LONG-TERM URBAN SUBSIDENCE ANALYSIS USING PSINSAR IN WUHAN

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Abstract

Wuhan city has experienced serious risks in its urban areas due to rapid expansion and land subsidence. Previous studies used interferometric synthetic aperture radar (InSAR) for monitoring land subsidence in Wuhan, but with short time and temporal gaps. To fill this gap, long-term monitoring has been implemented using the high-resolution COSMO-SkyMed and StripMap TerraSAR-X satellite imagery using the PSInSAR technique, which enables object subsidence monitoring up to millimeter-level accuracy. However, for long-term observations of a highly dynamic urban environment, such as Wuhan, several assumptions of PSInSAR, like PS stability over the acquisition period or linear deformation, are unsuitable. Changes to the processing framework are therefore necessary and are tested in this work. Our findings reveal significant subsidence in various parts of Wuhan city, with varying rates and spatial extents. Furthermore, our analysis highlighted the influence of geological conditions and urban infrastructure on the distribution of subsidence zones within the city. Integration of PSInSAR with high-resolution SAR images enhances our understanding of the complex interplay of many factors contributing to subsidence.

Introduction

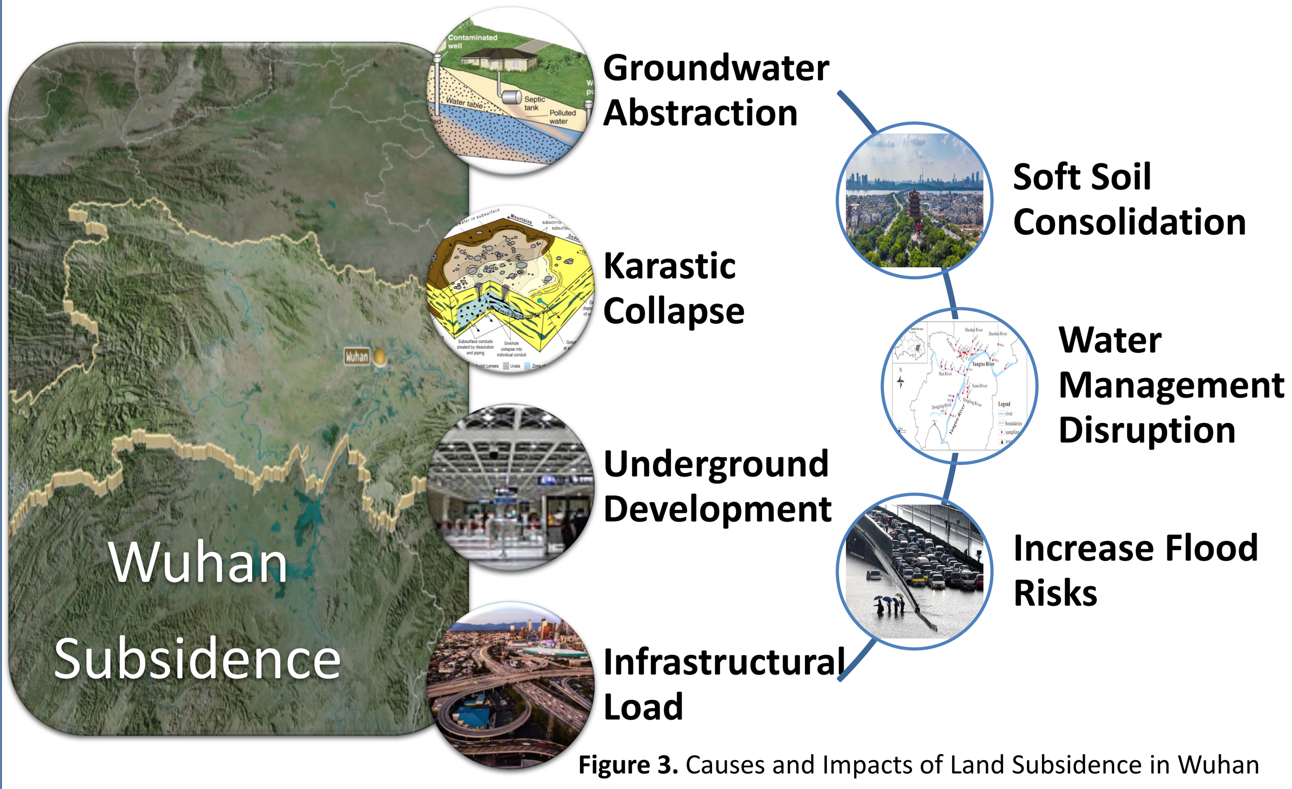


Figure 3. Causes and Impacts of Land Subsidence in Wuhan

Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials. *(USGS).*

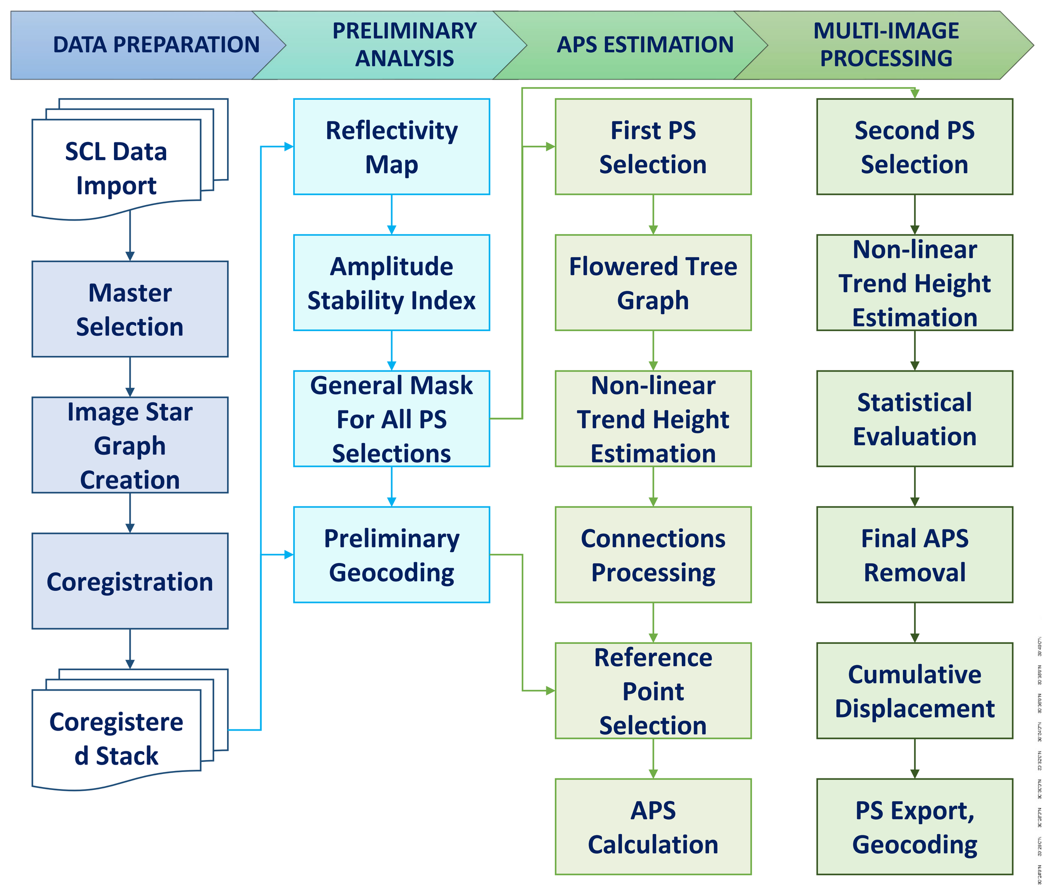
Objectives

Long-Term — **Monitor the long-term subsidence process affecting Wuhan and to reveal its spatiotemporal variations.**

Non-Linear PSInSAR — **Parameter estimation for Non-Linear PSInSAR to determine the Cumulative Displacement.**

Study Area — **Wuhan has experienced considerable ground subsidence over the past several decades due to fast urban growth and thus require specific investigation.**

Methods and Materials



Non-Linear PSInSAR

$$\Delta\varphi_{diff} = \frac{4\pi}{\lambda} T\Delta v + \frac{4\pi}{\lambda}\frac{B_{\perp}}{\rho \sin\theta}\Delta h + \Delta\varphi_{atmos} + \frac{4\pi}{\lambda}\Delta D_{Non-linear} + \Delta\varphi_{noise}$$

Figure 1. Non-Linear PSInSAR Processing in SARProZ

Satellite	COSMO-SkyMed	TerraSAR-X	TanDEM-X
Orbit Direction	Ascending	Ascending	Ascending
Looking Angle	26.5°	33.22°	35.3°
Ground Resolution	3m	3m	3m
Band (Wavelength)	X-Band (3.1cm)	X-Band (3.1cm)	X-Band (3.1cm)
Polarization	HH	HH	HH
Number of Images	396	32 (WEST) 33(EAST)	45(WEST) 45(EAST)
Temporal Coverage	29/5/2011-21/1/2020	30/5/2013-16/3/2017	26/8/2013-27/1/2019

Table 1. Key parameters of the SAR datasets Used.

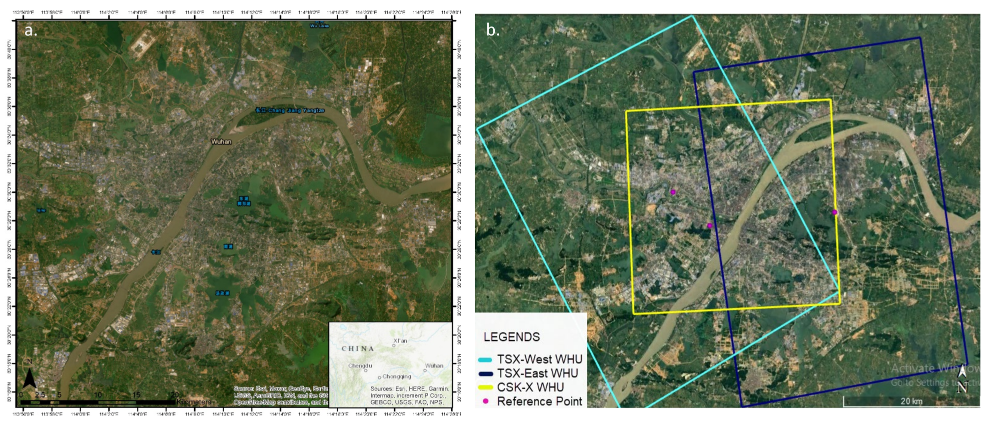


Figure 2. a. Study Area Map of Wuhan City. **b.** Research area of Wuhan, with outlined coverage of the three SAR data stacks used in this work

Results

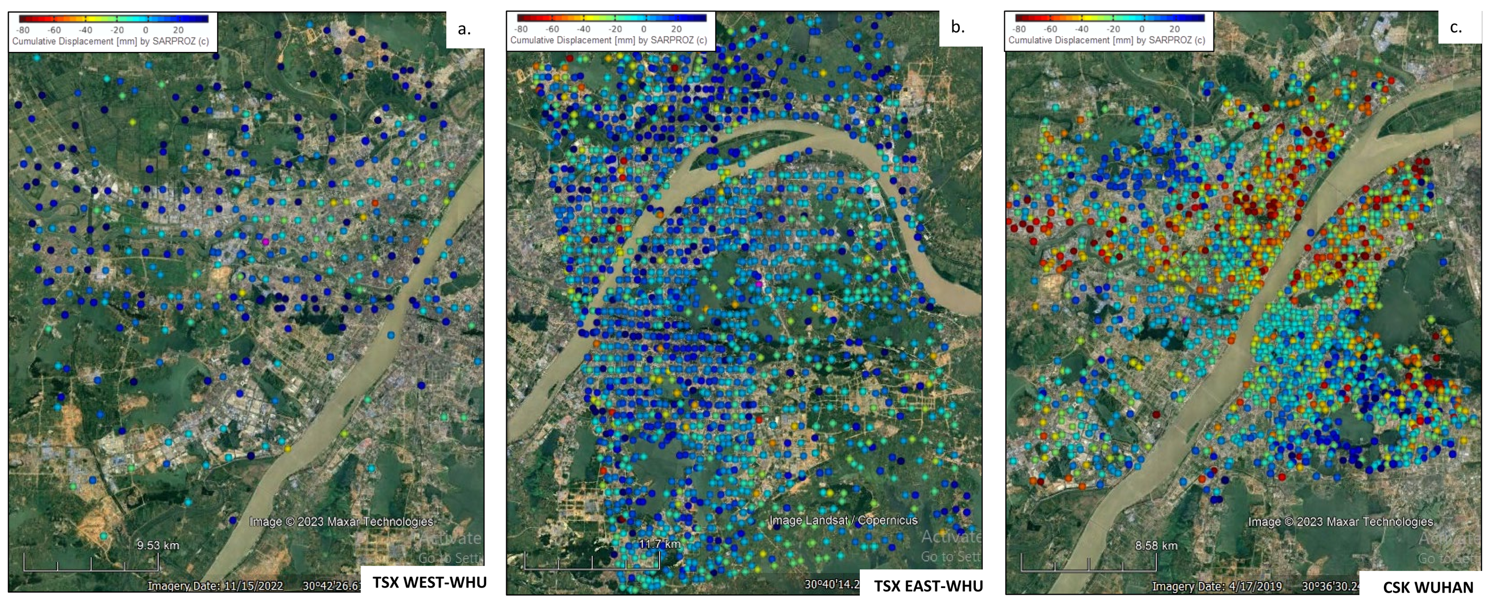


Figure 4. (**a**) PSInSAR TerraSAR-X Image of cumulative deformation map of WEST Wuhan from April 2013 to February 2019, with (**b**) PSInSAR TerraSAR-X Image of cumulative deformation map EAST Wuhan from April 2013 to February 2019. (**c**) PSInSAR CSK-X Image of cumulative from May 2011 to Jan 2020. The result is superimposed onto Google Earth imagery.

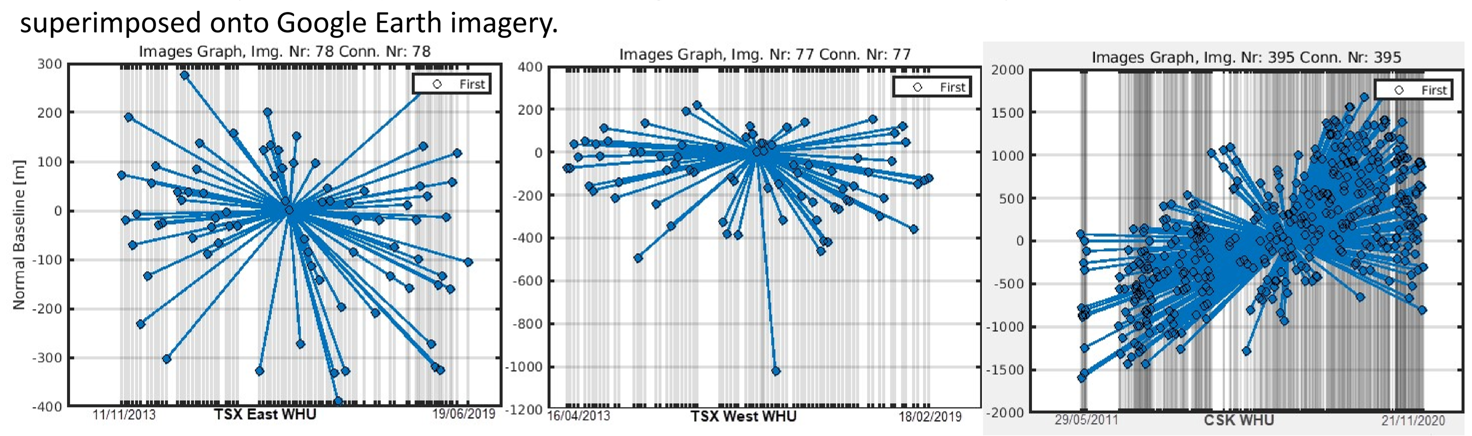


Figure 6. Star graphs showing the temporal/perpendicular baseline dispersion of the nearly 155 Strip Map TerraSAR-X and 396 CosmoSkyMed images processed over Wuhan from (2011-2020).

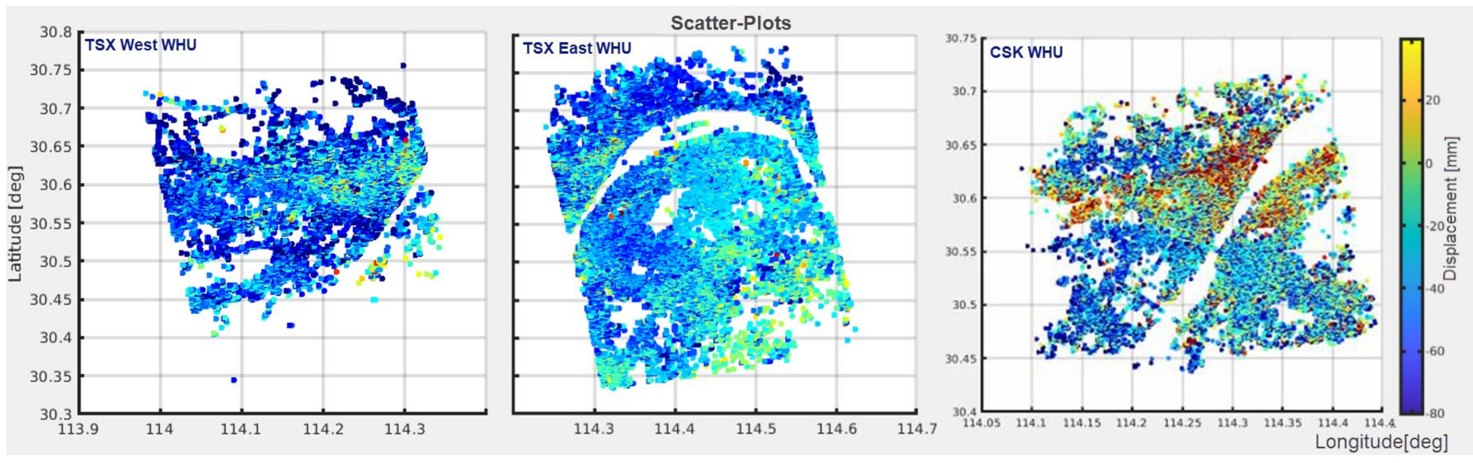


Figure 8. The scatter plots of the nearly 155 Strip Map TerraSAR-X and 396 CosmoSkyMed images processed over Wuhan from (2011-2020).

Selection of parameters during PSInSAR processing is based on hit and trial method as no model and formulas are defined already to select the values of parameters like Amplitude Stability Index and Coherence etc. It is not defined that values should be selected for specific type of area or dataset to get good PSI results. By applying same values to same area's different dataset, we got satisfactory results from TSX while CosmoSkyMed Data results shown were not satisfactory, while reason is still unknown.

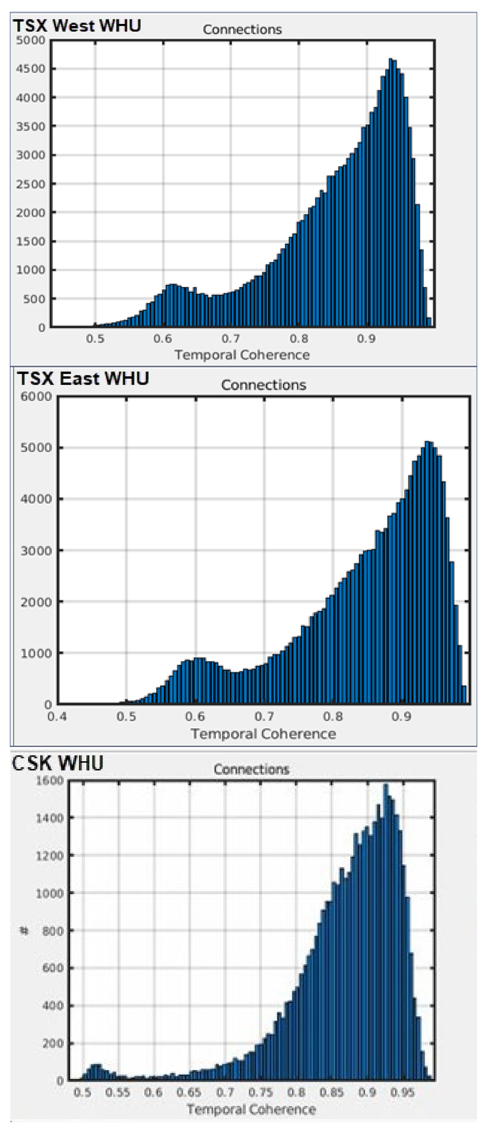


Figure 7. The graphs between the temporal coherence and connections for TSX and CSK Wuhan data.

Discussion

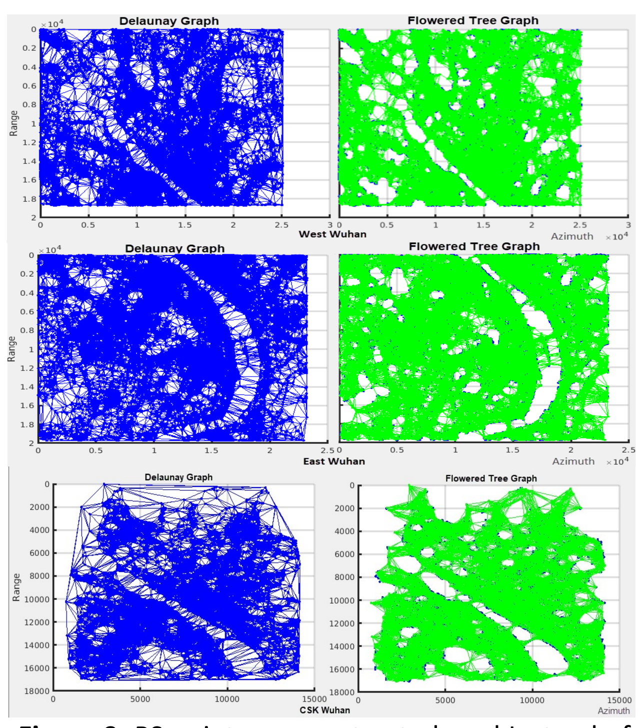
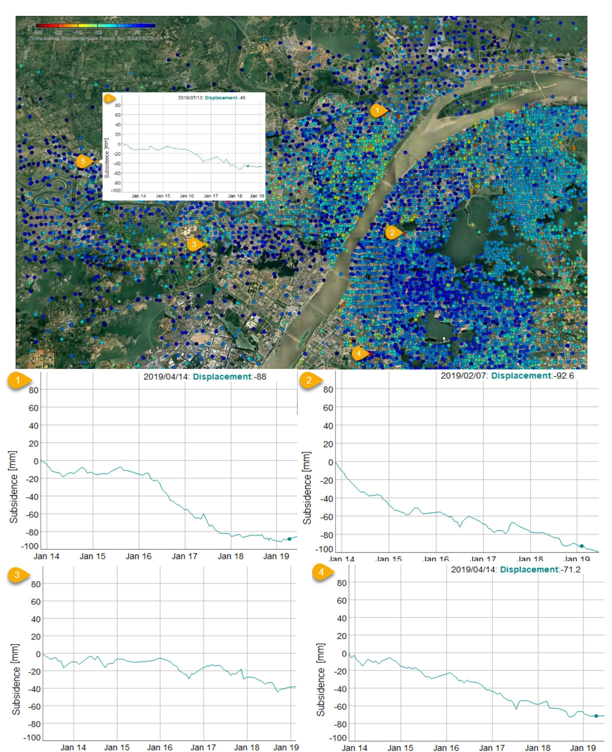


Figure 9. PS points were extracted, and Instead of Delaunay Graph we adopt Flowered Tree approach to reduce the atmospheric effects especially near the water bodies, as there are so many water bodies in Wuhan and the urban environment changed so quickly, also for long-term monitoring the displacement was greatly affected by the atmospheric artifacts between each PS connection.

Figure 5. PS Points investigation showing noticeable deformation both East Wuhan (right side) and West Wuhan(left side). 5 random PS points are chosen to show long term profile.



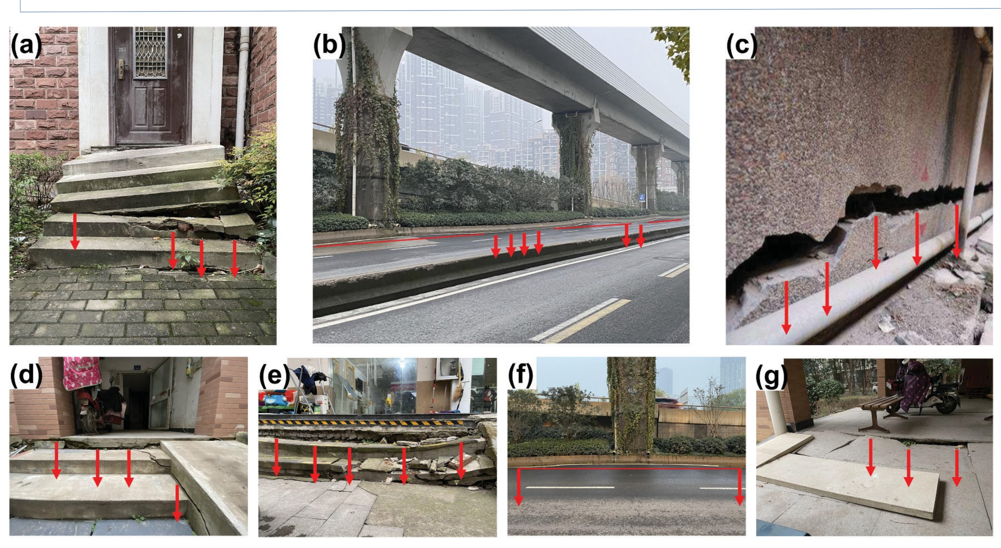


Figure 5. Field investigation showing noticeable cracks and discontinuities in the roads and building walls caused by the settlement. Photographs taken in September 2020 are from (Jiang et al. 2023) paper.

Conclusions

PSInSAR analysis of nearly 155 StripMap TSX-X and 396 CSK images was used to monitor the large-area surface subsidence affecting the city of Wuhan. This long-term investigation allowed, a complete overview and analysis of the spatiotemporal deformation trends. The results show that there are many subsidence areas in the main urban areas of Wuhan. The cumulative deformation across the Wuhan area from May 2011 to Jan 2020 is maximum -198mm. For future perspective we will look in details how these deformation are affecting cultural heritage sites in Wuhan.

References

1. Jiang H., Balz T., Cigna F., Tapete D. (2021) Land Subsidence in Wuhan Revealed Using a Non-Linear PSInSAR Approach with Long Time Series of COSMO-SkyMed SAR Data. Remote Sens., 13, 1256. https://doi.org/10.3390/rs13071256

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