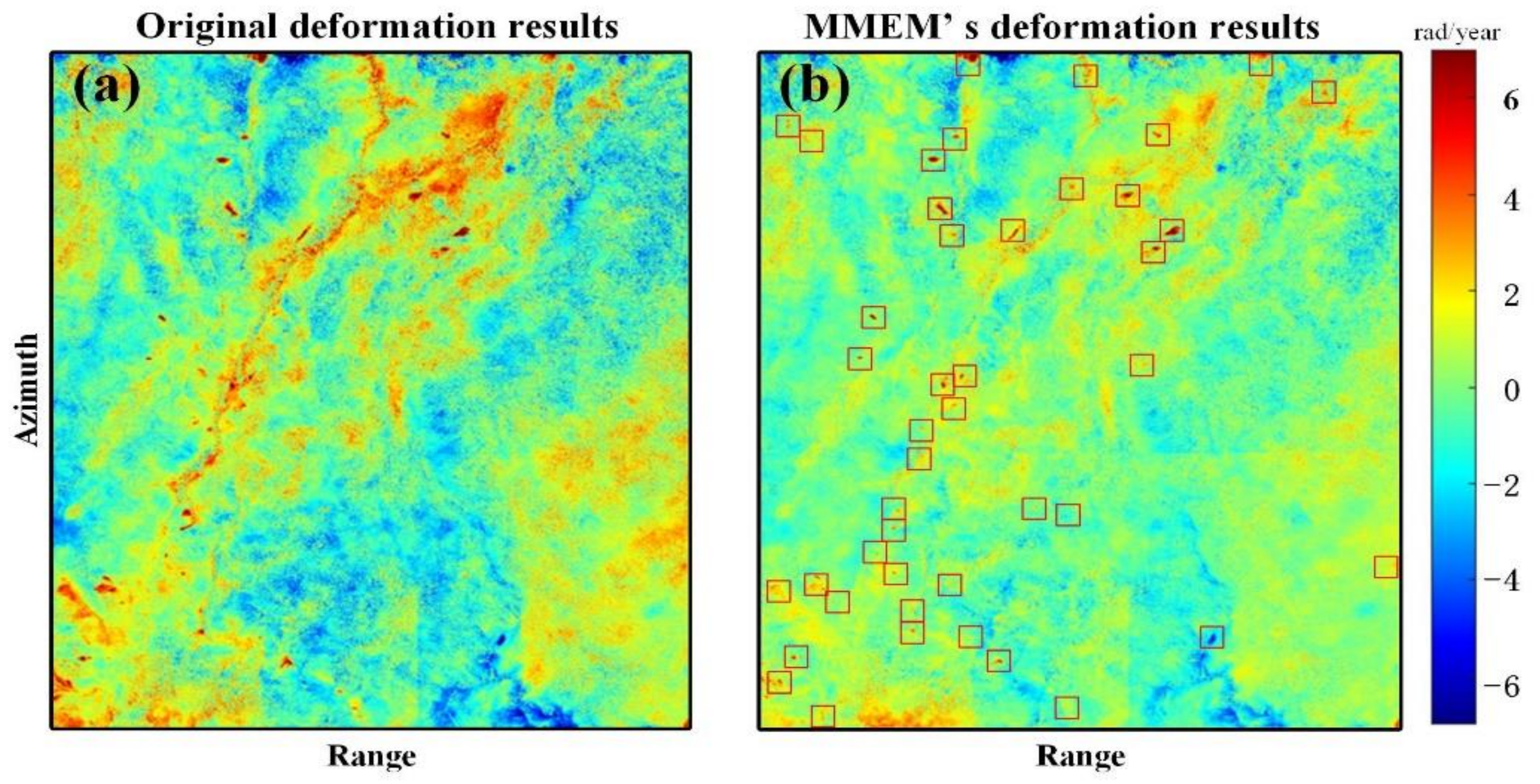


Figure 9 The original deformation results. (b) The MMEM-corrected deformation results.

Conclusions

- A comparative analysis was carried out with traditional method in terms of corrected interferograms and derived deformation to demonstrate the superiority of the proposed method.
- The experimental results demonstrate the superiority of the proposed method and provide support to disaster investigation department.

References

- M. Y. Shi, J. H. Peng, X. Chen, Y. Z. Zheng, H. L. Yang, Y. H. Su, G. Y. Wang, and W. W. Wang, “An Improved Method for InSAR Atmospheric Phase Correction in Mountainous Areas,” IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 14, pp. 10509-10519, Feb. 2021.
- H. Y. Liang, L. Zhang, X. L. Ding, Z. Lu, and X. Li, “Toward Mitigating Stratified Tropospheric Delays in Multitemporal InSAR: A Quadtree Aided Joint Model,” IEEE Trans. Geosci. Remote Sens., vol. 57, no. 1, pp. 291-303, Jan. 2019.