

Observation of Earthquake Swarm Consequences in the Baikal Rift System with ALOS-2 Interferometry

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Abstract— The paper describes detection of seismogenic deformations located in the northeast part of Baikal rift system on slopes of Muyakan ridge by means of differential SAR interferometric analysis of new Japanese spaceborne SAR system PALSAR-2 data.

1. INTRODUCTION

In recent decades Earth orbiting satellites provided the scientific community with a great amount of remote sensing data for different areas on the Earth surface, particularly data of synthetic aperture radar (SAR) having all-weather and day/night observation capability. Repeat-pass orbital schedule allows interferometric processing of data in order to reveal deformation of the earth surface in between two observations. The study focuses at detecting and evaluating the consequences of earthquakes series occurred in 2014–2016 in the Baikal rift system.

The first part of the paper gives a brief description of the interferometric technique, and the next part reports a geodynamic situation in the area. Last sections contain results of the interferometric processing and discussion.

2. TECHNIQUE

SAR repeat-pass interferometry is a powerful tool for the Earth surface deformations detection and assessment. Phase differences of two SAR signals acquired before and after a surface change can indicate deformation parameters of geodynamic events (co-seismic and post-seismic displacements, landslide and creep processes, etc.). This method is of crucial importance for investigating remote hard-to-reach terrains.

In our study, we used ALOS-2/PASAR-2 (L-band) data (Japan Aerospace Exploration Agency). According to interferometric background [1], the phase difference of 2π observed in a radar interferogram corresponds to the half of a wavelength displacement in slant ranges of the scattering surface. This value is equal to 11.8 cm for L-band PALSAR interferograms and 11.45 cm for PALSAR-2.

Thus, the technique allows detecting centimeter-level displacements of the surface. At the same time, the square of the subsided surface (e.g., seismogenic rupture or considerable active fault creep) can reach tens of square kilometers. The limitations of the method include temporal decorrelation that is due to the change in the surface characteristics (some of processed pairs decorrelated significantly) and influence of atmospheric and ionospheric effects [2, 3].

3. GEODYNAMIC SITUATION

The area under investigation is located within the Upper Angara-Muya interbasin link of the northeastern segment of the Baikal rift system. The latter represents by series of an echelon half grabens bordered by well-pronounced normal faults. Generally, the system of the left step NE oriented faults shows the typical left lateral strike-slip structure of lithospheric scale. The Upper Angara-Muya interbasin link is one of the most active areas within the Baikal rift system [4].

Our investigation focuses at the manifestation of the consequences of the earthquake swarm that have occurred in 2014–2016 on Muyakan ridge (Fig. 1). Earthquake events took place in 58 km from a Severomuysk tunnel, which is an important part of the Baikal-Amur Mainline railway (BAM). During this relatively short period the number of registered events in the area (about 300 earthquakes with $KP \geq 10$) became comparable to the total amount of earthquakes within the Severo-Muysk region in last 50 years. The most outstanding event of this series ($K = 14.3$, $Mw = 5.4$) occurred on May 23, 2014, and later in 2014 there 2305 earthquakes with $K = 5.6 \dots 14.3$ were registered. In the beginning of the year 2015 a new burst of seismic activity was detected in the nearby area, in the neighborhood of the east end of the Severomuysk tunnel [5].

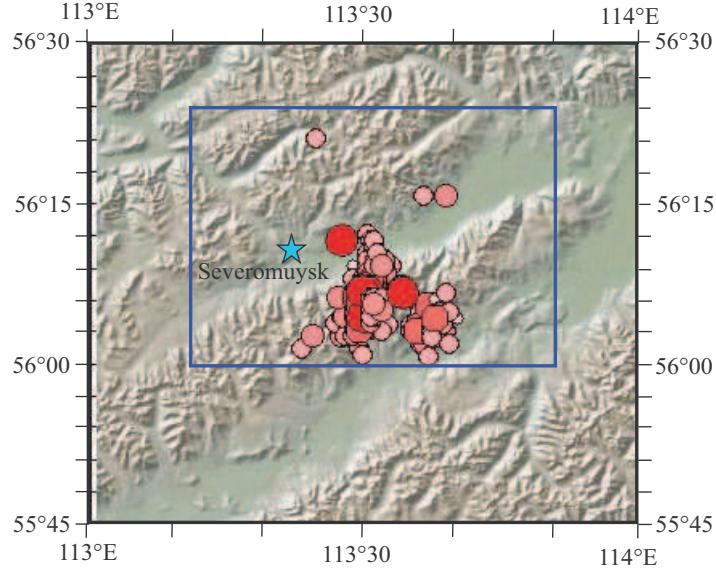


Figure 1: Seismic events (M_l 2.5–4.9) registered by BRSC GS RAS in the polygon between September 2014 and September 2015.

4. RESULTS

Earthquake-induced subsidence of the surface that has been observed using repeat-pass interferometry on ALOS-2/PALSAR-2 interferometric pair 26.09.2015–27.09.2014 (Fig. 2). The length of the subsidence area is about 8 km, width is from 1 to 4 km. Using the ROI tool (Region Of Interest) integrated in the SARscape software package we evaluated relative displacements. Phase difference examination gave us the estimated line-of-sight mean displacement of 60 mm with corresponding vertical shift of –68 mm (minus means a surface subsidence). The observed displacement of the earth surface is located exactly within the area of a swarm of earthquakes occurred during the period between observations (Fig. 1).

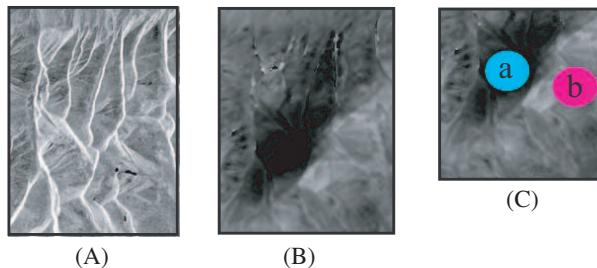


Figure 2: Deformations of the earth surface on Muyakan ridge according to SAR interferometry data. (A) Fragment of amplitude image; (B) Fragment of unwrapped interferogram (PALSAR-2 pair 26.09.2015–27.09.2014); (C) Fragment of unwrapped interferogram with point marks: a-spot designates the deformation zone; b-spot is a reference stationary surface.

5. CONCLUSION

Deformations in the Muyakan fault zone may be serious hazardous events to linear structures of the Baikal-Amur Mainline Railway [6]. ALOS-2/PALSAR-2 interferometric pair processing has a great potential for both studying the events already occurred in the region and monitoring the evolving processes in forested mountainous regions of Siberia. Measured displacements are in agreement with the previously suggested processes of expansion of surface depression due to subsidence of some parts of the mountain ridges and interbasin uplifts [5, 7, 8].

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