DInSAR techniques for studying the October 23, 2011, Van earthquake (Turkey), and its relationship with neighboring structures

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Abstract—**In October 2011 a strong earthquake hit the Van province, Eastern Turkey. Few days later (November 9th) an aftershock occurred few km southward. Finally in November 1976 another mainshock took place north of Van along the Caldiran fault. We have investigated the possible relations between 2011 mainshock and aftershock and the link with the 1976 earthquake. In order to complete the work SAR interferometry has been applied to measure surface displacements, while the fault geometries of the mainshock have been retrieved by a novel Neural Network approach. Moreover the CFF has been calculated to evaluate the role of 1976 earthquake in promoting the 2011 mainshock and, later on, the role of this latter respect to the aftershock in November 9th, 2011.**

I. Introduction

We have investigated the possible causal relationship between three earthquakes occurred in Turkey. In particular the Mw 7.2 October 23, 2011 earthquakes occurred in the Van province, located in the Eastern Turkey near Lake Van, its aftershock occurred the November 9 few kilometers southward, and another major event (Ms = 7.3) occurred north of Van in East Anatolia on 24 November 1976 along the Caldiran fault. The Mw 7.2 Van event took place along a previously unrecognized east-west thrust fault. The largest aftershock which hit Van Province, has a magnitude 5.5 at 4.3 km of depth very close to Van.

Figure 1: Seismotectonic summary of Turkey. The red square point out the investigated area of Van earthquake.

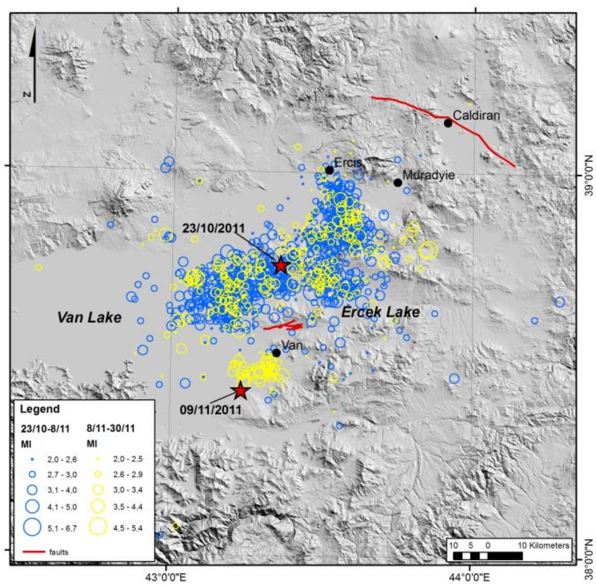

Figure 2: Seismicity of the epicentral region. The red lines are the Caldiran fault and the Van fault. The red stars indicate the locations of the October 23rd, 2011, mainshock and the November 9th, 2011, aftershock. The circles in blue color are

the earthquakes of the October main event, while the yellow circles are those ones following the November 9 aftershock.

II. DInSAR DATA PROCESSING

For the Van earthquake and its aftershock we used DInSAR measures for retrieving the faults parameters. A couple of COSMO-SkyMed images has been used to measure the coseismic deformation of the first event, while two TerraSAR-X interferometric images have been used for the second one. The topography contribution has been removed using the SRTM digital elevation model.

SAR data			
Date	Date	Asc/Desc	Satellite
10/10/2011	23/10/2011	Desc	COSMO-SkyMed
31/10/2011	11/11/2011	Asc	TerraSAR-X
9/11/2011	20/11/2011	Desc	TerraSAR-X

Figure 3: SAR dataset available for this study. Six images have been used, all at X-Band and Stripmap mode (3 m spatial resolution). The COSMO-SkyMed descending pair has been used to investigate the October 23rd mainshock. In particular, the post-event image is dated October 23rd, few hours after the seismic event. TerraSAR-X images have also been used to measure the deformation caused by the earthquake of November 9, 2011. Also in this case, the descending pre-seismic image has been acquired on the same date of the earthquake, while the ascending pair covers a different time span.

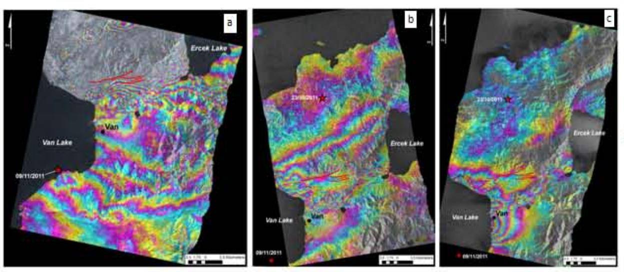

Figure 4: The COSMO-SkyMed interferogram (a) imaged the October 23rd main event and measured the surface displacement pattern. The fringes correspond to an uplift in the Northern portion of the interferogram that achieves a maximum of about 0.8 m. The red lines indicate the location of the Van fault. The November 9 aftershock has been studied with two image pairs from TerraSAR-X satellite. It is clearly visible how the interferogram along ascending path (b) measures a maximum displacement around Van city of about 3 cm. This is apparently in contrast with the displacement measured by the descending interferogram (c), where 6 cm (four fringes) are clearly visible, at least. The difference has two possible causes. First, the focal mechanism of the November aftershock is purely strike slip. This means that most of the surface displacement is along an horizontal (roughly EW) axis. This results in a difference of the LOS (Line Of Sight) detected movement that might be up to some cm. The second possible cause is the presence of post-seismic deformation (afterslip) or additional deformation due to one or more post-November 9 events. Indeed as the pre-November 9 image has been acquired few hours before the seism, while the interferogram spans about 11 days, few cm of post-seismic deformation might have occurred in such period. On the other side, among the seismicity following the November 9 earthquake a Mw 5.0 at least took place very close to it, enough to result in some cm deformation.

III. MODELLING AND CFF

Based on DInSAR outcomes we have then inverted the coseismic displacement field using a novel approach, based on the Okada model [1] and Neural Networks (NNs), to investigate the fault geometry of the two latest earthquakes [2]. The NNs have been trained by means of synthetic data generated considering sets of parameters compatible with the sources. One of the advantages of this method is that it rapidly achieves a determination of the rupture plane [3]. Concerning the earthquake occurred on 1976, the fault plane has been deduced using surface ruptures from ground survey. Once defined the geometries of the three seismogenic fault planes we have investigated the role of the Caldiran earthquake in promoting the Van rupture, and the latter in promoting its aftershock, by evaluating the Coulomb Failure Function. We performed a CFF analysis in order to investigate (i) the effect of the 1976 Caldiran earthquake on both 2011 events and (ii) the mainshock-aftershock interaction. The '76 rupture fault was modeled with two adjacent planes, using geometry given by Stewart and Kanamori (1976) [4] and constraining the surface projection of the planes to follow the fault trace (shown in red in figs. 5 and 6). The fault geometry of the mainshock is obtained with a neural-network inversion of the deformation field, while the aftershock fault plane is obtained by assuming geometric orientation from the CMT solution and fixing the fault center at the ipocentral location provided by KOERI. Yellow stars in figs. 5 and 6 show the position of CMT solutions for both events. Our analysis shows that the regional stress perturbation following the 1976

Caldiran earthquake (fig. 5) has loaded the mainshock fault, even if with very small stress levels (of the order of 0.1 bar), while it has unloaded the western portion of the aftershock fault. On the other hand, the mainshock stress field (fig. 6) has acted to strongly promote the aftershock rupture, with peak transferred stress levels of about 10 bar.

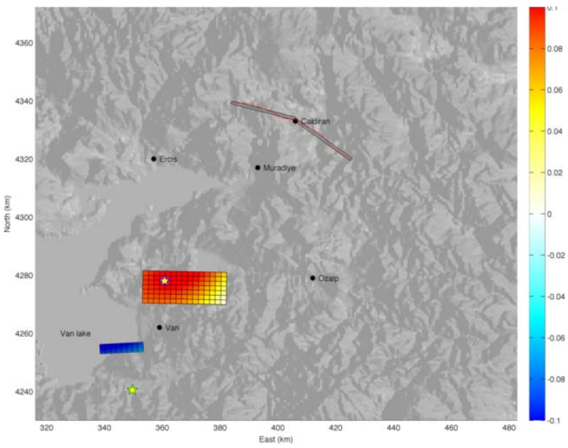

Figure 5, Coulomb stress change induced by the 1976 Caldiran earthquake on the 2011 mainshock and aftershock planes.

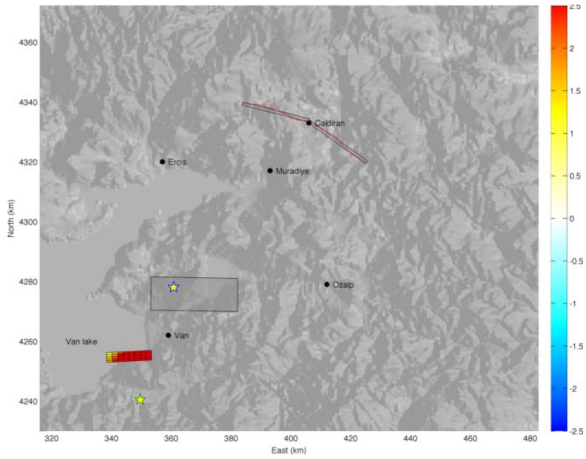

Figure 6. Coulomb stress change induced by the 2011 Mw=7.2 Van earthquake on the Mw=5.5 aftershock.

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