

2013 SCEC Annual Report: **1987 SUPERSTITION HILLS EARTHQUAKE: A TRIGGERED EVENT WITH A COMPLEX NUCLEATION AND RUPTURE DYNAMICS**

Principal Investigator: Ralph J. Archuleta Institution: Earth Research Institute, UC Santa Barbara

The 1987 Superstition Hills (SH) earthquake (Mw 6.6) is of great interest to earthquake scientists from multiple aspects: (1) SH earthquake and ER (Elmore Ranch) earthquake (Mw 6.2 which happened around 12 hours before on a conjugate fault) are highly correlated both in space and time, it is reasonable to infer the triggering relationship between the two events. (2) Kinematic source inversion studies of the SH earthquake (Frankel & Wennerberg, 1989; Wald et al., 1990) imply a multiple, complex event which could be divided into 3 sub-events. Their moments are 0.4, 0.9, and 3.5×10^{25} dyne-cm with time delays of 0s, ~3s and ~8s, respectively. More importantly the 3 sub-events are estimated as initiating at the northwestern end of the SH fault near the intersection with the ER fault. (3) The total energy release determined from the local strong motion records is about half the amount observed from teleseismic data, indicating differentiation of the energy release between high- and low-frequency.

According to previous studies of the SH event sequence (Hanks & Allen, 1989), we have a basic idea about the influence area of this Mw 6.6 event and local tectonic settings. We built a catalog for the ER-SH event sequence out of high quality relocated Southern California earthquake catalog (Hauksson et al., 2011). We made a Google Earth KML file with timeline, which help illustrating how the seismicity grows both in space and time (Figure 1).

Due to the lack of resolution of details of ER event (or any other smaller events in the sequence), we simply treat this seismicity, other than the main SH event, as point sources. We use SORD in the Coseis software package (Ely et al., 2008, 2009), which is also used by several other SCEC projects (Big Ten, M8 simulation), to calculate the wave propagation and dynamic rupture process. To formalize the workflow of investigating existing earthquakes using dynamic rupture modeling, we take the fault geometry models directly from SCEC CFM (Tsurf files), convert them to CUBIT friendly formats (sat or fac) and generate a numerical meshing which coincide with the two fault planes using CUBIT (Figure 2). The python functions used for driving CUBIT meshing could be easily extended to mesh other similar fault system configurations. For simplicity we use a homogeneous velocity structure, although given the helper functions in Coseis it is not hard to incorporate SCEC CVM into our modeling.

We use SORD to calculate the response (perturbation of stress on the fault plane) of the SH fault due to each point source (ER earthquake or any smaller events). We take the hypocenter and focal mechanism from SCEC data center. We pass the information to Coseis to generate rotated point source inputs in favor of our rotated coordinate system. We calculate the normal, shear stress perturbation on the main SH fault due to distant point sources located on the conjugate ER fault. Examples of the stress perturbations are

illustrated in Figure 4. The dynamic range of the stress perturbation could be much larger than the quasi-static solution (asymptotic values when time goes to infinity), which characterizes the higher possibility of dynamic stress triggering than static stress triggering.

For the dynamic rupture process of the SH event, we noticed that the mechanism of delayed triggering is a big question mark. We evaluate the possibility and timing of earthquake initiation within dynamic rupture simulation framework (using slip-weakening friction law). Kinematic inversion results indicate the Superstition Hills earthquake is a combination of 3 sub-events. The sub-event 2 is suspected to rupture at a high rupture velocity (near P-wave speed) within a confined area (~2km along strike). We make 2km by 2km square patch around the hypocenter of SHF event. In the patch initial shear stress is assigned such that the patch is on the verge of failure (initial shear stress = $0.99 \times$ yield stress). We want to utilize the known kinematic inversion conclusions to better constrain the dynamic rupture parameters (such as D_c in slip-weakening friction relation), as well as getting a more physical sense of the rupture process. In our dynamic rupture simulation setup, almost all the conditions are uniform along the fault except that in the nucleation patch initial shear stress is different than that in surrounding areas. We use M 6.2 event as point source to generate dynamic stress perturbations and experiment with various values of the parameter D_c , which is uniform over the SHF. In this way we understand under what conditions dynamic triggering might take place within a short time range, e.g., 20s (Figure 5). For the Elmore Ranch (taken as a point source) to trigger rupture on the Superstition Hills Fault the D_c must be less than 0.061 m.

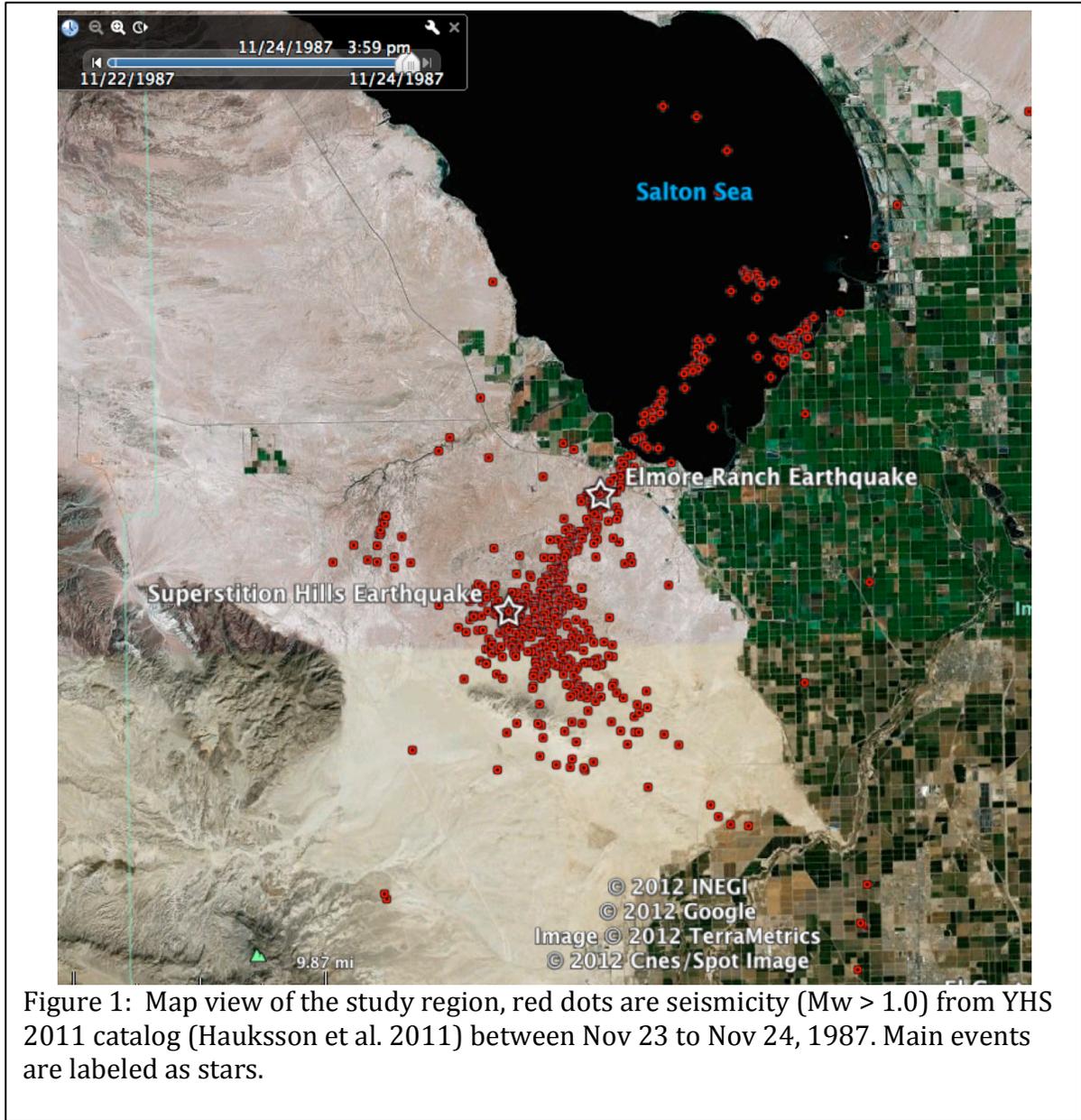


Figure 1: Map view of the study region, red dots are seismicity ($M_w > 1.0$) from YHS 2011 catalog (Hauksson et al. 2011) between Nov 23 to Nov 24, 1987. Main events are labeled as stars.

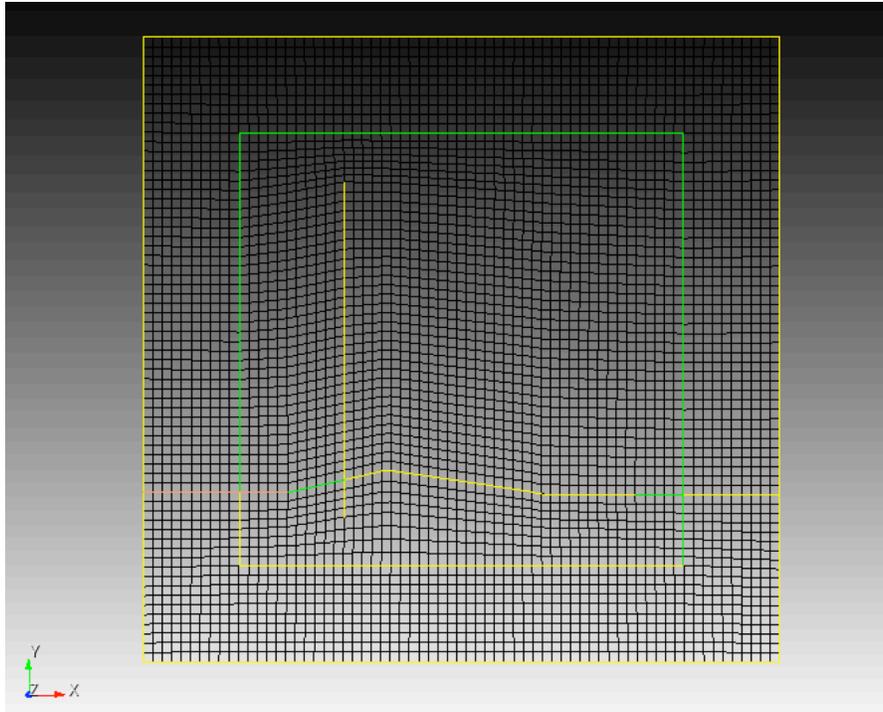


Figure 2: (2D) Map view of the numerical mesh. The yellow line along Y direction represents ERF, while the line along X direction with curvature contains the SHF. We rotate the coordinate to a local coordinate system where ERF is strictly pointing to Y direction. PML grid points fill in the area between inner and outer rectangular to reduce boundary effects.

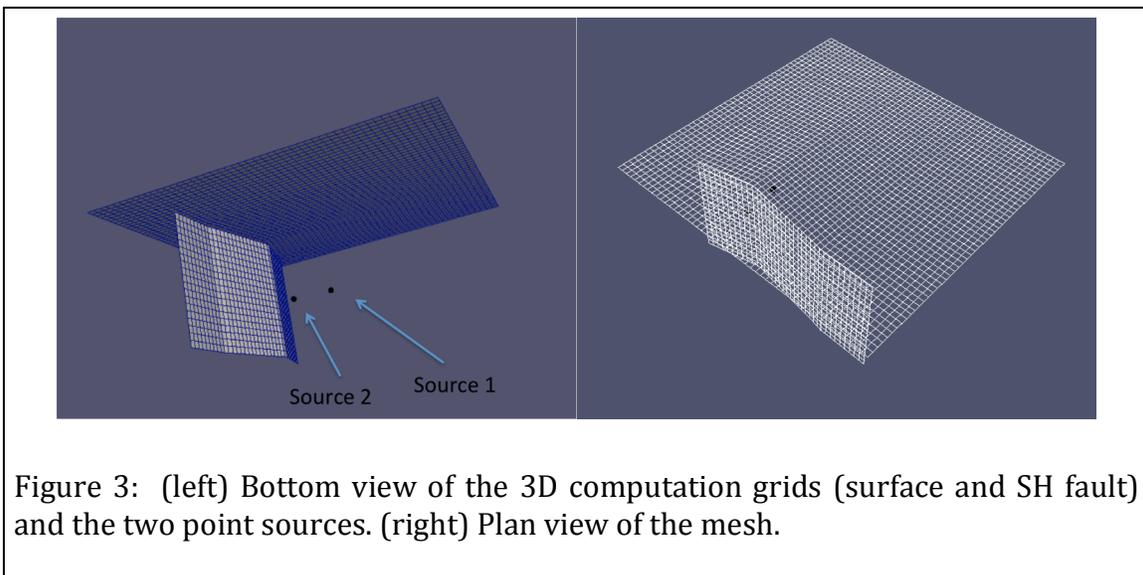
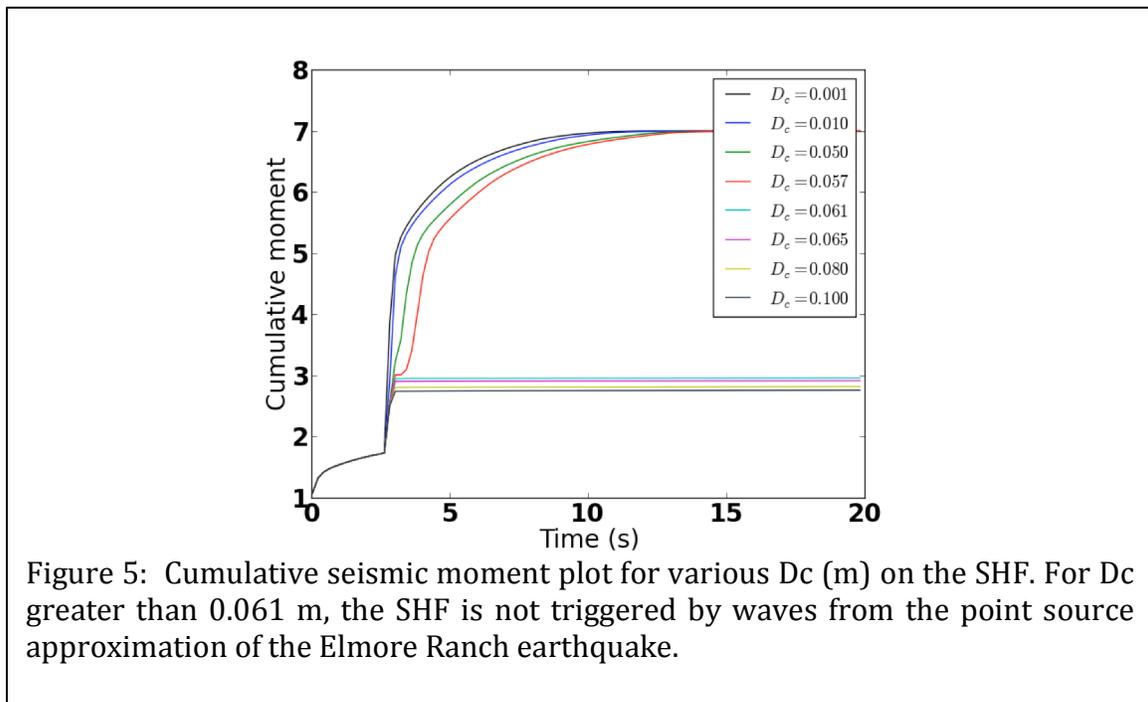
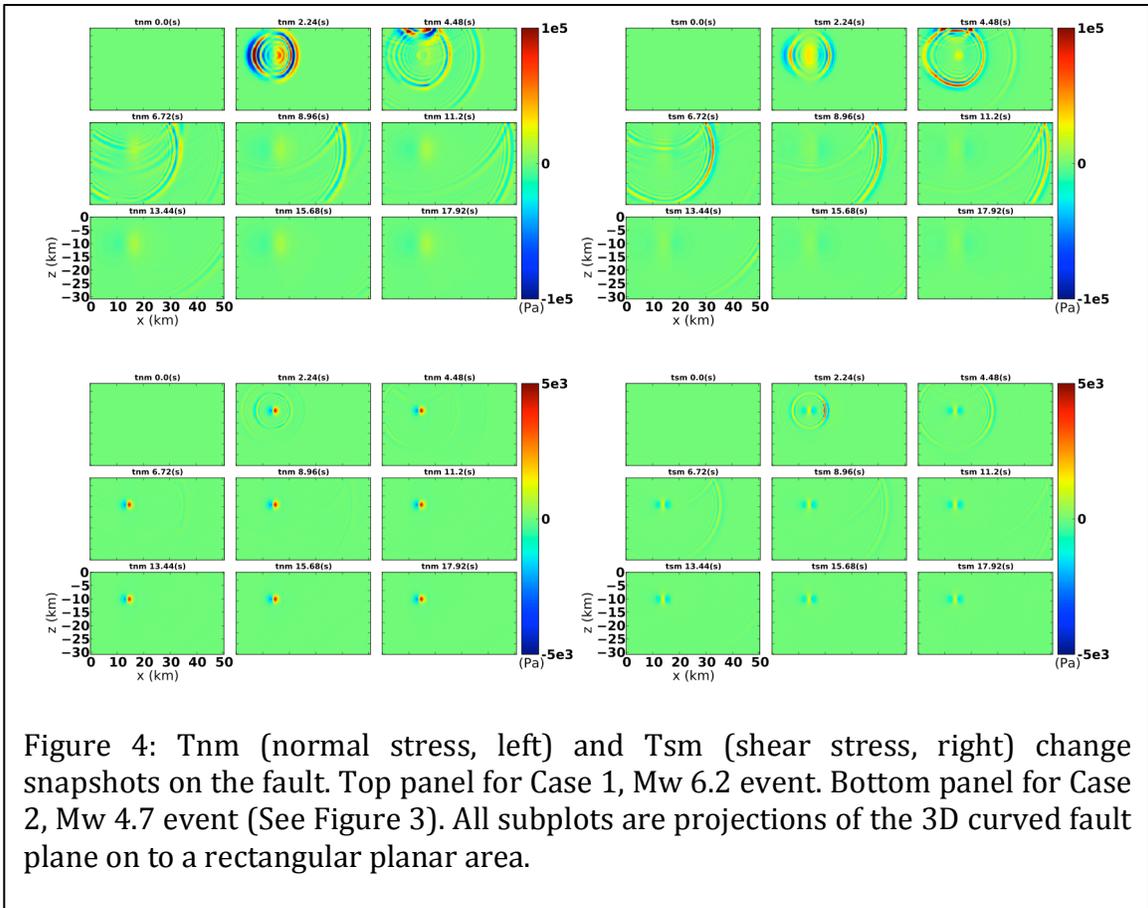


Figure 3: (left) Bottom view of the 3D computation grids (surface and SH fault) and the two point sources. (right) Plan view of the mesh.



References

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