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# Study on the Volcanic Activities of Changbaishan Based on Time-series InSAR

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## Abstract

In this paper, facing the demand of volcanic activity analysis in Tianchi, Changbaishan, the existing time-series InSAR deformation monitoring method and volcanic point source model are improved, and a set of volcano monitoring scheme suitable for Changbaishan is proposed. Firstly, to address the problem of high vegetation coverage and deformation monitoring being greatly affected by vegetation decoherence, a time-series InSAR deformation monitoring method based on normalized difference vegetation index (NDVI) constraint is proposed. Based on 33 Envisat ASAR images between 2004 and 2010 and 19 ALOS PALSAR images between 2018 and 2020, the accurate surface deformation parameters of the Changbaishan Tianchi crater and the surrounding area were extracted using the small baseline subset technique (SBAS-InSAR). Due to the lack of level data between 2018 and 2020 for comparison, the surface deformation parameters between 2018 and 2020 were also extracted using the persistent scatterer technique (PS-InSAR). The two sets of results were cross-validated and analyzed together with the seismic activity data of the same period. Secondly, we systematically analyzed the three-dimensional geometric relationship between the volcanic surface deformation field and the radar line of sight direction, established a generalized projection conversion equation from the horizontal and vertical deformation of the volcano to the LOS direction, improved the original point source model based on the horizontal and vertical deformation respectively to a point source model based on the LOS direction deformation, and inverted the magma chamber parameters for each time period of Changbaishan Tianchi volcano. Finally, based on the inversion results of the improved point source model, the surface deformation field of Tianchi volcano was orthorectified. The orthorectified results were compared and analyzed with seismic monitoring and fluid geochemical monitoring data to accurately assess the changes of magma chamber of Tianchi Volcano, and to explore the process of volcanic activity in Tianchi, which changed from strong to weak around the end of the disturbance period and gradually became active in the last two years. The results of this paper show that the Tianchi volcanic magma chamber first experienced a brief expansion between 2004 and 2010, with the $M_L$ 3.7earthquake on September 8, 2004 as the turning point, and then began to enter a fluctuating gradual contraction after the earthquake until it stabilized in 2008. The volcanic magma chamber of Tianchi showed a fluctuating gradual expansion state between 2018 and 2020, and the whole change process was cyclical, with extreme values of deformation once the summer season. Similarly, the temporal deformation of PS-InSAR also has a cyclical trend, which is consistent with the results of SBAS-InSAR.

## Data Processing and Results

### Study Area

Changbaishan Volcano is located on the eastern edge of the Eurasian Plate and the leading edge of the subduction zone of the Western Pacific Plate, and is the most dangerous eruptive active volcano in China. Among the many volcanoes in Changbai Mountain, Tianchi Volcano is the largest and highest in elevation, with a crater diameter of about 4.5 km and a central cone elevation of more than 2.600 meters.

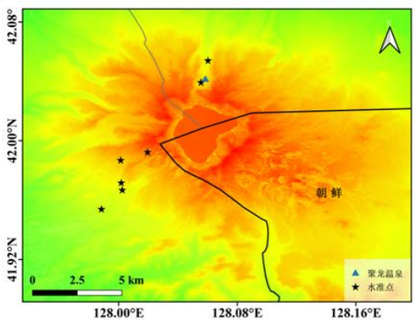


Fig.1 Topography of the Study Area

### Methodology

In order to study the dynamic changes during and after the active period of Changbaishan Tianchi volcano, this paper improves on the problems in the volcano time-series InSAR deformation monitoring and point source model inversion studies. First, in order to suppress the interference of vegetation decoherence on the time-series InSAR deformation monitoring results, a time-series InSAR deformation monitoring method based on the normalized vegetation index constraint is proposed. Secondly, the three-dimensional geometric relationship between the volcanic surface deformation field and the radar line of sight direction is systematically analyzed, and a universal equation for the projection transformation from the horizontal and vertical deformation of the model volcano to the LOS direction is established. Then, the original point source model based on horizontal and vertical deformation, respectively, is improved to a point source model based on LOS-oriented deformation based on the above conversion relational equation. Unlike the results of existing studies, the inversion is directly based on the InSAR LOS deformation results instead of ignoring the effect of horizontal deformation, which avoids wrong a priori assumptions and makes the inversion results more reliable.

### Results from 2004 to 2010

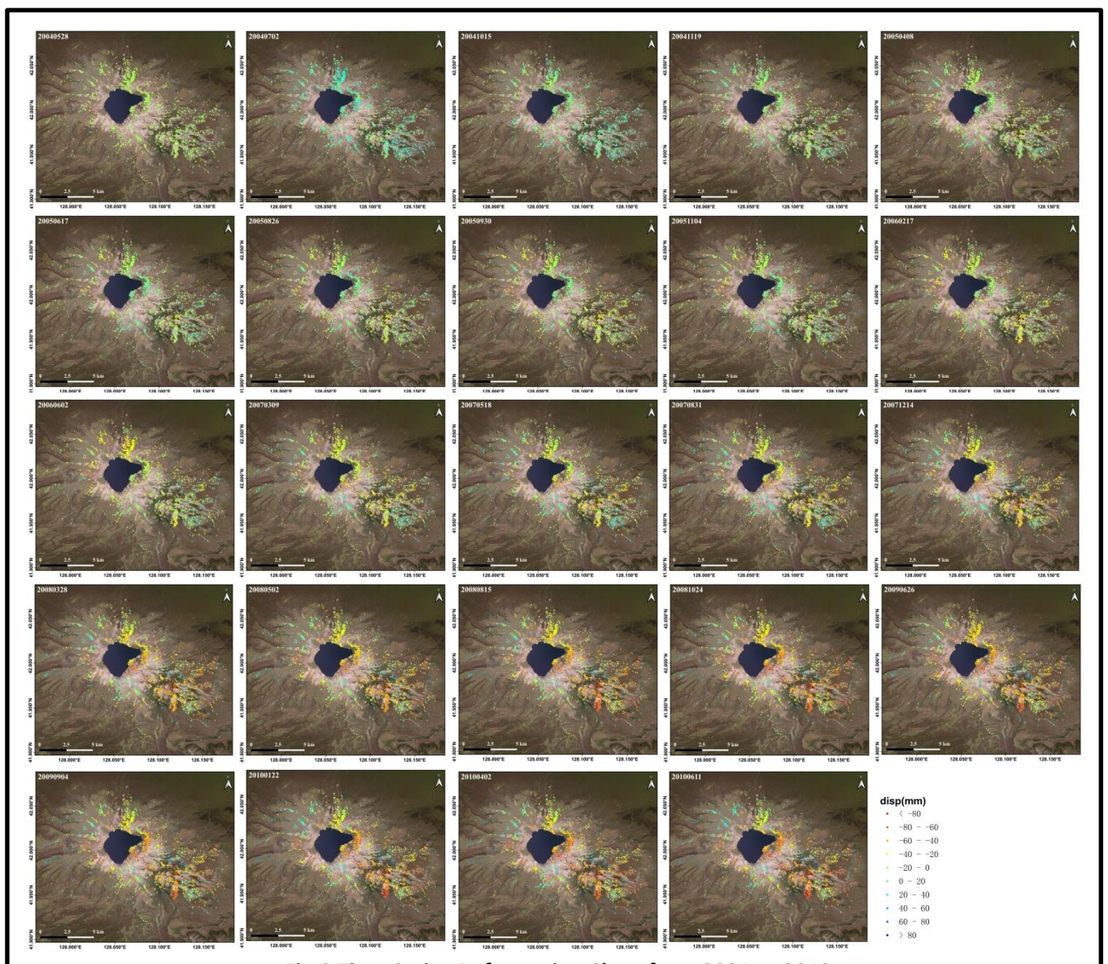


Fig.2 Time Series Deformation Chart from 2004 to 2010

### Results from 2018 to 2020

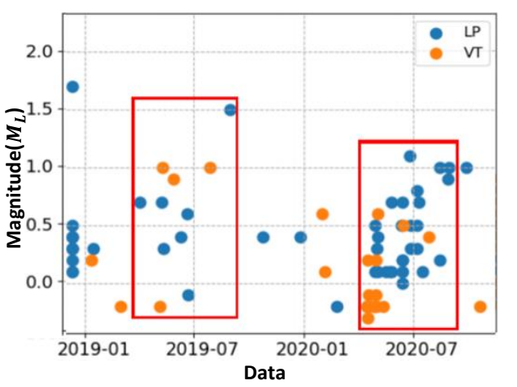


Fig.4 Seismic Activity

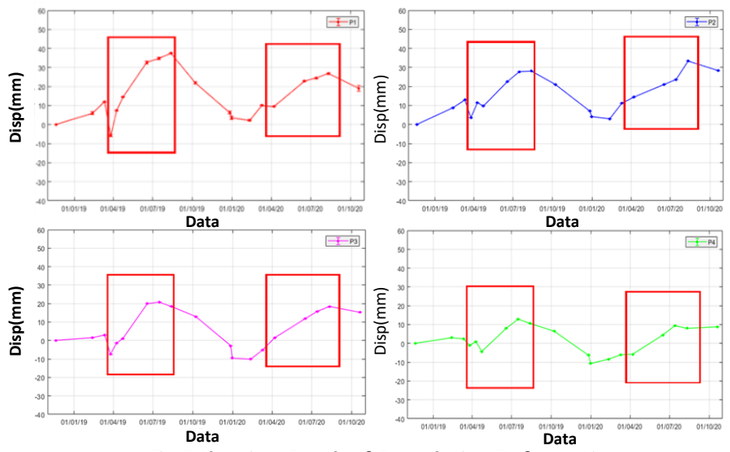


Fig.5 the Line Graph of Cumulative Deformation

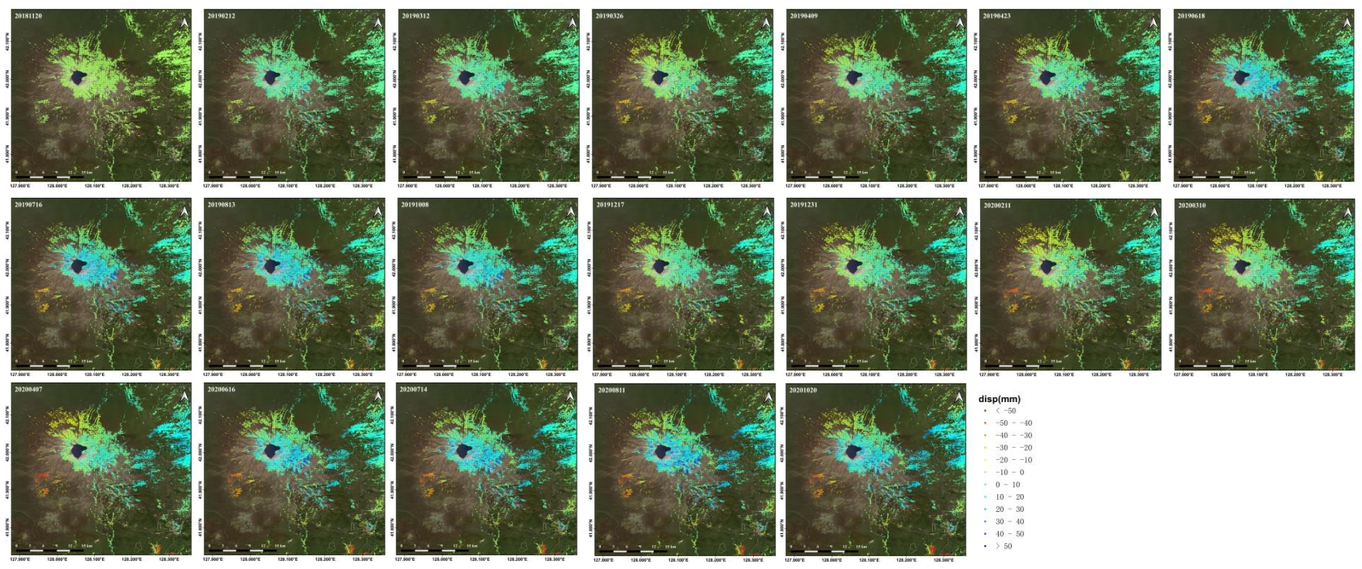


Fig.6 Time series deformation chart from 2018 to 2020

Table.1 Volume change and energy release in late active phase

| Date | Volume Chang/m³ | the Energy Released Relative to the Last Earthquake/$10^6$ ·J |
|---|---|---|
| 20040702 | $5.31\times10^6$ | 152.77 |
| 20041015 | $-3.51\times10^6$ | 22912.97 |
| 20041119 | $-1.12\times10^6$ | 0.49 |
| 20050408 | $-1.31\times10^6$ | 251816.33 |
| 20050617 | $0.83\times10^6$ | 63404.16 |
| 20050722 | $-0.03\times10^6$ | 985.45 |




Fig.3 Seismic Energy Release

## Conclusions

The results of this paper show that the Tianchi volcanic magma chamber first experienced a brief expansion between 2004 and 2010, with the $M_L$3.7 earthquake on September 8, 2004 as the turning point, and then began to enter a fluctuating gradual contraction after the earthquake until it stabilized in 2008. The volcanic magma chamber of Tianchi showed a fluctuating gradual expansion state between 2018 and 2020, and the whole change process was cyclical, with extreme values of deformation once the summer season. Similarly, the temporal deformation of PS-InSAR also has a cyclical trend, which is consistent with the results of SBAS-InSAR.

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