Monitoring large-scale linear hydraulic engineering using time series Sentinel-1 dataset——A case study of the Middle Route of China's South-to-North Water Diversion Project

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Abstract

Large-scale man-made linear hydraulic engineering has the features of long line, wide areas, complex engineering layout and many types of functional buildings. The South-to-North Water Diversion (SNWD) Project is a great infrastructure of China to alleviate the serious water shortage in Northern China and optimize the water supply pattern.

In this study, a long-term time-series Sentinel-1 IW dataset, covering 3 image frames, was processed by Persistent Scatters InSAR (PS-InSAR) to monitor the dike of the Middle Route of the SNWD Project. The unstable canal sections were detected and some key sections were analyzed in details.

Introduction

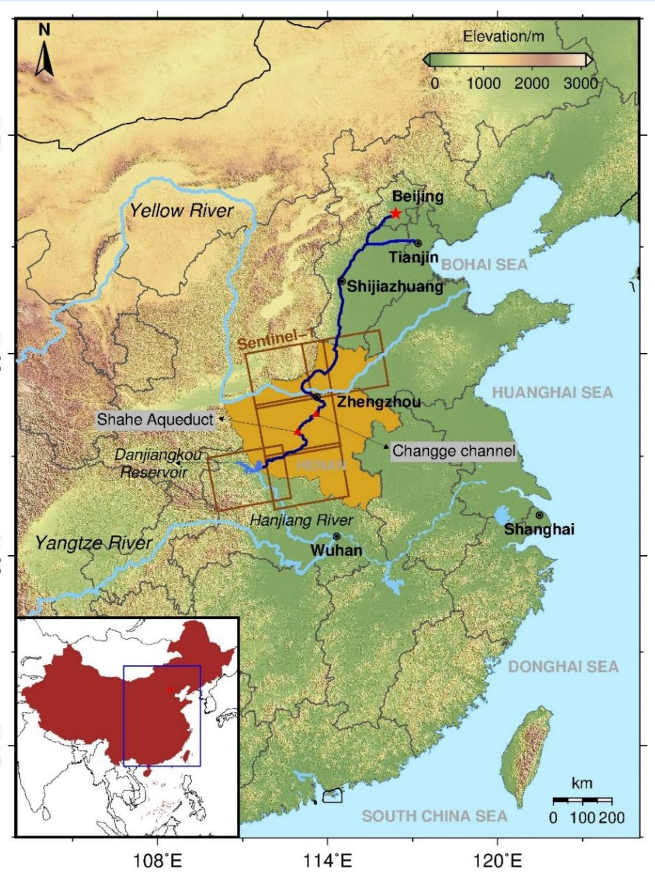
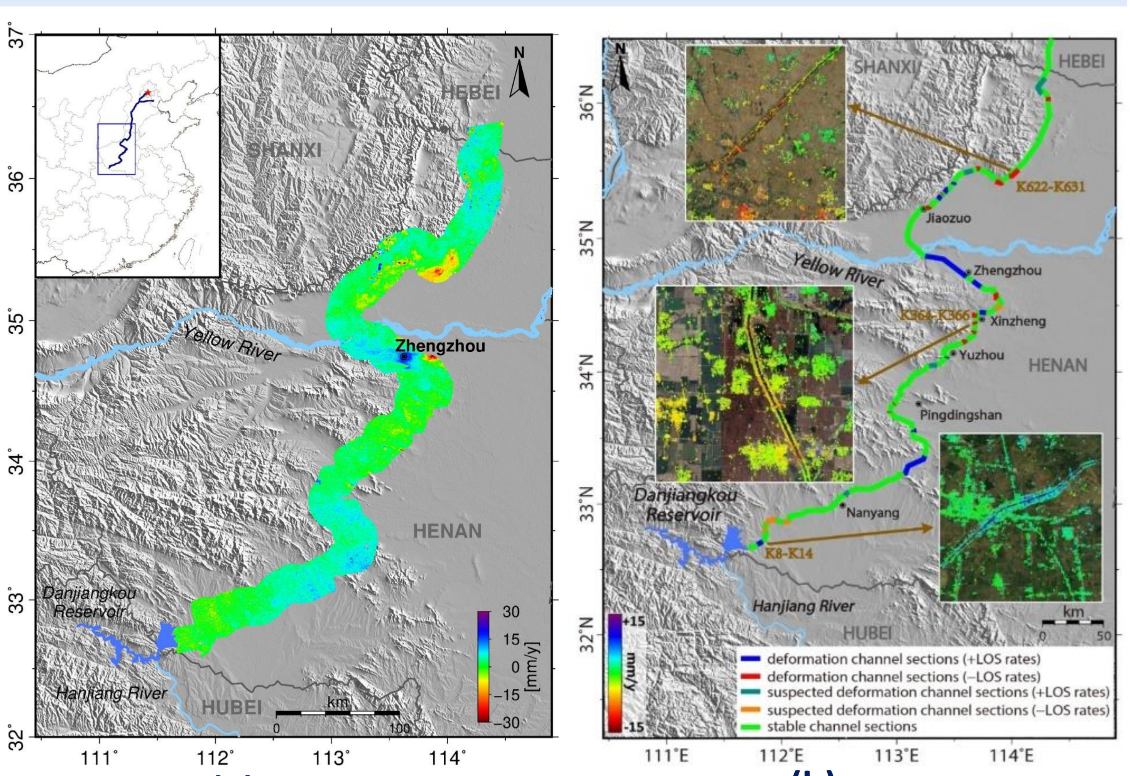


Figure 1. The location of the Middle Route of the NSWD Project and the image coverages.

The Middle Route Project transfers water from the Yangtze River to North China, with a total length of 1432 km, involving a water receiving area of more than 150 thousand km^2 and 60 million residents. It has greatly improved the water supply pattern in northern China and promoted sustainable development. Continuous surface monitoring of the MRP canal is an essential guarantee for uninterrupted water supply to Beijing-Tianjin area.

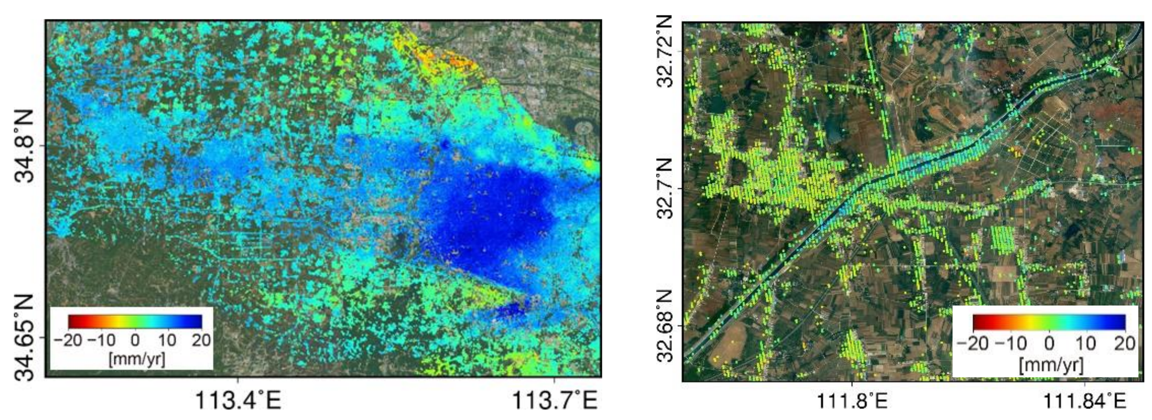
Large-scale Unstable canal Sections Detection



(a) (b)

Figure 2. The InSAR deformation rate map (a) and the deformed canal sections (b) of the Middle Route of NSWD Project.

We obtained the distribution map of deformation rate of the canal in the Henan Province with a length of 730 km, as shown in Figure 2. This result indicates that the canal is generally stable, except for partial canal sections. A total of 20 deformed canal sections were identified from the deformation rate map within Henan Province, including 10 canal sections with positive deformation rates and 10 canal sections with negative deformation rates. Some deformation of canal sections is caused by the surrounding ground subsidence, while others are deformation of the canal itself.



(a) (b)

Figure 3. The canals with deformation related to surrounding ground (a) and with deformation itself (b).

Analysis of Key Sections Ⅰ

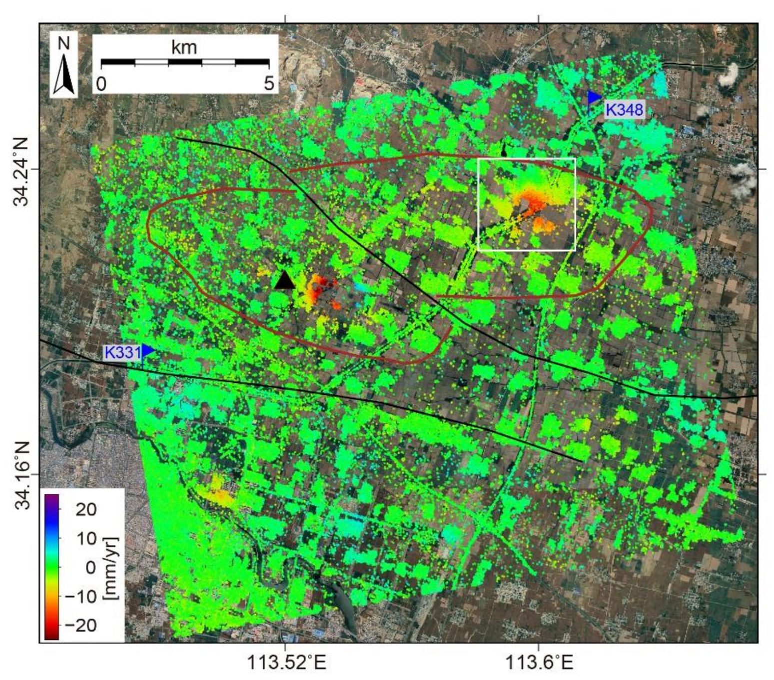


Figure 4. The deformation rate of the canal of Yuzhou-Changge section.

The Yuzhou-Changge canal section crosses through a subsidence region with an area of about 4.5 km^2, as shown in Figure 4. Its maximum deformation rate exceeds -20 mm/yr and the profile of the deformation rate along the canal line presents a very uneven deformation of the canal slope. The result is verified by in-situ leveling measurements and they agree well with each other.

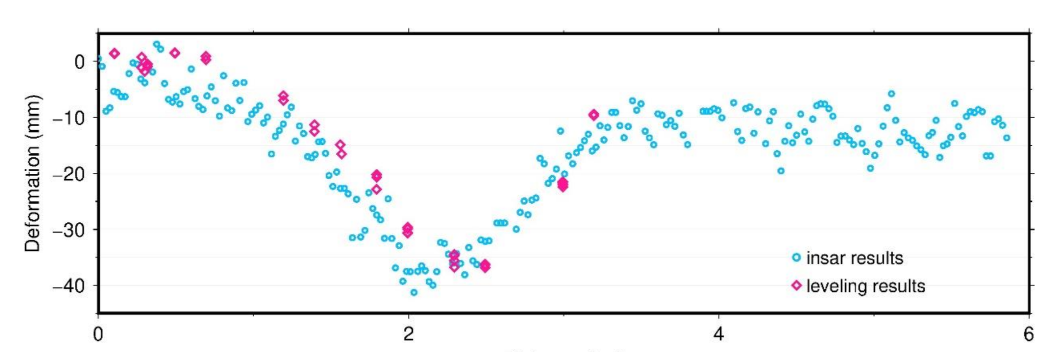


Figure 5. The comparison of InSAR accumulative vertical deformation and the leveling measurement.

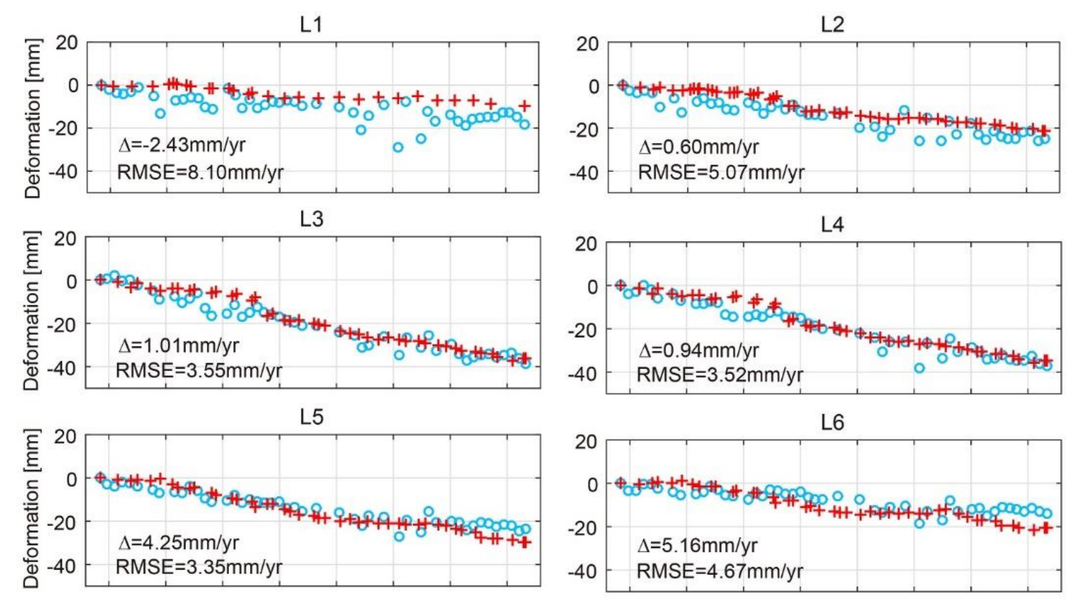


Figure 6. The displacement time series of InSAR and leveling.

Analysis of Key Sections Ⅱ

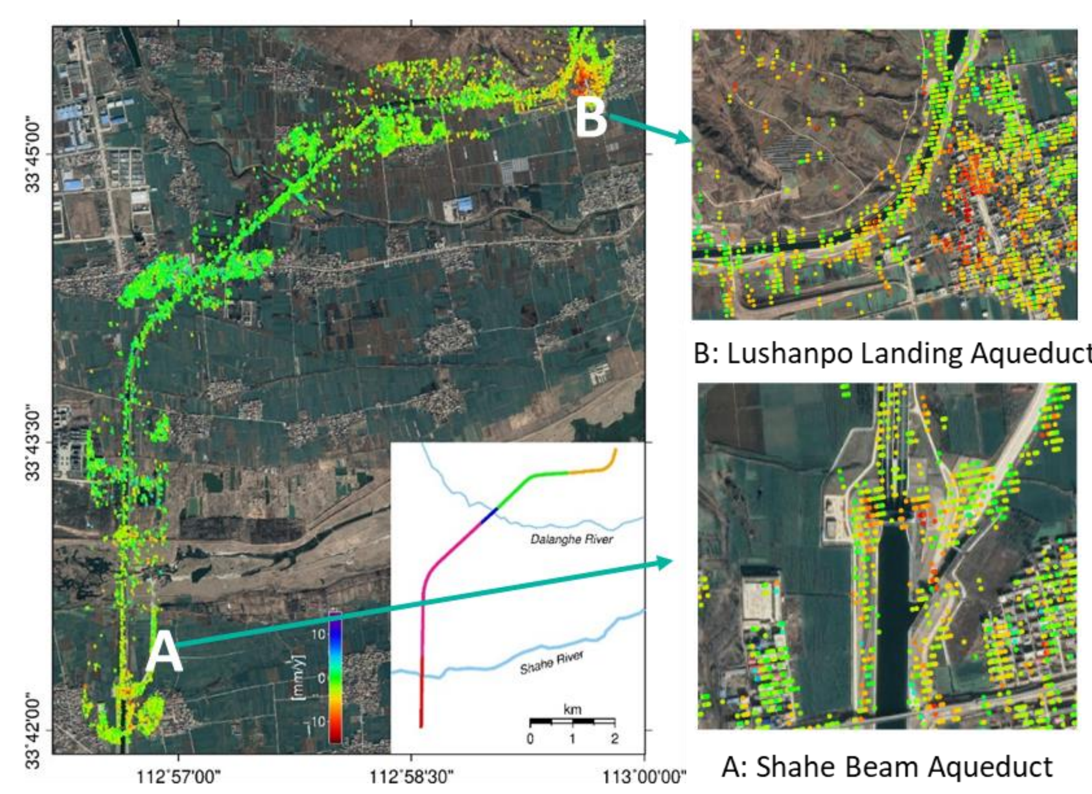


Figure 7. The deformation rate of the Shahe Aqueduct.

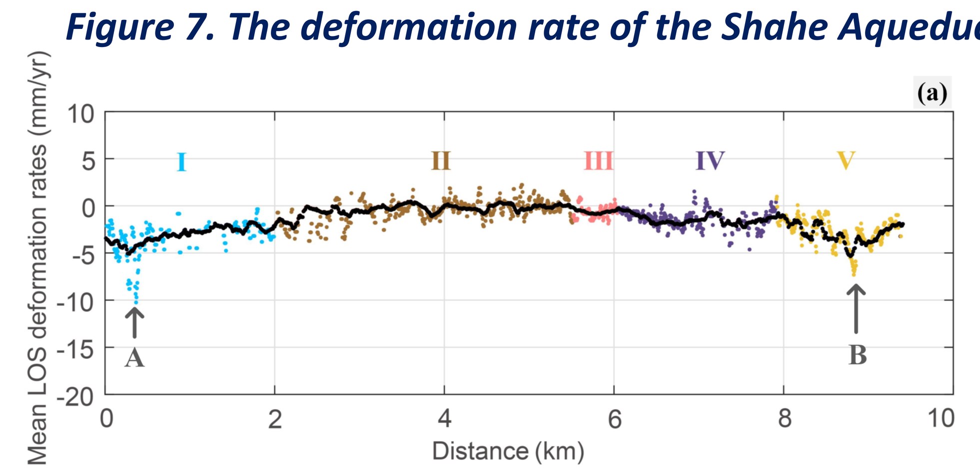


Figure 8. The profile of deformation rates along the Shahe Aqueduct.

Shahe Aqueduct, one of the most technically complex control engineering in the SNWD Project, is relatively stable, except for two design sections , as marked by A and B in Figure 7. For the first design part, the deformation rate of its main body is smaller than that at its entrance. The other one, the left side of which is excavated from the slope while the right side of which is high fill, is undergoing obvious deformation.

Conclusions

The time-series InSAR technique with high efficiency, high precision makes it a powerful tool for long-term safety monitoring of the SNWD project. It can greatly reduce the monitoring cost for the SNWD Project. It can not only measure the deformation of the canal slope itself, but also detect the stability of the surrounding area of the canal slope. This is more conductive to identify the root causes of deformation and provide guidance for subsequent canal safety maintenance. The InSAR technique can be extended to other routes of the SNWD Project or other water conservancy projects.

Main References

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