# Study on Landslide Disaster Extraction Method Based on Spaceborne SAR Remote Sensing Images-Take ALOS PALSAR for an Example

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**ABSTRACT:**

In this paper, sequence ALOS PALSAR data and airborne SAR data of L-band from June 5, 2008 to September 8, 2015 are used. Based on the research of SAR data preprocessing and core algorithms, such as geocode, registration, filtering, unwrapping and baseline estimation, the improved Goldstein filtering algorithm and the branch-cut path tracking algorithm are used to unwrap the phase. The DEM and surface deformation information of the experimental area were extracted. Combining SAR-specific geometry and differential interferometry, on the basis of composite analysis of multi-source images, a method of detecting landslide disaster combining coherence of SAR image is developed, which makes up for the deficiency of single SAR and optical remote sensing acquisition ability. Especially in bad weather and abnormal climate areas, the speed of disaster emergency and the accuracy of extraction are improved. It is found that the deformation in this area is greatly affected by faults, and there is a tendency of uplift in the southeast plain and western mountainous area, while in the southwest part of the mountain area there is a tendency to sink. This research result provides a basis for decision-making for local disaster prevention and control.

## 1. INTRODUCTION

Landslide is a phenomenon in which slope rock or soil slides down along the continuous destruction surface under gravity and is a main form of slope failure. Through the analysis of past landslide events, the comprehensive use of remote sensing and other technologies to quickly extract landslide information has important practical significance for emergency information construction and the reduction of losses caused by disasters. However, landslide disasters are accidental and often accompanied by bad weather conditions, even at night. It is difficult to obtain remote sensing images with high spatial resolution and high temporal resolution by optical remote sensing alone. This has some limitations for the detection and evaluation of landslide disasters with "high timeliness". At the end of the 1960s, Interferometric synthetic aperture radar (InSAR) came into being. Using the phase information in multiple SAR images, high-precision three-dimensional surface information and change information can be obtained. it is gradually introduced into the field of disaster monitoring. Domestic and foreign researchers have carried out a large number of landslide disaster extraction and detection work(Pancioli et al.,2008).Studies have shown that long wave-length L-band SAR data have better spatial and temporal correlation in interferometric measurements than shorter-wavelength data, and are more suitable for areas with large topographic relief, high vegetation coverage, and large deformation gradients. Due to the unique imaging geometry of SAR, many key technologies in its processing are still under continuous research and development. In this paper, the L-band ALOS PALSAR data in Maoxian area are used to extract the deformation map of the study area by using differential interferometry based on the research of registration and unwrapping algorithm. At the same time, on the basis of composite analysis of multi-source images, a method of detecting landslide disaster combining coherence of SAR image is developed, which makes up for the deficiency of single SAR and optical remote sensing acquisition ability. Especially in bad weather and abnormal climate areas, the speed of disaster emergency and the accuracy of translation are improved.

## 2. OVERVIEW OF THE STUDY AREA

The study area is located in Maoxian County and Anzhou District (Anxian County) of Sichuan province in china, which are more seriously affected by the Wenchuan earthquake "5.12" (Figure 1). It is located in the transitional zone from the Tibetan Plateau to the western Sichuan Plain, and the area where the central and southern section of Longmenshan merges with the Sichuan Basin,It is a very typical representation of the fragile alpine valley in the eastern edge of the Qinghai-Tibet Plateau and the upper reaches of the Yangtze River. The terrain is diverse in the area, including plains, mountains and river valleys,and so on. The relative height difference of the terrain is up to 3000m or more, and the features of topography and landform are representative.The transportation network is relatively developed, with important traffic lines such as National Highway 213, Provincial Highway 302, Mianguang Expressway and Baocheng Railway. There are many 3rd and 4th-grade highways are densely integrated in the territory,but the road conditions are not good. Most of the low-grade highways have narrow roads, steep slopes and deep valley,

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frequently causing vulnerability and danger, they are vulnerable to collapses, and other slope-like geological disasters.

The Daguangbao-Hongdongzigou giant landslide is the largest landslide triggered by the Wenchuan earthquake in the study area, with a volume of 742 million $m^3$ and a dam of up to 690m. It is also one of the ultra-large-scale landslides above 500 million $m^3$ in the world at present (Huang Runqiu,2008).The lithology of the Daguangbao landslide area is mainly composed of carbonate rocks and a small amount of clastic rocks, and is mainly composed of limestone,mudstone,limestone with shale, aluminite, dolomite, siltstone, limestone and phosphate rock layers,and so on.they are displayed on the SAR image in gray and white tones, which are obviously different from the surrounding ground objects.

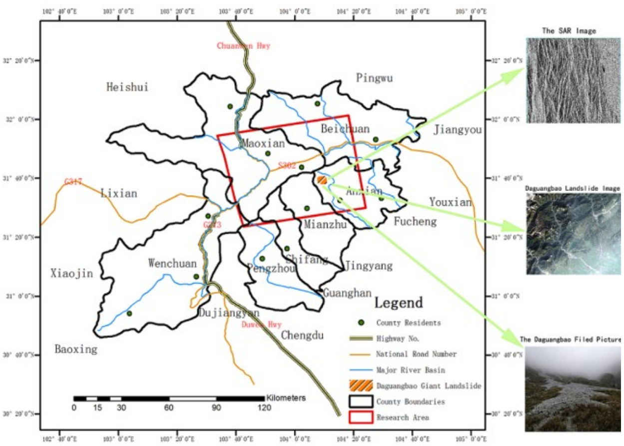


Figure 1. Reseach area sketch

## 3. PROCESSING TECHNOLOGY OF INSAR AND DEFORMATION ANALYSIS

SAR(Synthetic Aperture Radar) interferometry combines two or more SAR images to derive more information about the scene being viewed by exploiting phase differences.SAR interferometry has developed into an effective technique to generate topographic maps. A further development of SAR interferometry is differential SAR interferometry.By means of differential SAR interferometry (DInSAR) maps of geophysical displacement can be generated.By analyzing the principle of InSAR interference, the main factors affecting the phase of interference include: noise, reference ellipsoid, terrain, settlement and atmosphere. All will affect the transmission of signals, such as:

$$\varphi_m = \varphi_f + \varphi_t + \varphi_d + \varphi_a + \varphi_n \tag{1}$$

In this expression, $\varphi_m$ represents the interferometric phase of the SAR image,also known as the primary differential phase; $\varphi_f$ refers the phase caused by the reference ellipsoid, $\varphi_t$ is the phase contributed by the topographic factor;while $\varphi_d$ represents the phase due to the deformation and $\varphi_a$ is the result of the atmospheric effect Phase,Moreover $\varphi_n$ phase due to noise.When the interferometric phase map contains the phases contributed by the reference ellipsoid, topography, and ground deformation(Figure 2):

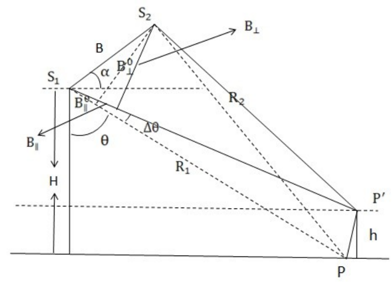


Figure 2.Geometric relationship of radar interference

$$\varphi_{abs} = \varphi_m + 2k\pi = \varphi_f + \varphi_t + \varphi_d \tag{2}$$

In which:

$$\varphi_f = \frac{4\pi}{\lambda} B_{\parallel}^0 \tag{3}$$

$$\varphi_t = \frac{4\pi}{\lambda} B_{\perp}^0 \Delta\theta \tag{4}$$

Due to the long slant distance, the corresponding undulating Δθ is so small that the slope corresponding to Δθ can be approximated as an arc, so the relationship between the central angle and the arc length and radius is as follows:

$$\Delta\theta = \frac{h/\sin\theta}{R_1} = \frac{h}{\sin\theta R_2} \tag{5}$$

$$\varphi_t = \frac{4\pi}{\lambda} B_{\perp}^0 \Delta\theta \approx \frac{4\pi B_{\perp}^0 h}{\lambda \sin\theta R_2} \tag{6}$$

For:

$$\varphi_d = (\varphi_m + 2k\pi) - \varphi_f - \varphi_t \tag{7}$$

The displacement of the phase in the corresponding slope distance is:

$$\Delta R_{def} = \frac{\lambda}{4\pi}[(\varphi_m + 2k\pi) - \varphi_f - \varphi_t] = \frac{\lambda}{4\pi}[\varphi_{abs} - \varphi_f - \varphi_t] \tag{8}$$

According to the formula above, the phase of the interferometric measurement of the radar is referenced to the removal of the reference ellipsoid and topographic phase, and the phase due to deformation can be obtained.

## 4. PHASE FILTERING AND UNWRAPPING

Due to the influence of various decoherence sources, there are often severe noises in the interferometric phase maps. In order to improve the signal-to-noise ratio of the image, weaken the noise in the interferogram, and improve the visual effect of the image, it is necessary to perform multi-look and filter processing on the interferogram to obtain high-quality images, preserve signal features and boundary information as much as possible, and reduce the number of residual point. The commonly used filtering methods include:Lee,Kuan,Forst, GAMMA,Boxcar,Goldstein filtering and so on(Lee,1983. Kuan,1987.).The Goldstein filter is a non-linear frequency weighting filter algorithm proposed by Goldstein et al. in 1998. This filtering method can highlight the signal components in the frequency and separate the noise from it. By comparing the


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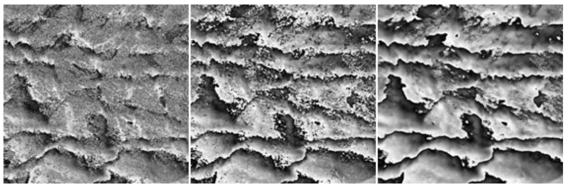
results of filtering the interferometric images in the study area (Figure 3), it was found that the Goldstein filter has a good effect. Not only the residual points are greatly reduced, but also the details of the interference fringe are kept relatively well, and the interferograms are clear and smooth. It is more conducive to phase unwrapping.



(a)Adaptive （b）Boxcar （c）Goldstein

Figure 3. Local filtering results in the study area

In 1988, Goldstein et al pointed that the phase unwrapping operation using the branch cut method. The branch cut method is a very typical path tracking algorithm. In the original Goldstein branching phase unwrapping, when the loop integral is not zero, only the residual points in the loop can be explained. However, there are several residual points in the loop, which are the residual points, and the polarity of these residual points, How much each one is cannot be determined. In the original method, this step was simplified, and the upper-left point was directly set as the residual point,so it was impossible to tell which of the real residual points in the loop at the time of scanning, and the true residual point polarity could not be calculated. It would lead to the pixel is set as an error of the residual point and misses the true residual point.The polarity value of these wrong residual points brings about a decrease in the accuracy of the understanding of the wrapping result. Based on this, an improved Goldstein path-tracking algorithm is proposed for phase unwrapping and terrain information of the study area is extracted(Wang Zhe and Xue Dongjian,2017). Under the computer simulation, the idea of the algorithm has reached a more ideal result, and the residual point is greatly reduced. At the same time, we find that as the image quality increases, the proportion of residual points decreases. The study aimed to improve the accuracy of the residual point search and obtain a globally better solution while reducing the number of residual points.

## 5. DEFORMATION ANALYSIS AND LANDSLIDE HAZARD DETECTION

D-InSAR is the use of interferometric techniques to obtain two interferograms in the same area, one can extract DEM (and can also use existing DEM directly), the other one is an interferogram that contains topographic relief information and surface micro-deformation, based on the two interferograms differential interferometric processing is the removal of terrain information from second pieces of influence in the interferogram, which can get the deformation field information. Traditional D-InSAR processing includes two-pass, three-pass and four-pass method. According to the research needs and data characteristics, based on the selection of SAR data and DEM data (DEM needs to be converted to SAR coordinate system), the two-pass was used to extract deformation information in the study area.In order to determine the land subsidence component, the topographic phase must be removed and the deformation information should be retained according to DEM's removal of the phase information caused by the topography. Based on this, the anomalous landslide area is extracted (Figure 5).

Figure 4. GEOEYE Color composite image

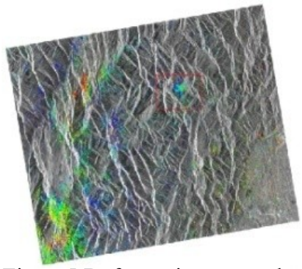


Figure5 Deformation anomaly detection in Disaster Area

The backscatter is more sensitive to the change of surface roughness due to the unique imaging mode of SAR. Landslide hazards have different backscatter coefficients and texture features from the surrounding area on the radar image, which creates a strong contrast in tone. Especially for landslides that occur on the edge of the river, it generally results in blockage of the river. In the SAR image, the calm water produces specular reflection of incident microwave on the surface, and the backscatter is weak and black. After the landslide, the surface of the landslide is rough, and it appears grayish-white on the image, which is very different from the hue of the water. It can be combined with the strong contrast between the river and the landslide to facilitate the identification of it (Figure 6).

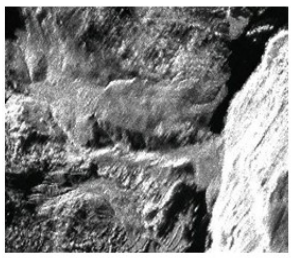


Figure 6. HH Polarized Airborne SAR

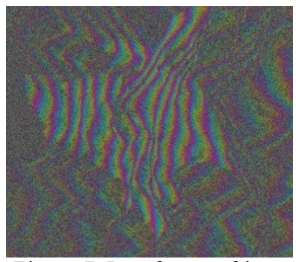


Figure 7. Interference fringes in the landslide area

When interpreting landslide hazard information, the information provided by a single data source is often limited. According to the characteristics of SAR imaging, a landslide extraction method based on SAR coherence is developed. Prati et al. proposed a method for calculating the coherence of SAR images in 1993. The coherence of two SAR images $u_1$ and $u_2$ is defined as:

$$\gamma = E\left[u_1 u_2^*\right] \Big/ \sqrt{E\left[|u_1|^2\right] E\left[|u_2|^2\right]} \tag{9}$$

Among them, $E[\ ]$ is the expected value, which is actually equal to the average value of the sample. The absolute value of $\gamma$ is the measure of the interference quality. The value is between 0~1, 0 means that the two images are completely irrelevant, and 1 means there is no difference between the two images, the coherent coefficient is high, the signal-to-noise ratio is higher, and the corresponding coherence can be defined as:

$$\gamma = \sum u_1 u_2^* \Big/ \sqrt{\sum |u_1|^2 \sum |u_2|^2} \tag{10}$$

The coherence analysis was performed on SAR data obtained at two different times, January 24, 2010 (SLC1) and March 11 (SLC2).According to the interferograms, different types of land use can be identified. In a related image, the correlation coefficient of general residential and bare land is greater than that of grassland and farmland, the correlation coefficient of the forest is greater than the correlation coefficient of the water body.Because most of the landslides are bare bedrock, the interference fringes are very good, and the coherence is generally high (Figure 8), it can be easily distinguished from the surrounding objects.At the same time , in order to highlight the features of object information in the land use,a new classification method was proposed by Wegmuller et al. Then, use color synthetic images for landslide interpretation analysis; take the interference correlation value (R) as red and the backscattered intensity (I) as green; the difference between the backscattered intensities (D) of the two images is blue and three colors are synthesized: The bare land is orange or yellow (high R, medium I, low D); the forest is light blue-green (low R, low D); water is blue (low R, low I, high D). As can be seen from the RGB color image (Figure 9), compared with a single SAR image, the edge of the landslide is relatively clear, and the landslide (most of which is bare land) has a large contrast with the surrounding vegetation, which is more conducive to extraction.

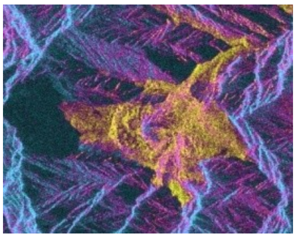


Figure 8. Composite image using coherent and intensity images

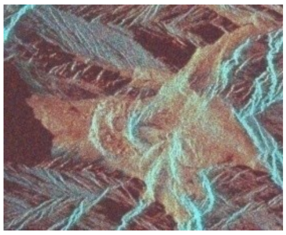


Figure 9. RGB color composite image

Comprehensively using SAR intensity images and interference images, typical landslide hazards in the study area are extracted combing RGB false color composite images based on the coherence analysis.Through the analysis of the interpreted landslide distribution, the regional tectonic framework plays an important role in the distribution of landslide disasters. The distribution of landslide disasters in the study area has stripped structure.They are along the linear structure dense belt or annular structure edges like the fault zone, pleated crankshaft section and jointed fissure zone in a linear or zonal distribution. At the same time, they are mostly distributed in the bank slope area along rivers, lakes (reservoirs), seas, and trenches and canyon areas with high terrain difference. Easy slides, soil distribution areas, frequent rainstorm areas, etc. are also areas of high incidence of landslides.

## 6. CONCLUSIONS

The satellite-borne SAR uses the microwave band for earth observation, which has a greater advantage than the optical remote sensing in the extraction of landslide disasters. In particular, radar images can provide abundant information as a supplement when clear optical images can't be obtained because of the horrible weather conditions like cloud and rain. In this paper, ALOS PALSAR single look complex image is mainly used as the main data source. Based on the analysis of SAR imaging characteristics and system parameters, the radar differential interferometry technology is mainly studied, and the anomaly area of disaster deformation is extracted. The coherence analysis was also applied to the extraction of landslide disasters, and good results were achieved, making up for the lack of the ability to extract information from a single source. After analysis, it was found that the accuracy was affected by many factors, among which the longer wavelength L-band data had a better correlation than the shorter wavelength.

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