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Seismic Hazard Estimation

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With Field and Dolan from USC, Jackson investigated fault-based source models like those in the Phase II report and the CDMG/USGS hazard model (Field *et al.*, 1999). These both predict more magnitude 6 to 7 earthquakes than observed historically. Possible explanations include temporal variations in earthquake rate (historical deficit), aseismic slip, and systematic underestimation of magnitude limits. Stein and Hanks (*BSSA*, **88**, 635-652, 1996) added that catalog deficiencies may contribute. We developed a Poissonian, deficit-free model (Figure 1) that satisfies all the data, including regression relations between fault length and magnitude. We had to adjust the b-value and minimum magnitude applied to Gutenberg-Richter seismicity and the percentage of moment released in characteristic earthquakes; correct a round-off error in the moment-magnitude definition; and allow for catalog incompleteness, uncertainty in magnitude-length regressions, and multi-segment ruptures (cascades). The maximum cascade event has an expected maximum magnitude of 7.85, but model uncertainties allow events over magnitude 8 with a recurrence time over 1800 years.

We investigated all the pairs of $M_w \geq 7.5$ shallow earthquakes in the Harvard global earthquake catalog which occurred at a centroid distance of less than 100 km. We showed that most of these pairs have similar focal mechanisms. Since these earthquakes generally have focal regions in excess of 100 km diameter, their rupture zones must intersect. In Tables 1a and 1b we display important parameters of the paired earthquakes, as well as the distance, magnitude and time differences between the event pairs. For all of these pairs the time interval is significantly less than the time span needed for plate motion to accumulate the strain released by the first event. These observations conflict strongly with quasi-periodic recurrence models on which the seismic gap hypothesis is based. This is important for southern California earthquake probabilities, because the 1988 and 1990 Working Group Reports, and the SCEC Phase II Report, were all based on variants of the seismic gap model. Power-law recurrence fits earthquake observations much better.

We present a testable forecast for magnitude 6.5 and larger earthquakes during the calendar year 1999. Our forecast is expressed as the probability per unit area everywhere on earth. We specify probabilities on a 1 degree by 1 degree grid, but we will interpolate probabilities between grid points for testing purposes. We assume that the probability of future earthquakes is proportional to a smoothed version of past seismicity (using the Harvard CMT catalog), on the assumption that future earthquakes are more likely in places near to recent ones. This is in some ways antithetical to the seismic gap model (e.g., McCann *et al.*, *PAGEOPH*, **117**, 1082-1147, 1979; Nishenko, *PAGEOPH*, **135**, 169-259, 1991), which assumes that recent earthquakes deter future ones. Our probability depends linearly on the magnitude and inversely on the horizontal distance from previous events out to a distance of a few hundred km. The details of our model are published elsewhere (Kagan and Jackson, *JGR*, **99**, 13,685-13,700, 1994). The forecast is meant to apply to the ensemble of earthquakes during the test period. It is not meant to predict *any* single earthquake, and no single earthquake or lack of one is adequate to evaluate such a hypothesis. We assume that 2% of all earthquakes will be *surprises*, assumed uniformly likely in those areas with no earthquakes since 1977. We have made specific predictions for seven regions of the earth: North Pacific, Northwest Pacific, Southwest Pacific, South America, California, Central America, and Eurasia. Foreshocks and aftershocks are treated as any other earthquake. We will test the forecast against the earthquake catalog using a Likelihood test and present the results next year. Figure 2 shows the forecast for California and surrounding regions such as Nevada and the offshore area.

Fig. 1. The rate of seismicity predicted by our model (solid line); the contribution from the GR seismicity (dotted line), and the cascade scenarios (dashed line). Also shown is our observed rate with 95% confidence limits.

Fig. 2. California seismicity forecast: Color tones show the probability of earthquake occurrence calculated using the PDE 1969-1996 catalog. Earthquakes in 1997-98 are shown in white.

Publications resulting from this project:

Field, E. H., D. D. Jackson, and J. F. Dolan, 1999. A mutually consistent seismic-hazard source model for southern California, submitted to *Bull. Seismol. Soc. Amer.*

Geller, R. J., D. D. Jackson, Y. Y. Kagan, F. Mulargia, and S. C. Stiros, 1998. Letter [on VAN], *Physics Today*, **51(6)**, 95-96.

Jackson, D. D., and Y. Y. Kagan, 1998. VAN method lacks validity, *Eos Trans. AGU*, **78(47)**, pp. 573, 579. (SCEC #396)

Kagan, Y. Y., 1999. Is earthquake seismology a hard, quantitative science?, manuscript, submitted to special issue of *Pure and Applied Geophysics* (Proceedings of 'Workshop on Seismicity Patterns, Their Statistical Significance and Physical Meaning', held May 11-13 in Nikko, Japan). (SCEC #454)

Kagan, Y. Y., 1999. Universality of the seismic moment-frequency relation, manuscript, submitted to special issue of *Pure and Applied Geophysics*, see above. (SCEC #455)

Kagan, Y. Y. and D. D. Jackson, 1999. Worldwide doublets of large shallow earthquakes, submitted to *Bull. Seismol. Soc. Amer.*

Abstracts resulting from this project:

Jackson, D. D., and Y. Y. Kagan, 1998. Parkfield earthquake: Not likely this year, *Seismological Research Letters*, **69(2)**, p. 151.

Jackson, D. D., and Y. Y. Kagan, 1998. The biggest earthquakes: What determines their size?, *Eos Trans. AGU*, **79(17)**, Spring AGU Meet. Suppl., p. S226.

Jackson, D. D., and Y. Y. Kagan, 1998. Global Tests of Earthquake Prediction Hypotheses, *Eos Trans. AGU*, **79(24)**, 1998 Western Pacific Geophysics Meet. Suppl., p. W72.

Jackson, D. D, and Y. Y. Kagan, 1998. Probabilistic global earthquake forecasts for

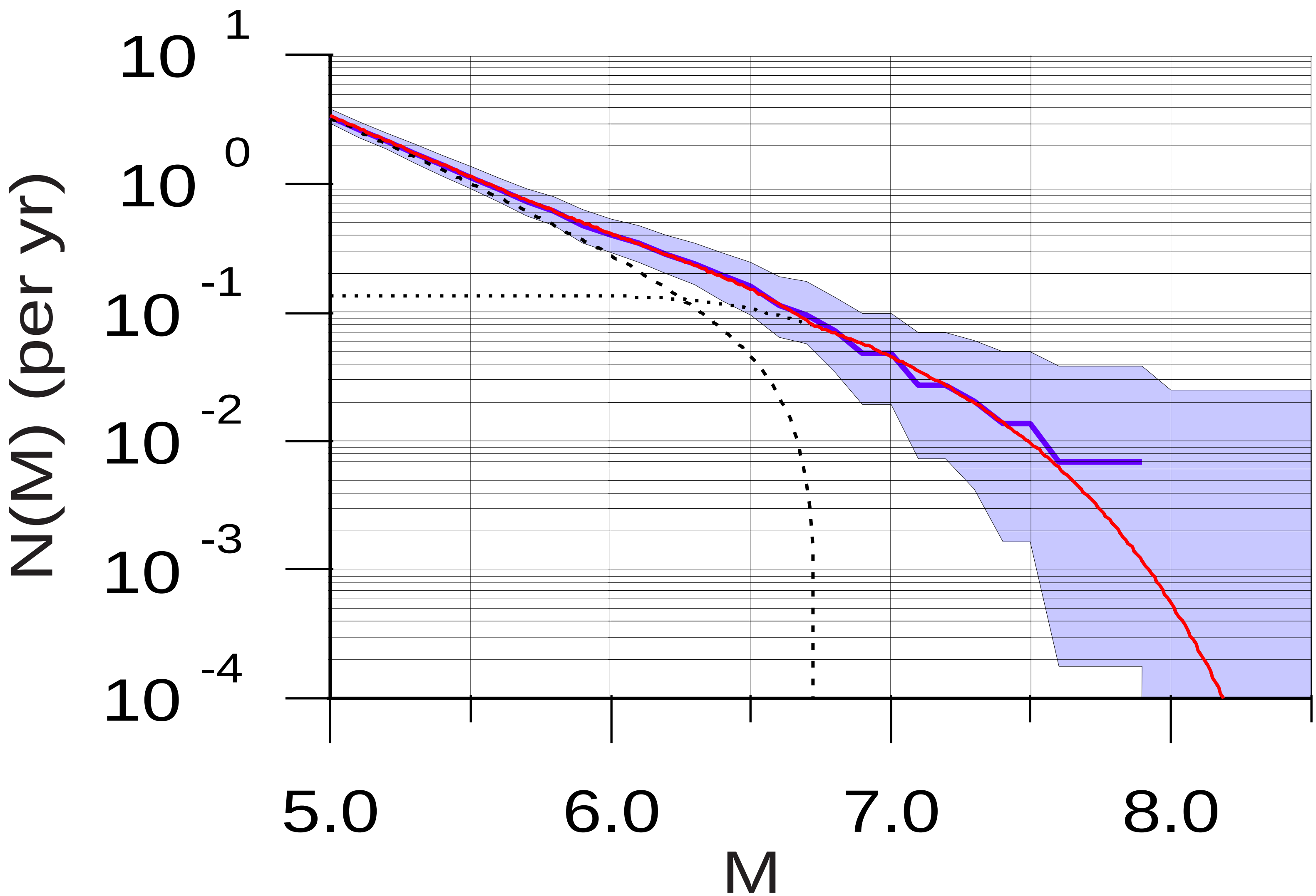
1999, *Eos Trans. AGU*, **79(45)**, Fall AGU Meet. Suppl., p. F585.

Kagan, Y. Y., 1998. Universality of the Seismic Moment-Frequency Relation, *Eos Trans. AGU*, **79(24)**, 1998 Western Pacific Geophysics Meet. Suppl., p. W73-74.

Kagan, Y. Y., 1998. Earthquake scale-invariance and prediction, *XXVI General Assembly European Seismol. Commission, Abstracts*, Tel Aviv, Israel, p. 39.

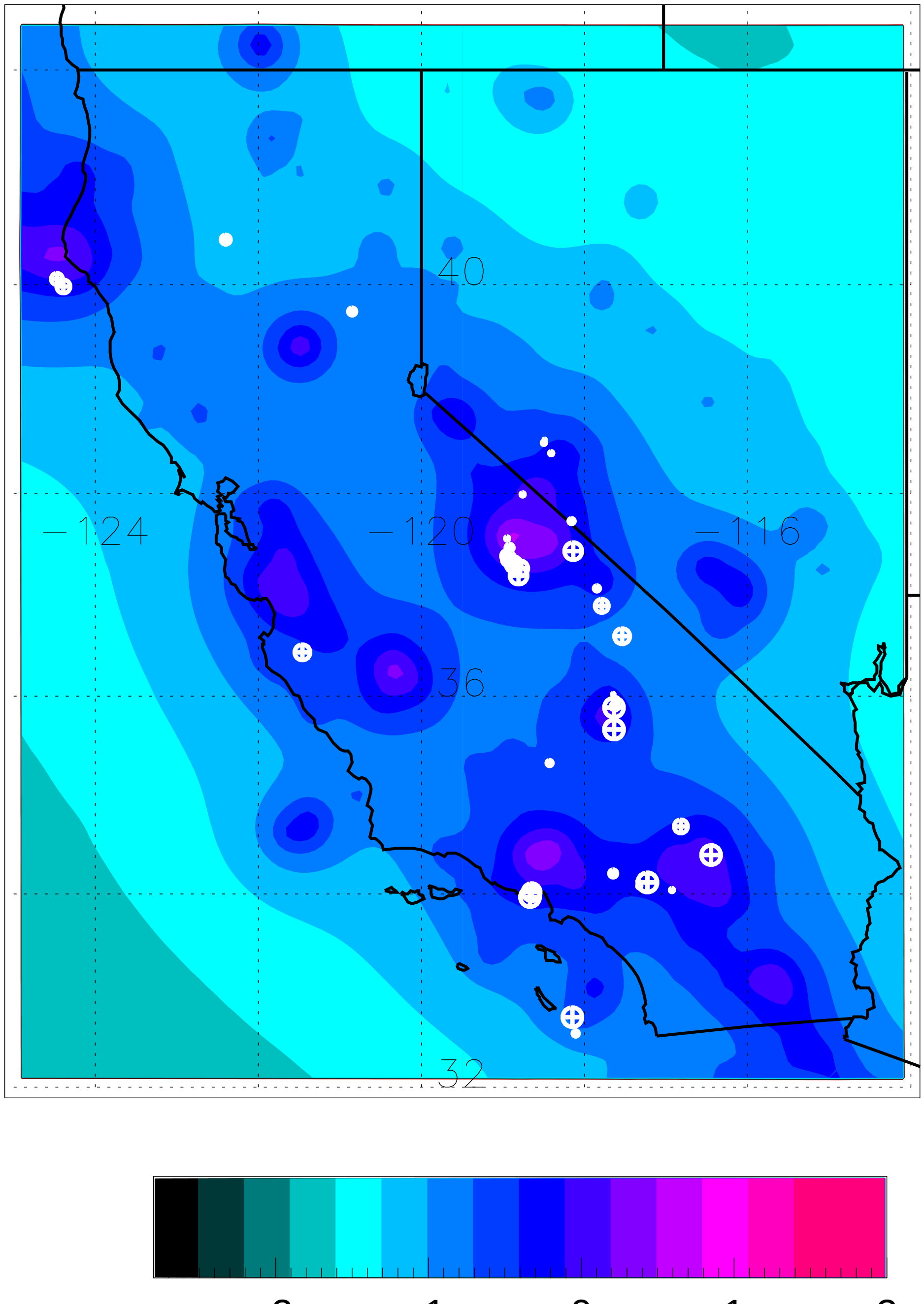
REPORTS RESULTING FROM THIS PROJECT:

Yan Kagan, Worldwide doublets of large shallow earthquakes; poster at SCEC Workshop on Earthquake Physics, Snowbird, Utah, June 20-23, 1998.



10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
N(M) (per yr)
5.0
6.0
7.0
8.0
M

California Forecast (r_s=15 km, l=1.1), PDE 1969-96: Eqs in 1997-98 (white)



Log$_{10}$ probability of earthquake occurrence, m_b > 4.0, eq/year*(100km)^2