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Seismic Hazard Estimation

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We have continued to develop and test parametric models of earthquake probability as functions of location, magnitude, and time based on seismicity, strain rate, and fault slip. We assume a modified Gutenberg-Richter magnitude distribution, which has three parameters: an "a-value," or threshold seismicity level; a "b-value," and a corner magnitude m_c, above which the rate of earthquakes drops exponentially with increasing moment. With this assumption, an earthquake forecast is equivalent to specifying the a-value, b-value, and m_c for points in space and time. In this work we assume time-independence.

The earthquake record in southern California is inadequate to determine the corner moment, m_c, within the region, let alone to infer local variations; m_c especially depends on large earthquakes for which the record is inadequate. For this reason, we have examined earthquakes globally to find measurable quantities that are correlated with the a-value, b-value, and m_c. We find that b is effectively universal, with a value of 0.93. While sample estimate differ, the differences are not statistically significant. Assuming that the long term seismic moment rate equals the tectonic moment rate estimated from plate tectonics or geodetic strain rate, we also find that the corner magnitude m_c is also nearly uniform on plate boundaries and continental interiors, with a value of 8.0 to 8.5. On mid-ocean ridges and oceanic transforms it varies from 5.8 to 7.2. We tentatively assume b=0.93 and m_c=8.2 for southern California while we continue to study this problem.

These results allow us to apply both seismic history analysis and tectonic deformation measurements for evaluation of earthquake potential in California and other regions. For the seismicity models, we optimized parameters using "pseudo-forecasts," that is by forecasting the latter part of the catalog using data from the early part. Figure 1 of our other report (Working Group on Earthquake Potential, SCEC 2000 report volume) displays a test of the predictive power for two methods: one based on strain measured in southern California, and another based on earthquake record. In the latter test we used a modified historical catalog of earthquakes in California updated by the Harvard CMT data. This catalog is important because it includes focal mechanisms, which we have shown to have predictive information for future event locations. A drawback of the Harvard catalog is a scarcity of earthquake records, because solutions are available only for events $M_w \geq 5.5$. To provide another estimate of earthquake potential we used the PDE catalog, which is reasonably complete for southern California starting with $m_b \geq 4.0$ (see Figure 1). We used also the Caltech catalog. The PDE and Caltech catalogs do not report fault-plane solutions.

Figures 2 and 3 display an example of such estimation for two regions of the western Pacific. The results of our forecast made during year 2000 are now satisfactory (that is, the catalog falls within the 95% confidence intervals of model prediction) in both regions (see more in http://moho.ess.ucla.edu/~kagan/test2001_text.txt).

PUBLICATIONS RESULTING FROM THIS PROJECT:

Kagan, Y. Y., and D. D. Jackson, 2000. Probabilistic forecasting of earthquakes, (Leon Knopoff's Festschrift), *Geophys. J. Int.*, **143**, 438-453, SCEC #516.

Kagan, Y. Y., and F. Schoenberg, 2001. Estimation of the upper cutoff parameter for the tapered Pareto distribution, (David Vere-Jones's Festschrift), *J. Appl. Probab.*, **38A**, 901-918, in press, SCEC #557;
available at http://www.stat.ucla.edu/~frederic/papers/cutoff/index.html

Bird, P., Kagan, Y. Y., and Jackson, D. D., 2001. Plate tectonics and earthquake potential of spreading ridges and oceanic transform faults, submitted to the Plate Boundary Zones book

Kagan, Y. Y., 2001. Seismic moment distribution revisited: I. Statistical results, ms, draft available at http://scec.ess.ucla.edu/~ykagan/moms_index.html

Kagan, Y. Y., 2001. Seismic moment distribution revisited: II. Moment conservation principle, ms.

ABSTRACTS RESULTING FROM THIS PROJECT:

Jackson, D. D., and Kagan, Y. Y., 2000. Tectonic Deformation and Earthquake Potential, *Eos Trans. AGU*, **81**(19), Spring AGU Meet. Suppl., (abstract), T21A-07, p. S407.

Jackson, D. D., and Kagan, Y. Y., 2000. Probabilistic Forecasting of Earthquakes in Pacific Rim Regions, *Eos Trans. AGU*, **81**(22), 2000 Western Pacific Geophysics Meet. Suppl., (abstract), S22B-05, pp. WP109-110.

Kagan, Y. Y., and Jackson, D. D., 2000. Tectonic Deformation and Earthquake Potential, *Eos Trans. AGU*, **81**(22), 2000 Western Pacific Geophysics Meet. Suppl., (abstract), S22B-06, p. WP110.

Bird, P., Kagan, Y. Y., and Jackson, D. D., 2000. Frequency-Magnitude Distribution, Effective Lithosphere Thickness, and Seismic Efficiency of Oceanic Transforms and Spreading Ridges, *Eos Trans. AGU*, **81**(22), 2000 Western Pacific Geophysics Meet. Suppl., (abstract), S51H-01, p. WP147.

Kagan, Y. Y., 2000. Earthquake Process Self-Similarity and its Consequences for Earthquake Physics, (abstract), NATO Advanced Research Workshop, "State of scientific knowledge regarding earthquake occurrence and implications for public policy", Arbus, Sardinia, October 15-19, 2000. http://ibogeo.df.unibo.it/arw2000/arw-abstracts.htm

Kagan, Y. Y., 2000. How big are the Largest Earthquakes?, *Eos Trans. AGU*, **81**(48), Fall AGU Meet. Suppl., (abstract), p. F587.

Kagan, Y. Y., 2000. Earthquakes as a Nonlinear Dynamic Process, *Eos Trans. AGU*, **81**(48), Fall AGU Meet. Suppl., (abstract), pp. F19-20.

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Frankel, A., *et al.*, 1996. *National seismic-hazard maps: documentation June 1996*, Denver, CO, USGS, Open-File Report 96-532, 110 pp.

Field, E. H., D. D. Jackson, and J. F. Dolan, 1999. A mutually consistent seismic-hazard source model for southern California, *Bull. Seismol. Soc. Amer.*, **89**, 559-578.

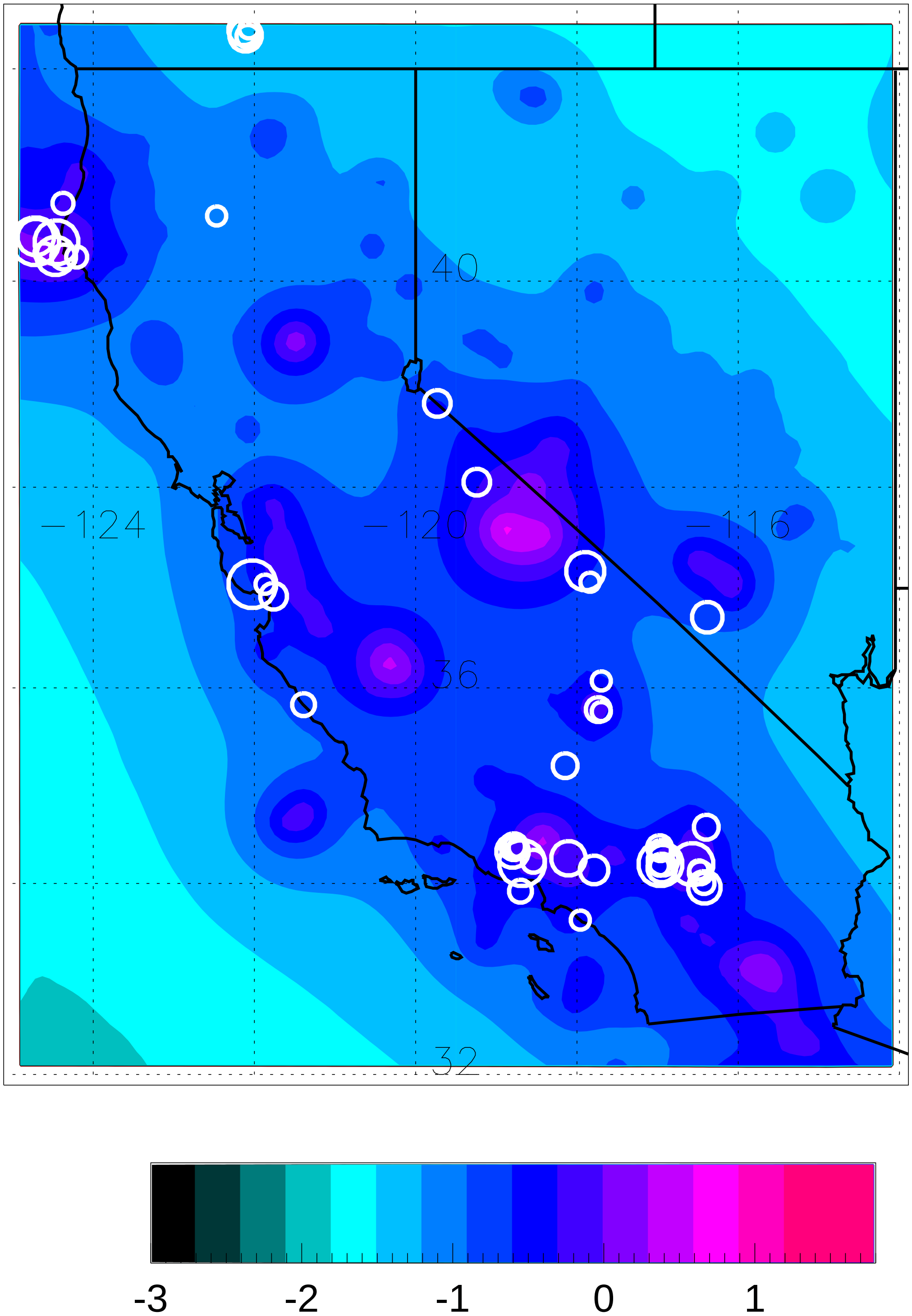
FIGURE CAPTIONS:

Fig. 1. California earthquake forecasts. Color tones show the probability of earthquake occurrence per unit area. Probability of earthquakes $m_b \geq 4.0$ is calculated using the PDE 1969-1988 catalogue. Earthquakes 1989-1999 used in testing, are shown in white.

Fig. 2. Northwest Pacific long-term seismicity forecast: latitude limits from 0.25°S to 60.25°N, longitude limits from 109.75°E to 170.25°E. Color scale tones show the probability of earthquake occurrence $M_w \geq 5.8$, calculated using the Harvard 1977-1999 catalogue; earthquakes 2000 are shown in white.

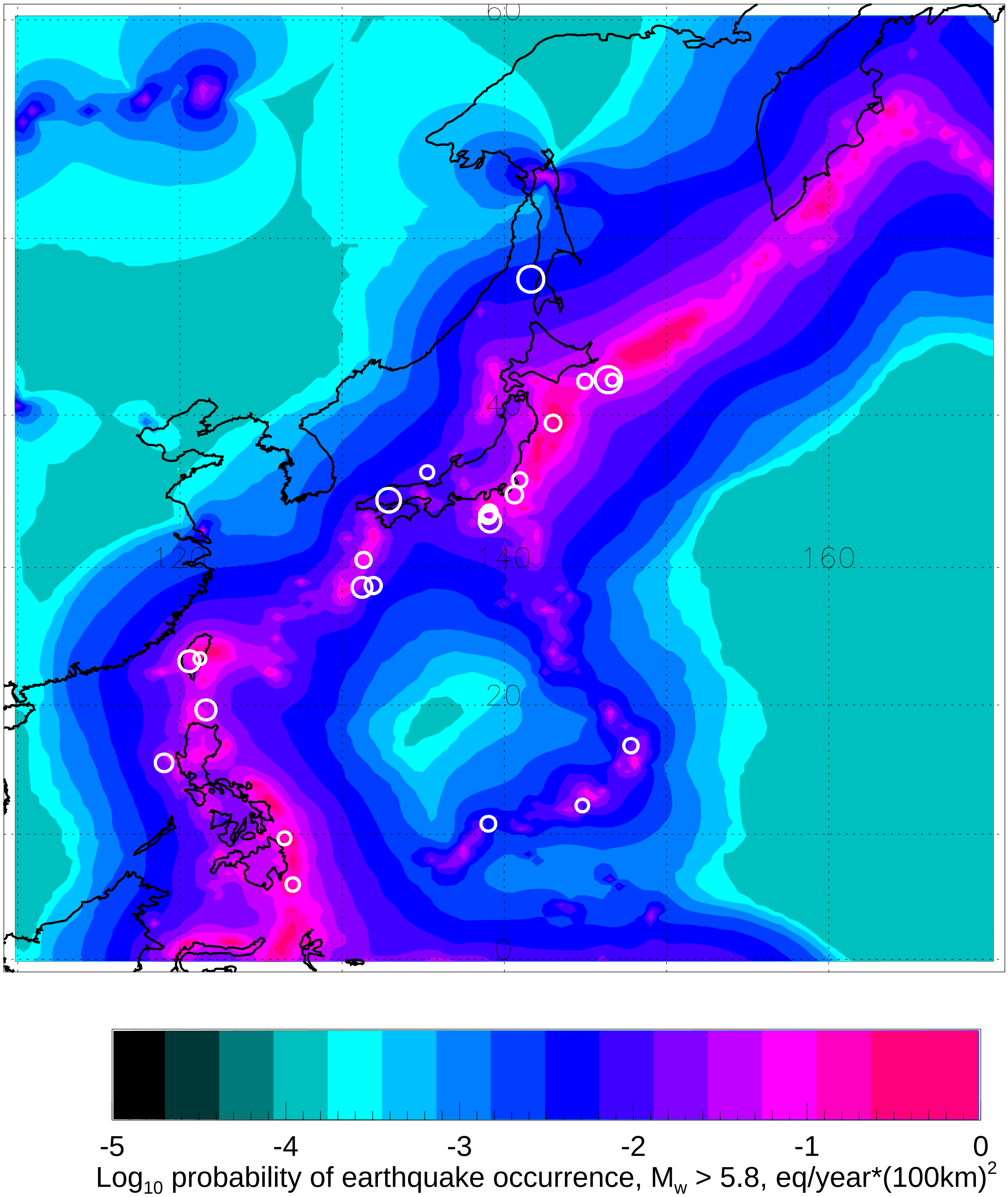
Fig. 3. Southwest Pacific long-term seismicity forecast: latitude limits from 0.25°N to 60.25°S, longitude limits from 109.75°E to 169.75°W. Color scale tones show the probability of earthquake occurrence $M_w \geq 5.8$, calculated using the Harvard 1977-1999 catalogue; earthquakes 2000 are shown in white.

California Forecast (r_s=15 km, l=1.1), PDE 1969-88: Eqs m_b > 5.0, 1989-99

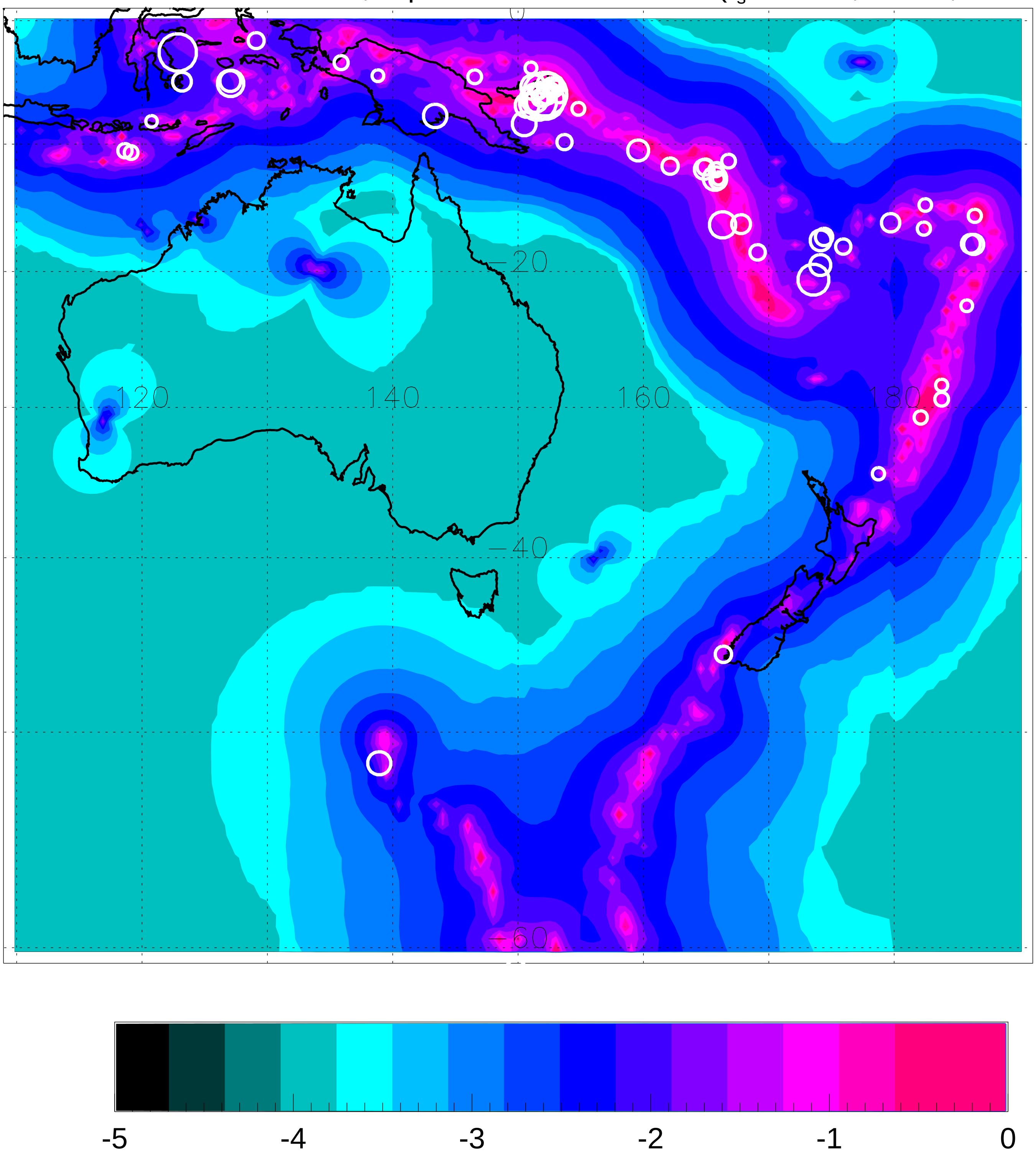


Log$_{10}$ probability of earthquake occurrence, m_b > 4.0, eq/year*(100km)^2

NW Pacific Forecast 1977-99, Eqs 2000/1/1-2000/12/09 (r_s=15 km, λ =1.0, δ =100)



SW Pacific Forecast 1977-99, Eqs 2000/1/1-2000/12/09 (r_s=2.5 km, λ =1.0, δ =25)



Log_{10} probability of earthquake occurrence, M_w > 5.8, eq/year*(100km)^2