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Coseismic Ground Deformation of the November 26, 2019 M6.4 Earthquake of Durrës, Albania Estimated by DInSAR

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ABSTRACT

An earthquake of magnitude 6.4 occurred in Albania on November 26, 2019 at 03:54:12 (local time). The epicenter of the earthquake was about 20 km from the coastal city of Durrës. The purpose of this study is to estimate the ground deformation associated with this earthquake by Differential Interferometric Synthetic Aperture Radar (DInSAR) technique. A differential interferogram was formed using the two Sentinel-1 Single Look Complex (SLC) images. The flattened and filtered differential interferogram was unwrapped and converted to ground displacement. The results indicate that in the area close to the epicentre the ground is uplifted at a maximum of 8 cm along the radar line-of-sight (LOS). Progressively smaller ground uplift is detected in an area of about 10-15 km around the major uplift zone. The earthquake could be related with under thrusting of Adria microplate or fault processes within the under thrusted Adria microplate itself. Further monitoring by satellite imagery is needed to investigate the post-seismic ground deformation in the area.

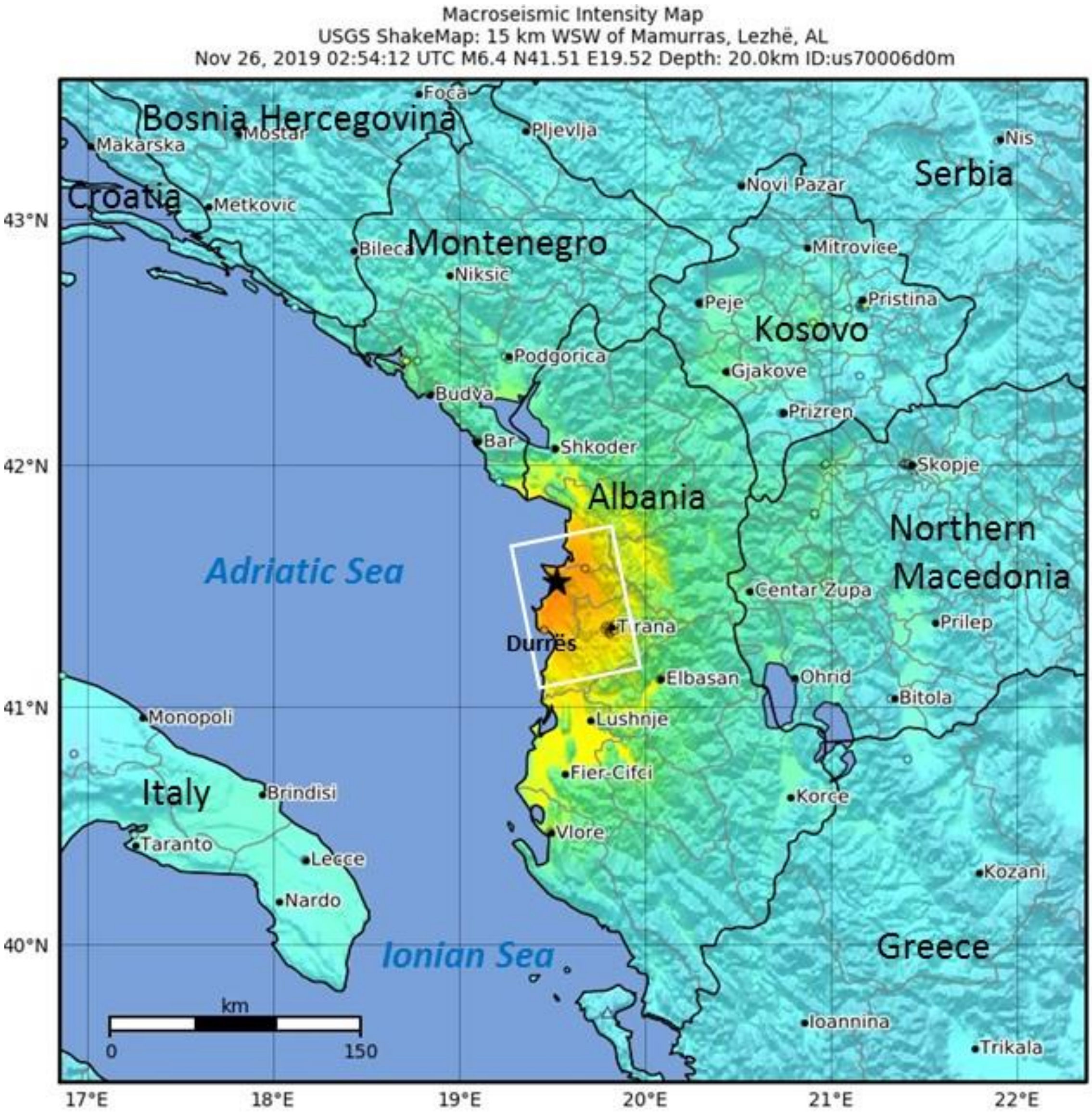
Keywords: Albania; earthquake; Sentinel-1; ground deformation; remote sensing

1. INTRODUCTION

An earthquake of magnitude 6.4 occurred in Albania on November 26, 2019 at 03:54:12 (local time). The epicentre of the earthquake is estimated from the USGS at 41.511°N, 19.522°E, about 20 km from the coastal city of Durrës, and about 30 km from the city of Tirana, the capital of Albania (Figure 1). The hypocentre of the earthquake is estimated at a depth of 20 km [1]. The quake lasted for at least 35 seconds and caused severe damage. Based on the geology of the area [2, 3] the earthquake is considered to have occurred as a result of thrust faulting near the convergent boundary of the Africa (Adria microplate) and Eurasia plates. This is consistent with the closing of the Adriatic Sea, and shortening across the mountain belts stretching from Croatia to Albania to Greece [1]. An illustrative cross section is provided in Velaj [4]. Reverse faulting accompanies the thrust faulting in the coastal area of Albania. A detailed discussion on the fault mechanism and the seismic activity of the area is presented in Aliaj [3].

The Differential Interferometric Synthetic Aperture Radar (DInSAR) technique using radar imagery acquired before and after a seismic event is promising for estimating the ground deformation and the model of the earthquake [5-11]. The DInSAR technique exploits the differences in the phase of the radar signals to measure the ground deformation. In this paper are presented results of DInSAR analysis of

Sentinel-1 satellite imagery to estimate the ground deformation associated with the November 26, 2019 M6.4 Durrës earthquake, Albania.



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.05	0.3	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.02	0.13	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 8: Processed 2019-12-18T23:05:47Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Figure 1. Map of the shaking intensity of the Durrës earthquake of November 26, 2019 (modified from [1]). The white rectangle shows the approximate extent of the Sentinel-1A imagery subsets analysed by the DInSAR technique to estimate the ground deformation associated with the earthquake event.

2. MATERIALS AND METHODS

2.1 Sentinel-1 IW imagery

The Sentinel-1 sensor records C-band (5.3 cm) SAR imagery [12]. The SAR imagery is provided with accurate sensor orbit position useful for interferometric analysis [12, 13]. The Sentinel-1 offers an improved SAR data acquisition capability for deformation monitoring, considerably increasing the monitoring potential (e.g. [14-17]). The Sentinel-1 IW images are recorded using the Terrain Observation by Progressive Scans (TOPSAR) acquisition technology [18], which produces image data in sub-swaths. Within the sub-swath, the Sentinel-1 IW images are acquired by recording subsets of echoes of the SAR aperture, which are called bursts [12, 13]. The Sentinel-1 IW images have a swath of 250 km, and ground resolution of 5m × 20m.

The data analysis is based on two ascending orbit Sentinel-1A Interferometric Wide (IW) Single Look Complex (SLC) images acquired in vertical transmitting – vertical receiving (VV) polarization on November 20, 2019 and December 2, 2019 (Figure 2).

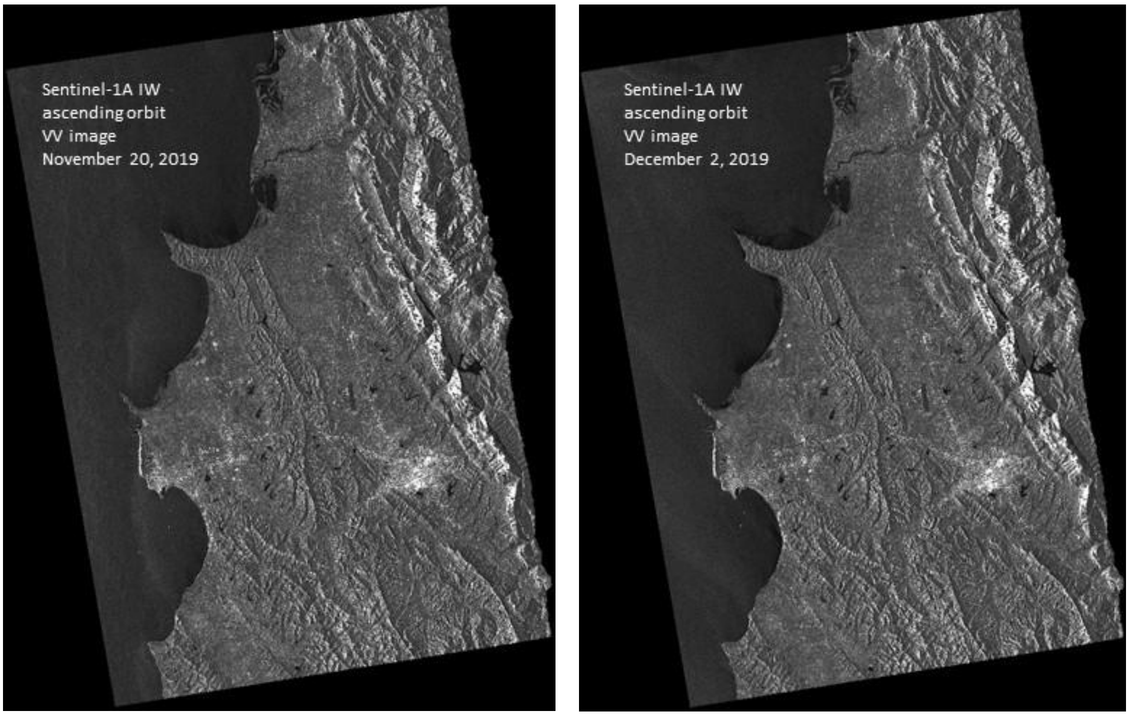


Figure 2. Geocoded subsets of Sentinel-1A Interferometric Wide (IW) Single Look Complex (SLC) images acquired in vertical transmitting – vertical receiving (VV) polarization on November 20, 2019 and December 2, 2019.

2.2 The DInSAR technique

The Differential Interferometric Synthetic Aperture Radar (DInSAR) technique exploits the information contained in the radar phase (φ) of at least two complex SAR images acquired in different times over the same area, which are used to form an interferometric pair [7].

The SAR images forming the interferometric pair are usually acquired from the same sensor. Let us consider two complex radar images T_1 and T_2 recorded by the same SAR sensor at times t_1 and t_2. The change in the radar phase (φ) at ground target P, between the two measurements, unexplained from other factors (different positions of the sensor at times t_1 and t_2, noise in the data, atmospheric distortions, topography etc.,), is the result of ground displacement (φ_{Displ}) (Figure 3). The DInSAR technique has been extensively exploited in the field of seismology (e.g. [5, 7-11]).

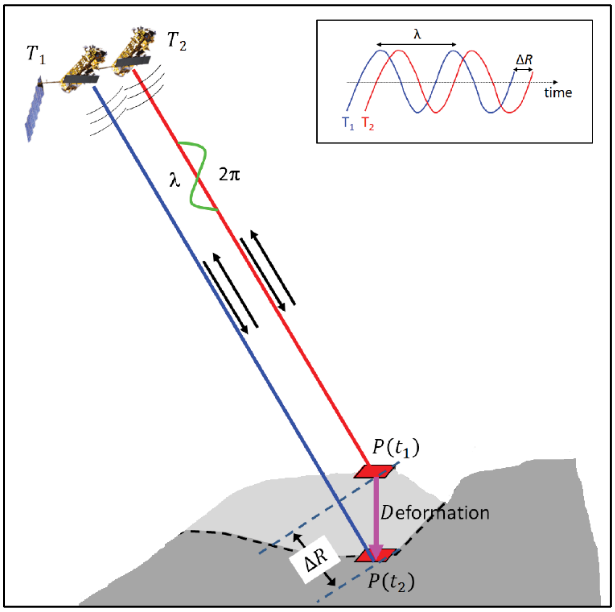


Figure 3. Schematic representation of the DInSAR basic concept. The phase difference of two radar measurements T_1 and T_2 of a ground target P, recorded at time t_1 and t_2, due to a ground displacement occurring within this time period at the ground target from position $P(t_1)$ to position $P(t_2)$ (modified from [19]).

2.3 Data analysis

The Sentinel-1A images (VV polarization) of November 20, 2019 and December 2, 2019 were initially debursted and a subset was selected to focus at the area affected by the earthquake (Figures 1, 2). The data were co-registered and the differential interferogram was calculated by using the image of November 20, 2019 as the master image and the image of December 2, 2019 as the slave image. The differential interferogram was flattened in order to remove the phase component related with the variation of the range distance in the radar image due to Earth's curvature. Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) with spatial resolution of 30 m was used to flatten the differential interferogram (Figure 4).

The flattened interferogram was filtered using an adaptive filter [20]. The filtered and flattened differential interferogram was then unwrapped and converted to ground deformation measured along the radar Line of Sight (LOS). In order to avoid influence from noise and atmosphere in the interpretation only ground deformation larger than 2 cm was retained, and presented in a map format (Figure 5).

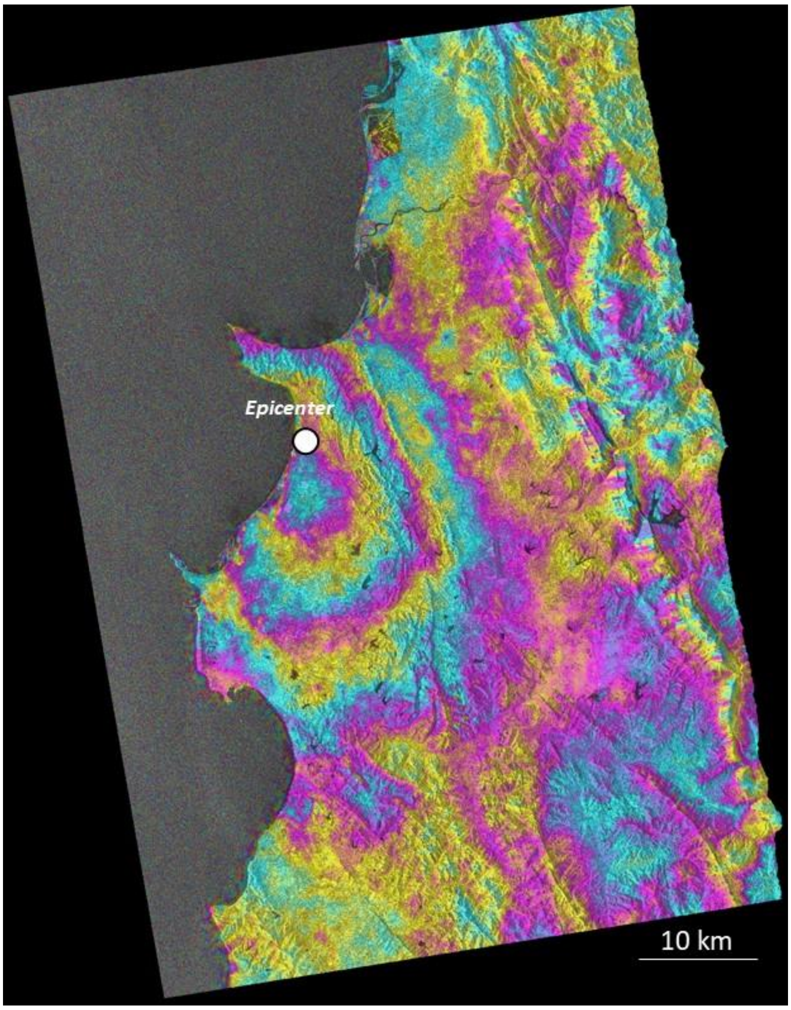


Figure 4. Filtered and flattened differential interferogram to investigate the ground deformation of the M6.4 Durrës earthquake of November 26, 2019. The differential interferogram is computed from Sentinel-1A IW SLC VV image pair of November 20, 2019 and December 2, 2019. The epicentre of the earthquake from the USGS [1].

3. RESULTS AND DISCUSSION

The interferogram formed from the two ascending orbit Sentinel-1A images clearly shows the ground deformation caused by the earthquake in the epicentre zone and the surrounding area (Figure 4). The map of ground deformation (Figure 5) indicates uplift of up to 8 cm in the vicinity of the epicentre area. The uplift is measured along the radar line-of-sight (LOS). Progressively smaller uplift is detected in an area of about 10-15 km away from the major uplift zone (Figure 5). Analysis of a descending pair of Sentinel-1A images produced similar results for the ground deformation.

Modelling the earthquake fault plane based on data from the Global Centroid Moment Tensor (CMT) Catalog [21], geology of the area [3], the observed displacement (Figure 5), and the depth of 20 km of the hypocentre indicate that the processes causing the earthquake could be related with the under thrusting of Adria microplate or fault processes within the under thrusted Adria microplate itself.

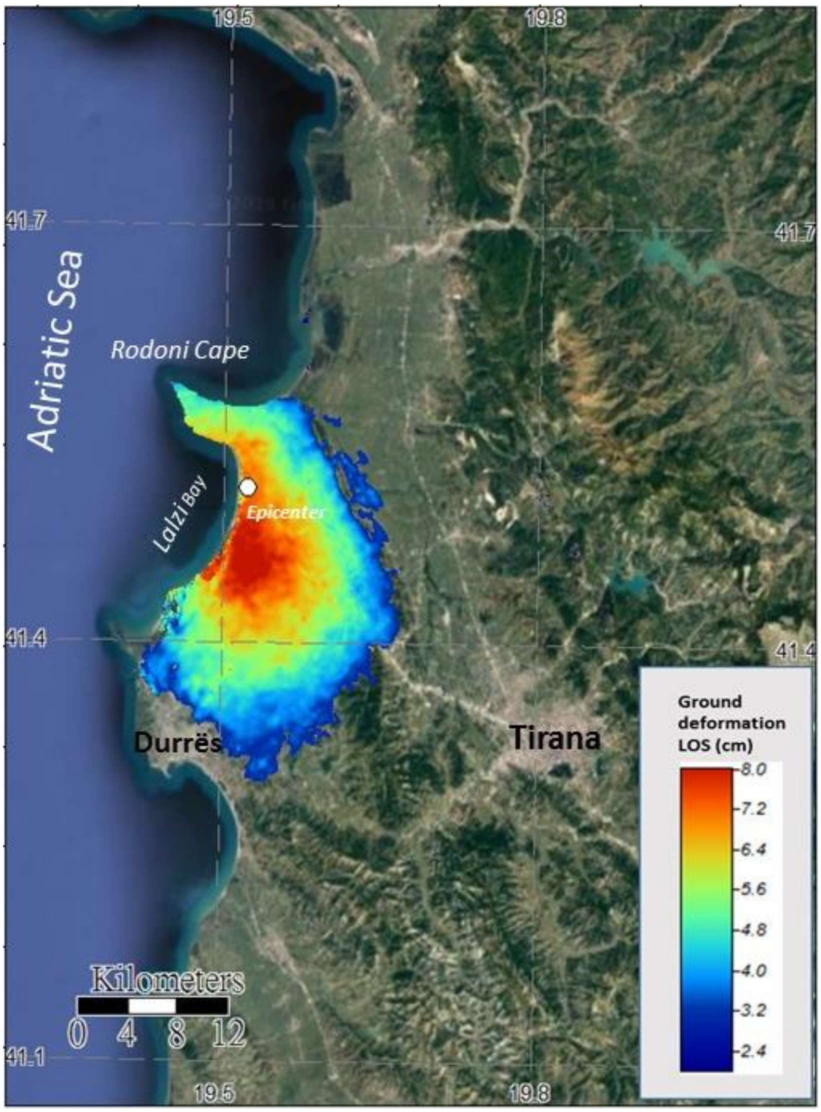


Figure 5. Map showing the ground deformation (uplift) in the radar line-of-sight (LOS) associated with the M6.4 earthquake of November 26, 2019 of Durrës, Albania. The LOS ground deformation is based on the DInSAR analysis of Sentinel-1A ascending orbit IW SLC image pair of November 20, 2019 and December 2, 2019. The epicentre of the earthquake is from the USGS [1]. The background is from Google Earth^{TM} imagery.

4. CONCLUSION

The Sentinel-1A radar imagery was used to estimate the ground deformation associated with the November 26, 2019 M6.4 Durrës earthquake, Albania. The radar imagery was analysed by the DInSAR technique. The results indicate an uplift close to the epicentre of up to 8 cm measured along the radar line-of-sight (LOS). Progressively smaller uplift is detected in an area of about 10-15 km around the major uplift zone. The earthquake could be related with the under thrusting of Adria microplate or fault processes within the under thrusted Adria microplate itself. Further monitoring is necessary to estimate post seismic ground deformation in the study area.

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