Differences among Seismic Hazard Estimates in the Vicinity of Reno-Carson Region, Nevada Based Entirely on Geodetic, Geological or Seismicity Inputs

Final Technical Report

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Project Title: Differences among Seismic Hazard Estimates in the Vicinity of Reno-Carson Region, Nevada Based Entirely on Geodetic, Geological or Seismicity Inputs (USGS Grant #: 06HQGR0004)

We have conducted a multidisciplinary approach to seismic hazard analysis in the Reno-Carson-Tahoe region under the support of this project. We have developed four different geodetic strain models based on our newly collected GPS data and constraints from geological and seismicity information. We have collected a significant amount of fault data based on information from a series of recent meetings and workshops. Based on information from meeting presentations, expert recommendations and suggestions, and other recent publications, we have assembled a full range of seismic hazard input information for the region. We then developed a set of preliminary seismic source models based on independent geodetic, geological, and seismological inputs and calculated probabilistic seismic hazard maps for each of these different models and compared them with the USGS National Seismic Hazard Map estimates (Frankel et al., 1996, Frankel et al., 2002) for the region. The following figures summarize some of these results.

Figure 1 shows our defined study region (outlined by the box) in the Reno-Carson-Tahoe area. The orientation of the box area is chosen so that it is consistent with the regional deformation pattern. The faults distributed throughout Nevada and eastern California are those used in the USGS 2002 hazard maps calculation. Figure 2 shows our estimated seismic moment rates from geodetic, geological and seismicity data separately in the defined region. It is very clear that the moment rate from geodetic, geological and seismological data disagree significantly. Geodetic and geological rates ought to agree, but disagreements between these and the seismicity are to be expected considering the small area and short seismic history. The differences between geodesy and geology motivate more intensive geological studies in the region. To better understand the full impact and uncertainty in seismic hazard estimates due to this difference, we conducted a multidisciplinary approach to seismic hazard analysis using independent geodetic, geological and seismicity inputs. Figure 3 to Figure 5 highlight some of the results based on the geodetic data. Figure 3 shows one of our calculated strain models based on GPS velocities. Since there are uncertainties that are associated with obtaining a strain rate model from GPS velocities, we have developed four different strain models based on additional constraints on the distribution of geodetic strain rate from geological and seismicity information. Figure 4 is the uncertainty result from these four strain models. It shows a small variance in our study region which indicates that uncertainty from strain modeling is small compared to uncertainties recognized by using other approaches. Figure 5a is the probabilistic seismic hazard map we calculated based on the strain model shown in Figure 3, compared with the 2002 USGS map (Frankel et al, 2002; Figure 5b) for this area. Figures 6 and 7 highlight some of the results based on geological data. Figure 6a shows the faults with newly collected fault parameters in the region based on information from the workshop and a literature search, in comparison to the original fault database used in the USGS 2002 hazard maps calculation. We can see a significant amount of fault information, some are totally new, and some are with updated information on fault traces and slip rates have been added into our hazard map

calculation. The hazard maps generated by the new fault database and the original USGS fault database are compared in Figure 7a and 7b. In general, our study suggests: (1) seismic hazard estimate from geodetic input is higher in a broad area in the Reno-Carson region than the USGS national seismic hazard maps. (2) Seismic hazard estimate from fault slip rates in this region is significantly increased in the Reno and Lake Tahoe area when recent updates are included.

We have made significant progress in applying geodetic measurement directly to the seismic hazard estimation and seismic hazard map generation recently. We are in the process of writing the results into a paper. In general, our results show: 1). Seismic hazards are significantly higher with the transient post seismic deformation than that without it. It is critical to remove those transient motions from geodetic observation. 2). The hazard maps calculated from GPS observations tend to spread the hazards over a broader area as compared to the results from geological faults. 3). The areal shear zones used by USGS national hazard maps could be modified to better reflect the areas of high strain according to our strain rate modeling results.

Geodesy, geology, and historical seismicity each provides a different view of the regional deformation. In the Reno-Carson-Tahoe region, with incomplete paleoseismic fault data and limited seismic instrument history, geodetic measurement provides important constraints on seismic moment release in the region. For a hybrid seismic hazard model, the total moment budget from faults, seismicity and area source zones should be constrained to the geodetic budget, that is,

Faults+Seismicity+Shear zones = Geodetic data

The interpretation from GPS velocity observation to geodetic strain rate model and from geodetic strain rate model to seismic moment release are not unique. Further studies and tests are needed as more GPS data becomes available. The goal is to be able to apply geodetic measurement directly to the seismic hazard estimation by developing models of regional deformation that have incorporated regional seismicity, paleoseismic slip rates. The geodetic observations should have corrected for transient motion as well as nontectonic movements, such as local subsidence, hydrologic effects, volcanic processes, and other aseismic effects.

Resulting publications and presentations:

Su, F., C. Kreemer, J. G. Anderson and Y. Zeng (2007). Using GPS data to study probabilistic seismic hazard in Great Basin, to be submitted to BSSA.

Pancha, A., J. G. Anderson, F. Su, J. Louie, A. Anooshehpoor, G. Biasi (2006). Characterizing seismic hazar in the Basin and Range Province: Case study for Reno, Nevada, Proceedings of EERI Conference on 100 Anniversary of 1906 San Francisco earthquake, April 18-22, San Francisco.

Su, F., J. G. Anderson and A. Pancha (2005). A multidisciplinary approach to seismic hazard in the Reno-Carson metropolitan region, Proceedings of the Basin and Range Province Seismic Hazards Summit II, Bill Lund editor, miscellaneous publications 05-2, Utah Geological Survey.

Su, F., and J. G. Anderson (2005), Quantifying seismic hazard uncertainty in the Reno-Carson metropolitan region, *SSA Annual Meeting* , Lake Tahoe.

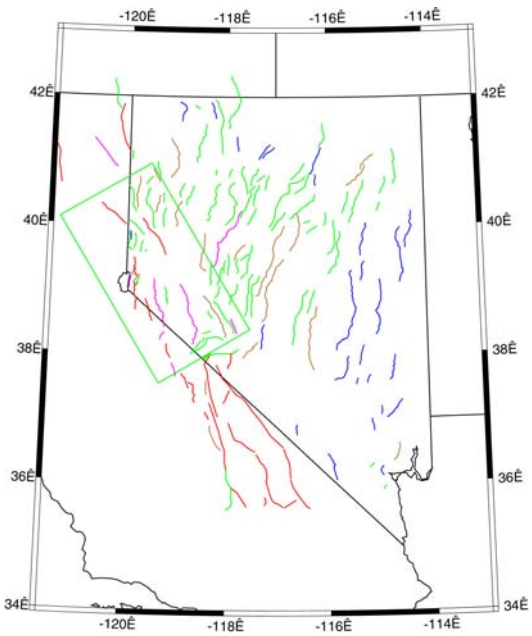


Figure 1: Map of faults in Nevada and eastern California used in the USGS 2002 hazard maps calculation. Faults are color coded by slip rate r. Red for r>0.6, Purple for 0.3<r<0.6; Brown for 0.1<r<0.3; Green for r=0.1and Blue for r<0.1. The box indicate the study region.

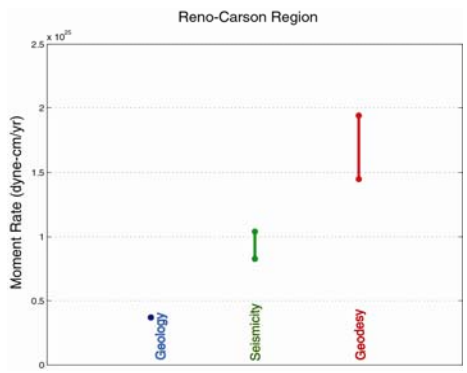


Figure 2: Comparison of seismic moment rates estimated from geodetic, geological and seismicity data in the study region.

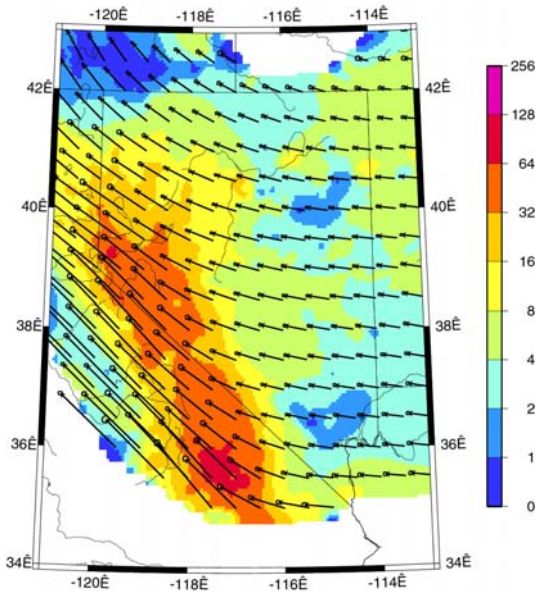


Figure 3: Contour plot of strain rate inferred from the interpolation of GPS velocities. Modeled velocities on regular grid are shown as well.

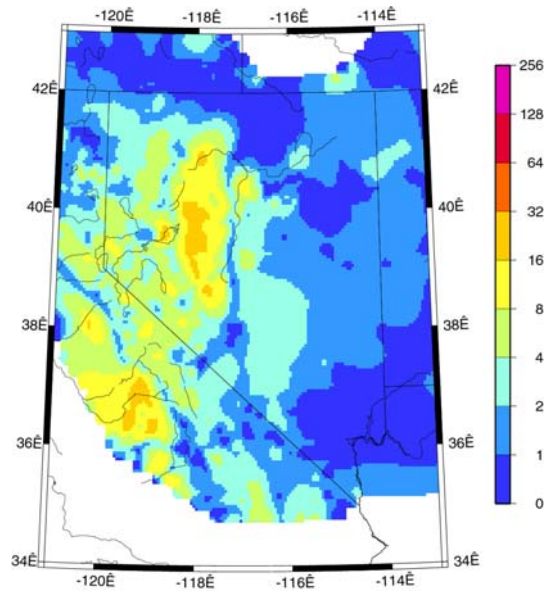
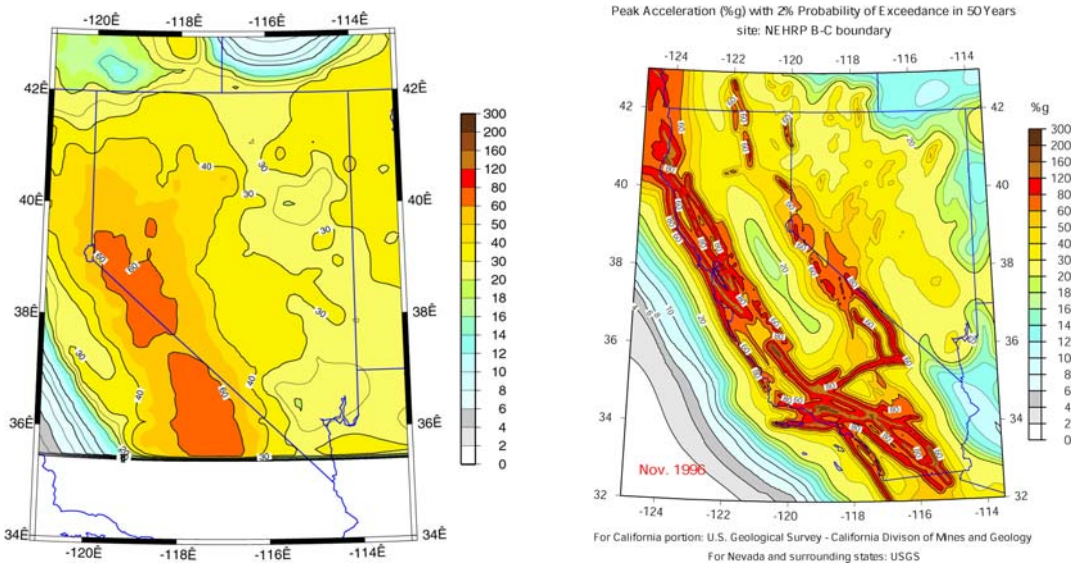
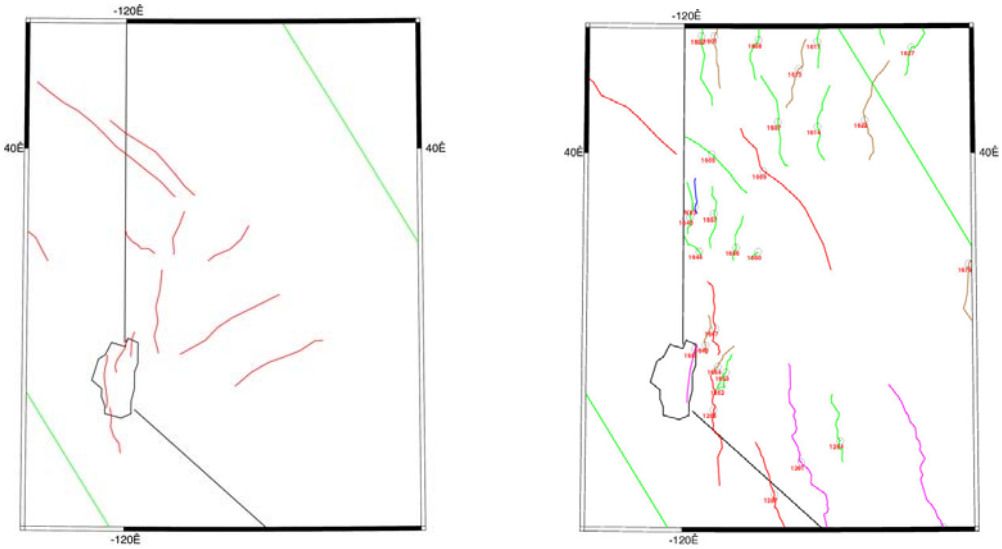


Figure 4: Contour plot of the strain rate variance based on four different geodetic strain rate models, each with slightly different assumptions in the data interpolation.



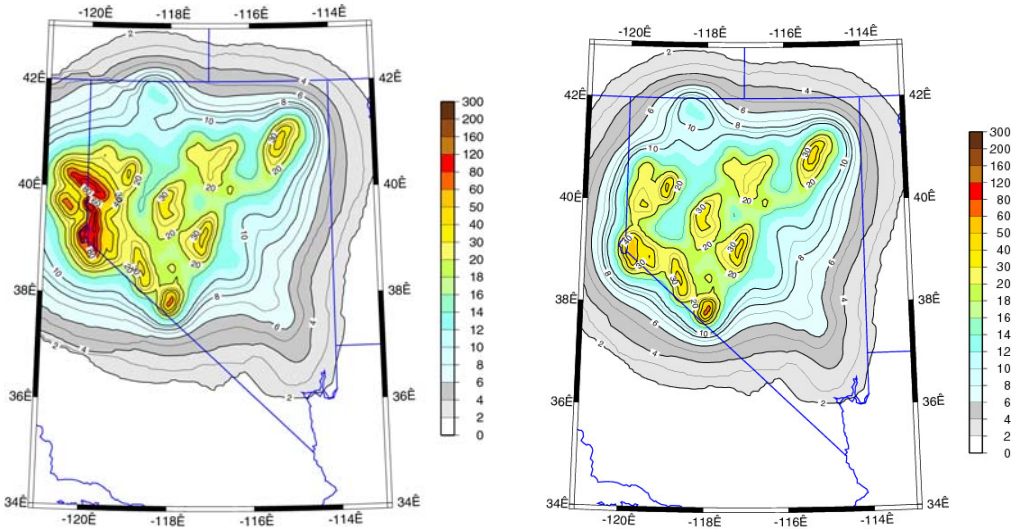
(a) **(b)**

Figure 5: (a) Probabilistic seismic hazard map that we have calculated based on the strain rate model shown in Figure 4; (b) regional probabilistic seismic hazard map from USGS.



(a) **(b)**

Figure 6: (a) Newly collected fault information in the study region; (b) existing faults used in the USGS 2002 hazard maps calculation.



(a) **(b)**

Figure 7: (a) Hazard map showing peak acceleration (% g) with 2% probability of exceedance in 50 years generated by our new fault database; (b) same as (a) but generated based on original USGS faults.