

2018 Annual Report #17104
Global Earthquake Activity Rate Model
Principal Investigator: David D. Jackson
November 7, 2019

Technical Report

Focal mechanism forecast

Forecasts of the focal mechanisms of future shallow (depth 0–70 km) earthquakes are important for seismic hazard estimates and models of earthquake occurrence. In the new forecasts we have improved the spatial resolution to 0.1_ and the latitude range from pole to pole. The new results are described in Kagan (2018). Our focal mechanism estimates require distance-weighted combinations of observed focal mechanisms within 1000 km of each grid point. Simultaneously we calculate an average rotation angle between the forecasted mechanism and all the surrounding mechanisms, using the Kagan and Jackson method proposed in 1994. This average angle reveals the level of tectonic complexity of a region and indicates the accuracy of the prediction. Figure 1 displays forecasted global focal mechanisms. To avoid the figure congestion, the mechanisms are shown on a 5 deg. by 5 deg. grid, but they are calculated at 0.5 deg. spatial resolution. We exclude from the display the areas where no earthquake was registered within 1000 km distance. Comparing these predicted mechanisms with their actual distribution demonstrates that our forecast reasonably reproduces earthquake sources properties. An advantage of the new forecast is that the prediction accuracy is evaluated.

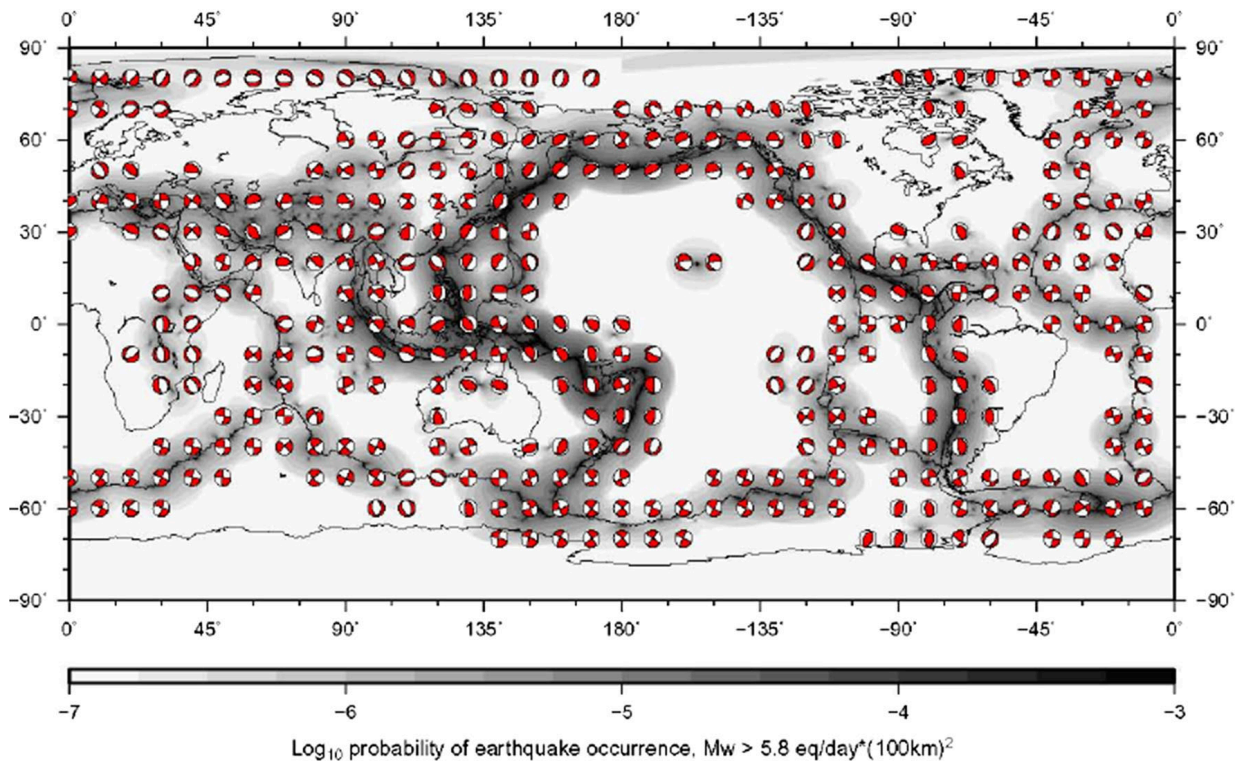


Figure 1: Global earthquake long-term focal mechanism forecast based on smoothed seismicity, latitude range (90° S–90° N). Focal mechanisms are shown on 5 deg. by 5 deg. grid.

Using the PDE catalog and lowering the magnitude threshold

Our published GEAR1 forecast is based on the GCMT catalog, with the magnitude completeness threshold 5.8, includes an estimate of focal mechanisms of future earthquakes and of the mechanism uncertainty. As described in Kagan (2018), we also introduce here a new approach that circumvents the need for focal mechanisms. This permits the use of the PDE catalog that reliably documents many smaller quakes with a higher location accuracy. The result is a forecast at a higher spatial resolution and down to a magnitude threshold 5.0. Such new forecasts can be prospectively tested within a relatively short time, such as a few years or even months, because smaller events occur with greater frequency. The forecast's efficiency can be measured by its average probability gains per earthquake compared to a reference forecast with spatially and temporally uniform Poisson distribution. Given that the magnitude threshold is lower for the PDE catalog, it shows more details since many more earthquakes were used in the computation. The PDE forecast also shows a greater probability gain with respect to the reference than does the GCMT forecast.

Forecast model testing

Peter Bird, a member of our team and first author of the GEAR1 model, published the 2018 paper listed below. In it he applied statistical tests

published by Kagan in 2009. One of those tests measures the probability gain, expressed as the logarithm in base 2 of a forecast likelihood, compared to that of a spatially and temporally uniform reference forecast. A probability gain of 2.0 implies that the likelihood of a test model is twice that of the reference, for the same number of observed events. Table 1 shows results for the GEAR1 composite model, the smoothed seismicity component of the GEAR1 model, the latest (at publication) global tectonic strain rate map, and an earlier, more basic tectonic map. As the table shows, all models show significant improvement over the reference, the GEAR1 composite shows more improvement than any of the single ingredient models, and the order of the probability gains is the same for each test year.

Table 1 Kagan (2009) I_1 (Success) of Four Forecasts over Three Years			
Calendar Year	2014	2015	2016
Earthquake count, n	200	177	196
Long-term forecast model			
GEAR1	4.3287	4.7270	4.4597
Smoothed seismicity	4.1163	4.4688	4.1911
SHIFT_GSRM2f	3.7043	4.1795	3.9251
SHIFT_GSRM	3.6666	4.1188	3.8074
GEAR1, Global Earthquake Activity Rate model v.1; SHIFT, Seismic Hazard Inferred from Tectonics; GSRM, Global Strain Rate Map.			

Since 1 October 2015, the GEAR1 model has undergone prospective evaluation within the Collaboratory for the Study of Earthquake Predictability (CSEP) testing center, forecasting $M_w \geq 5.95$ seismicity. Anne Strader, who obtained her PhD at UCLA during the period funded by this project, is first author on the paper listed below (Strader et al., 2018). That paper reports preliminary results of applying CSEP tests to the GEAR1 forecast. The authors tested GEAR1 over the period 2015.10.01 to 2017.09.07. During the evaluation period, observed earthquakes were consistent with the GEAR1 forecast and comparative test results likewise support that GEAR1 is more informative than either of its components alone. Based on a combination of retrospective and prospective testing, the tectonic forecasts do not effectively anticipate observed spatial earthquake distribution, largely due to over-localization of the model with respect to observed earthquake distributions. However, because GEAR1 is based on optimizing performance over an 8-yr retrospective period, a similar prospective time period will likely be necessary to conclusively validate the model selection.

Publications

Bird, P. [2018] Ranking some global forecasts with the Kagan information score, **Seismol. Res. Lett.**, **89**(4), 1272-1276, doi: 10.1785/0220180029

Jackson, D. D. (2018). Testing the Classic 1988 Forecast. **Seismological Research Letters**, **89**(4), 1288-1297. doi: 10.1785/0220180039.

Kagan, Y.Y., [2017]. Worldwide Earthquake Forecasts, **Stoch Environ Res Risk Assess**, **31**:1273–1290, DOI 10.1007/s00477-016-1268-9.

Schorlemmer, D., Werner, M. J., Marzocchi, W., Jordan, T. H., Ogata, Y., Jackson, D. D., Mak, S., Rhoades, D. A., Gerstenberger, M. C., Hirata, N., Liukis, M., Maechling, P. J., Strader, A., Taroni, M., Wiemer, S., Zechar, J. D., & Zhuang, J. (2018). The Collaboratory for the Study of Earthquake Predictability: Achievements and Priorities. **Seismological Research Letters**, **89**(4), 1305-1313. doi: 10.1785/0220180053.

Strader, A., M. Werner, J. Bayona, P. Maechling, F. Silva, M. Liukis, and D. Schorlemmer (2018). Prospective evaluation of global earthquake forecast models: 2 yrs of observations provide preliminary support for merging smoothed seismicity with geodetic strain rates, **Seismol. Res. Lett.****89**, no. 4, 1262–1271, DOI: <https://doi.org/10.1785/0220180051>

Presentations

Jackson, D. D. (2016, 09). The bridge from earthquake geology to earthquake seismology. Oral Presentation at 2016 SCEE Annual Meeting.

Jackson, D. D. (2017, 08). Prospective test of the 1995 WGCEP SoCal earthquake forecast.
Poster Presentation at 2017 SCEE Annual Meeting.

Jackson, D.D., 2018. Testing Fault-Based Rupture Models. Presentation at Seismological Society of America, Miami FL, 5/16/2018.

Jackson, D.D. , 2018. The Collaboratory for the Study of Earthquake Predictability: Achievements and Priorities. Presentation at Seismological Society of America, Miami FL, 5/17/2018

Kagan, Y. Y., & Jackson, D. D. (2016, 08). Earthquake Number Forecasts Testing . Poster Presentation at 2016 SCEE Annual Meeting.

Savran, W. H., Werner, M. J., Rhoades, D. A., Jackson, D. D., Field, E. H., Milner, K. R., Michael, A. J., Jordan, T. H., & Maechling, P. J. (2019, 08). Pseudo-Prospective

Evaluation of Operational UCERF3-ETAS Forecasts during the Ridgecrest, California, Earthquake Sequence. Poster Presentation at 2019 SCEC Annual Meeting.

Weiser, D., Porto, N. B., & Jackson, D. D. (2017, 08). Can maximum magnitude be derived from fault dimensions?. Poster Presentation at 2017 SCEC Annual Meeting.