Monitoring Known Seismic Faults using the Permanent Scatterers (PS) Technique

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Abstract

In this paper, we show the results obtained using the PS technique to locate seismic faults in Southern California with high spatial resolution, and to monitor the evolution of the line of sight (LOS) displacement both in time and space.

1 PS Technique

The PS technique developed at POLIMI ([2], [3]) allows to retrieve on a dense (>50 points/km^2) sparse grid of high coherence points (Permanent Scatterers) the LOS displacement field of the area under observation, starting from a high number (>30) of DInSAR images. The accuracy of LOS displacement rate measurements is high (better than 1mm/yr) and allows to appreciate the LOS velocity field discontinuities across active faults.

For applying successfully the PS technique the following conditions must be satisfied:

(1.) A high number (>30) of SAR images should be available (regardless of their normal baseline values, since Permanent Scatterers show high coherence over years even for normal baselines larger than the decorrelation one).

(2.) The PS density should be high enough ($\geq$10 points/km^2). Each point should not show great LOS displacement with respect to other PS in immediate neighborhood that is strongly non-uniform in time.

After selecting a sparse grid of PS Candidates (points that we believe will eventually proved to be PS), we perform on these points a multibaseline phase unwrapping. We separate the residual topography phase contributions from the LOS displacement ones and we obtain an estimate of the Atmospheric Phase Screen (APS) in correspondence of the PSC. The APS is resampled on a regular grid and low-pass filtered through kriging interpolation.

The original differential interferograms are then compensated for APS; the estimation of DEM errors and LOS displacement phase contributions is carried out on a pixel by pixel basis finding out many PS which could not be identified previously (The PS density increases from 10-15 points/km^2 to 50-150 points/km^2).

In practice the high density PS grid obtained can be regarded as an extremely dense GPS network working in C band, but able to reveal displacement along the line of sight only. In particular, the average LOS displacement rate can be determined for each PS.

2 Seismic Faults

A fault is in general a fracture of rocky mass marked by the offset of one side with respect to the other. The plane of fracture is called fault plane and its intersection with the horizontal plane defines the strike direction. The angle between the fault plane and the horizontal plane is called dip and defines the dip direction. The side below the fault plane is named footwall, the side above is named hanging wall. Since along active faults there is movement, the faults are classified by how the rocks of each side move past each other [8], [9].

Two main types of faults are distinguished: (1.) Strike-Slip faults: the motion occurs along the strike direction. In particular left-lateral and right-lateral faults can be distinguished. (2.) Dip-Slip faults: the motion occurs along the dip direction. If the hanging wall moves down with respect to the footwall, the dip-slip fault is said to be normal and is typical of tectonic extension phenomena. If the hanging wall moves up (with respect to the footwall) the fault is called reverse and denotes usually tectonic compression. Many faults show a predominant character, exhibiting however some amount of motion along the cross-direction too.

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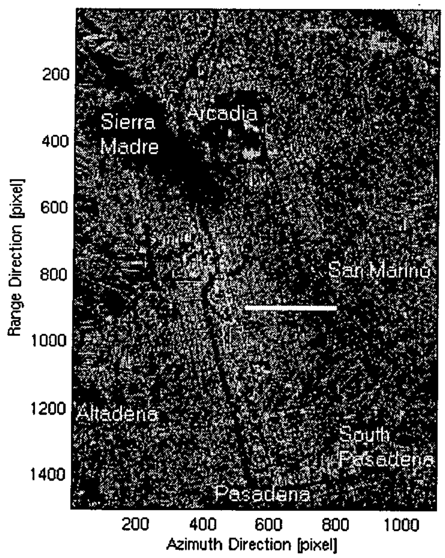

Figure 1: Average LOS displacement rate along the Raymond fault. Dark blue: +2 mm/yr, light blue to green 0 mm/yr, yellow -1 mm/yr.

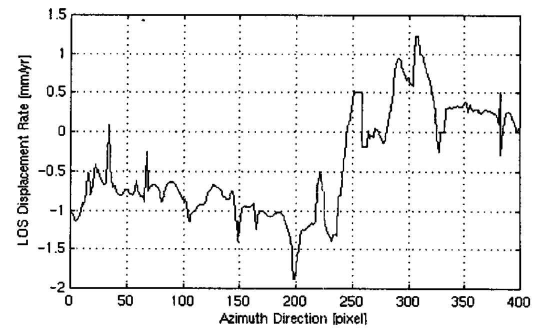

Figure 2: Variation in the average LOS displacement rate (about 1 mm/yr) along the white line (Fig. 2) crossing the Raymond fault.

3 Results

The data set used consists is 55 ERS-1/2 SAR images gathered over Southern California. Acquisition dates range from June 1992 till November 1999. 4 Tandem pairs were used to generate the reference SAR DEM by means of the wavelet technique [1]. After co-registration of the images on a single master image (ERS-2, April 6, 1996), 54 differential interferograms were processed.

The area imaged is approximately the quadrangle delimited by Pasadena, Los Angeles, Pomona and Chino Hills. The region is crossed by the Raymond (or Raymond Hill) Fault as well as the San Jose Fault.

The exact nature of the Raymond Fault has not been clarified. Anyway the fault has a strike-slip left-lateral character as well as a minor dip-slip reverse motion component [5]. The length of the fault is about 26 km from South Pasadena to Arcadia. The slip rate should be <1 mm/yr [6].

The results obtained are shown in Figs. 1 and 2. The discontinuity in LOS velocity field across the fault varies between 0.5 and 2.5 mm/yr.

The San Jose Fault is a left-lateral strike-slip fault with probably a reverse motion component [4]. The length amounts to about 18 km near the urban areas of Claremont, La Verne and Pomona. The slip rate should be between 0.2 and 2 mm/yr.

The results obtained are shown in Fig. 3. The discontinuity in LOS velocity field across the fault

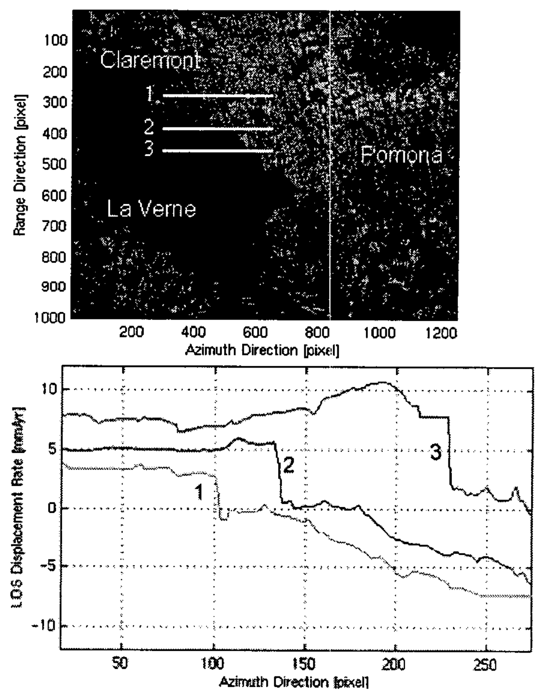

Figure 3: Average LOS displacement rate along the San Jose fault. Dark blue: +10-15 mm/yr, light blue to green 0 mm/yr, yellow -5 mm/yr, red -15 to -24 mm/yr. Below, variation in LOS displacement rate crossing the San Jose fault along the white lines (1, 2, 3).

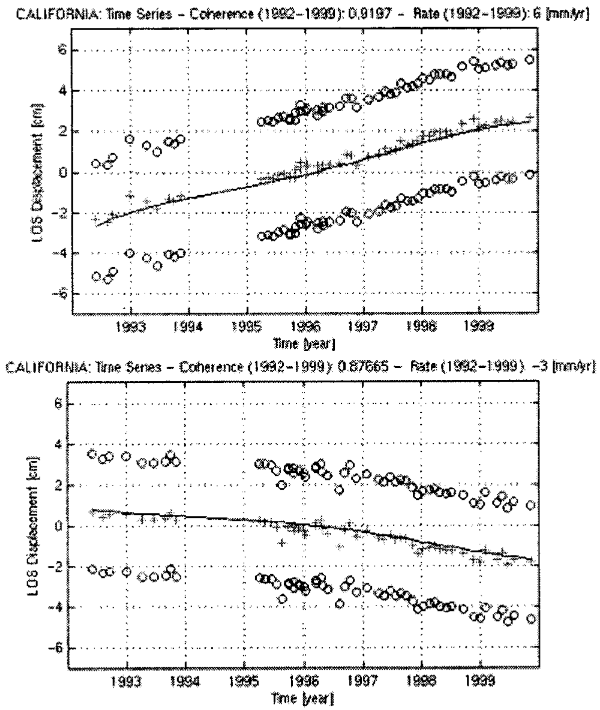

Figure 4: Time histories of the motion of two PS located across the San Jose fault. The synchronicity of the "stepwise" progression of the motion will be further studied, using many more PS.

amounts to about 4-5 mm/yr. Anyway, part of the discontinuity is also due to the strong (LOS deformation rate <-20 mm/yr) subsidence at Pomona caused by intensive water pumping [7], [3].

4 Conclusions and future work

We have shown that the displacement rate discontinuity across active faults can be appreciated using the PS technique. In particular the high density of PS in urban areas allows to locate with high precision the surface trace of seismic faults and to study the evolution of LOS displacement along single fault segments.

The combined use of PS technique and GPS networks could be extremely powerful in monitoring seismic faults taking advantage of the high density PS grid and of the 3D displacement data available at GPS stations.

Future work will be to measure time irregularities of the motion of each PS to understand and assess the effects of light seismic events.

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