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A fault model of the 1993 Klamath Falls earthquakes estimated from SAR interferometry

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1. Introduction

Two M6 class normal fault earthquakes struck near Klamath Falls, Oregon, on September 20, 1993. Klamath Falls is located at the northwestern edge of the Basin and Range province. There are many Quaternary normal faults throughout the Klamath Basin. These faults trend north-northwest. The western margin of the Klamath Basinis defined by the Lake of the Woods Fault Zone (LWFZ). In spite of the existence of many Quaternary normal faults in the Klamath Falls area, no surface ruptures related to the earthquakes were found [Wiley et al., 1993].

The northern part of aftershock distribution trends N-S, and the southern part trends NW-SE. These two trends are parallel to strike in the CMT solutions for the first main shock and second one, respectively [Crider et al., 2000]. From the pattern of aftershocks and CMT solutions for the two main events, some seismological studies proposed the Lake of the LWFZ as the causative structure [Braunmiller et al., 1995, Dreger et al., 1995].

There are some seismological studies about the earthquakes, but no study used geodetic data because there is no traditional geodetic measurement of displacement derived from the earthquakes. Fortunately, ERS-1 and ERS-2, which are the SAR satellites of European Space Agency, observed this area before and after the earthquakes. So, we generated interferograms using these SAR data to detect the deformation and estimate source parameters for the earthquakes.

2. SAR interferometry

Interferograms of the Klamath Falls area were generated from ERS-1 and ERS-2 satellite data. These data were acquired from not only descending passes but also ascending passes. Unfortunately, most of interferograms are affected with atmospheric noise. We selected two descending interferograms and an ascending one, which have less atmospheric noise and better coherence than others, to build the fault model of the Klamath Falls earthquakes.

3. Modeling

A typical Interferogram consists of millions of pixels. For more efficient modeling, we applied quad-tree partitioning to reduce the number of interferogram data points [e.g., Jonsson et al.,2002]. The number of data points was reduced to a few hundred points from each interferogram. These points were weighted by the pixel numbers included in each cell.

In the modeling, we assumed two uniform slip faults in homogeneous and isotropic elastic half-space. In the aftershock distribution, the northern cluster trends N-S, and southern cluster trends NE-SW. These features are consistent with published focal mechanisms. So, we applied the CMT solutions for restricting strike and dip of the two main shock faults. We also constrained fault openings for each fault at 0 and estimated the geometry (except for strike and dip), slip and rake for each fault.

The fault parameters were determined in the inversion procedure, which minimized the square residual between observation and predicted displacement using a non-linear least square inversion. Estimated fault parameters are consistent with CMT solutions, except moments.

4. Discussion

The surface extension of our estimated fault planes do not match the LWFZ. They pass 4 or 5 km east of the LWFZ surface traces. It shows that the LWFZ surface traces do not relate directly to the source faults of the earthquakes, although there might be some relationship between the earthquakes and the LWFZ, because some features (strike, dip and turning strike) of aftershock distribution pattern and CMT solutions are consistent with the LWFZ.

Our estimated geodetic moment of the earthquakes is equal to about 70-80 % of the moments of two main shocks derived from CMT solutions. We tried to constrain geodetic moments to equal the seismological moments, but estimated parameters were unstable. Therefore, this underestimate is not error, we think. A more detailed study of the Klamath Falls earthquakes is needed.