

Near real-time radar interferometry of the Mw 7.1 Hector Mine Earthquake

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Abstract. The Hector Mine Earthquake (Mw 7.1, 16 October 1999) ruptured 45 km of previously mapped and unmapped faults in the Mojave Desert. The ERS-2 satellite imaged the Mojave Desert on 15 September and again on 20 October, just 4 days after the earthquake. Using a newly-developed ground station we acquired both passes and were able to form an interferogram within 20 hours of the second overflight. Estimates of slip along the main rupture are 1-2 meters greater than slip derived from geological mapping. The gradient of the interferometric phase reveals an interesting pattern of triggered slip on adjacent faults as well as a 30 mm deep sink hole along Interstate 40.

Introduction

The eastern California shear zone (ECSZ) accommodates a significant portion of strike-slip motion (~ 12 mm/yr) between the Pacific and North American plates [Dokka and Travis, 1990; Sauber *et al.*, 1994]. During the past 10 Ma, strain in the ECSZ has shifted westward so that today, the Ludlow Fault (LD in Figure 1) is believed to be the easternmost active fault in the region. The recent Hector Mine earthquake ruptured 45 km along the mapped, but unnamed, Lavic Lake fault [Dibblee, 1966; USGS *et al.*, 2000] just 7.3 years after the Landers Mw 7.3 event. These two major events may have increased the loading on the San Andreas [Stein *et al.*, 1992].

Near real-time interferometry

We report on the use of synthetic aperture radar interferometry (InSAR) to map crustal strain in near real-time. While the InSAR method is well developed [Massonnet *et al.*, 1993; Zebker *et al.*, 1994; Peltzer *et al.*, 1996; Rosen *et al.*, 1996; Massonnet and Feigl, 1998], results have always been published months or even years after events. For example, many small-scale fractures associated with the Landers, 1992 event were not noticed in ERS interferograms until 2-4 years after the rupture, by which time evidence of the displacements had been erased by natural forces and off-road vehicles [Massonnet *et al.*, 1994; Price and Sandwell, 1998].

InSAR processing software, ground-station capabilities, and real-time orbits [Scharroo and Visser, 1998] have improved to the point where near real-time interferometry is possible. The Hector Mine earthquake offered the first meaningful test of our X-band receiving station and interferometry software (topex.ucsd.edu). To prepare for the 20 October pass, we assembled prior ERS passes over the area. Fourteen frames were available including an ERS-1/ERS

-2 tandem pair having a 1-day time separation and a 95 m perpendicular baseline (E1_24664 and E2_04991). This pair was unwrapped using the tree algorithm [Goldstein *et al.*, 1988] to serve as the topographic phase for the, still to be determined, deformation pair. Beginning in June 1999 we began ordering all overflights along this trackline from SpotImage Co. so our local archive contained passes from June, July, August, and September. One day prior to the overflight we obtained the predicted ERS-2 orbit from Delft University [Scharroo and Visser, 1998] and established that the best interferometric match was the 15 September pass. Fortunately, in an effort to re-image the area devastated by the Izmit Turkey earthquake, ESA navigated the 20 October pass to within 17 m perpendicular baseline of the 15 September pass; a typical 1-month baseline is about 500 m.

During interferogram formation, the phase due to both the curvature of the earth and the topography was removed from the full resolution interferogram on a pixel-by-pixel basis using precise orbital information [Scharroo and Visser, 1998]. The first interferogram, formed 19 hours after the download, had an artificial cross-track slope of 20 fringes (560 mm) caused by errors in the predicted orbit. The interferogram was re-computed 5 days later using the more accurate "fast-delivery" orbit and no slope corrections were needed (Figure 2). Indeed, given precise orbits and precise topography, we believe that it is unnecessary to flatten interferograms. Moreover, flattening may mask the desired tectonic signal.

The coherence of the interferogram was generally very high because of the short time interval of the reference and repeat passes, the short interferometric baseline, and the arid, unvegetated surface of the Mojave Desert. The high coherence permitted phase unwrapping almost everywhere except the areas close to the main rupture where the phase rate exceeded one half cycle per pixel or the ground displacement approached the azimuthal resolution of the SAR image [Michel and Avouac, 1999]. In addition to computing phase, we computed the phase gradient following the approach of Price and Sandwell [1998]. Both the unwrapped phase and the phase gradient are needed to interpret the complex displacement patterns in the area surrounding the main rupture. Phase gradient maps were provided to field geologists within a week after the earthquake to aid their mapping efforts. One of the more interesting features of the interferogram is a 30 mm deep, 1 km diameter sink-hole on the southern margin of Troy Dry Lake bed (34.805, -116.525); Interstate-40 passes directly over this sinkhole.

Displacement along the main rupture

Because of the large ground displacements, the main rupture is partly decorrelated in the interferogram. However,

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