Yan Y. Kagan

Dept. Earth and Space Sciences, UCLA, Los Angeles,
CA 90095-1567, kagan@moho.ess.ucla.edu, http://eq.ess.ucla.edu/~kagan.html

Forecasting focal mechanisms and evaluating forecast skill

http://moho.ess.ucla.edu/~kagan/M5P.ppt

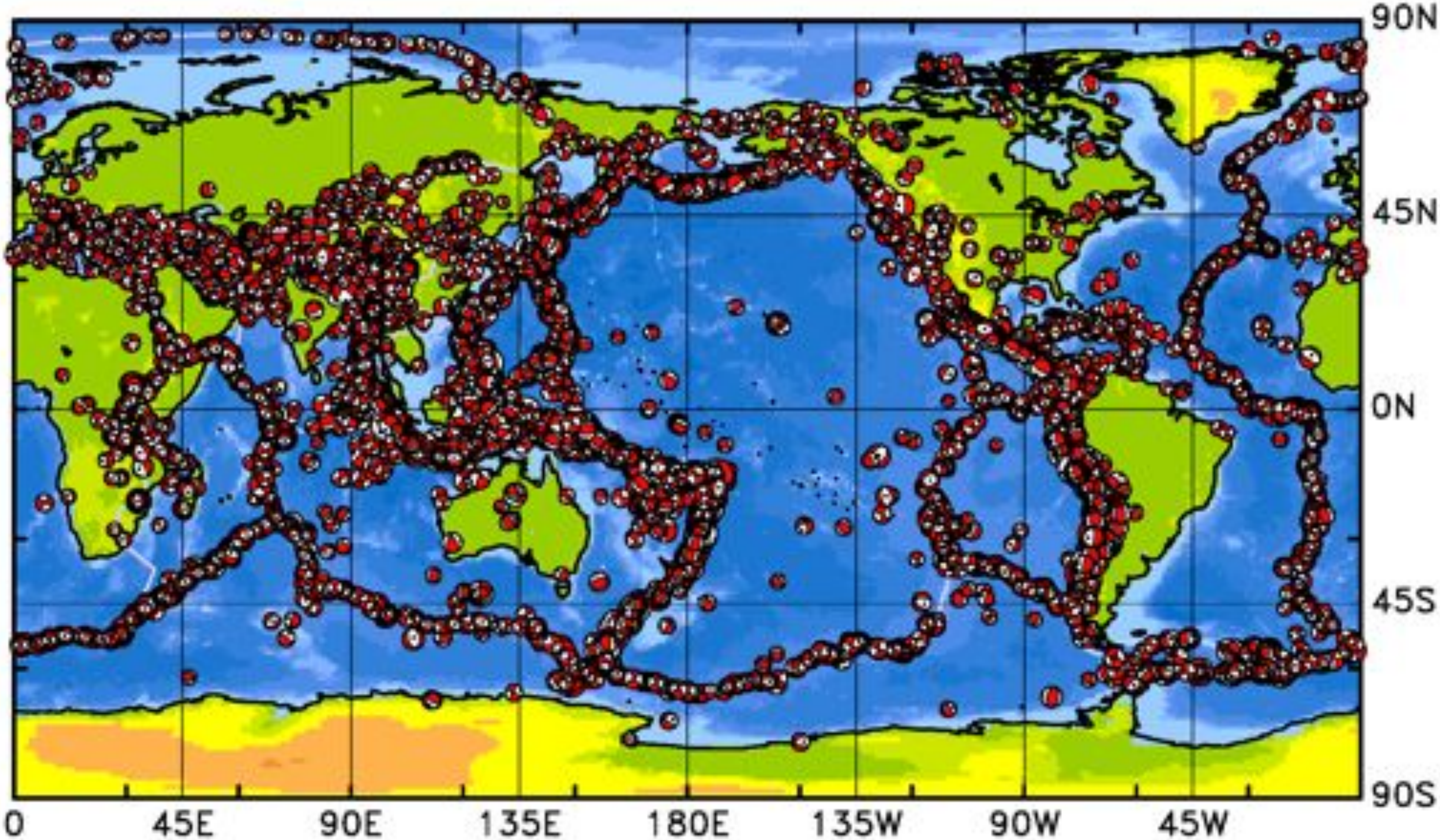
Publications

Kagan, Y. Y. and D. D. Jackson, 2014.
Statistical earthquake focal mechanism forecasts,
Geophys. J. Int., 197(1), 620-629 (K&J_2014).

Kagan, Y. Y. and D. D. Jackson, 2014.
Likelihood analysis of earthquake focal mechanism
distributions, ms, submitted to GJI, (K&J_2015).

Available at http://eq.ess.ucla.edu/~kagan/kagan.html

World seismicity: 1976 – 2012 (GCMT)



STATISTICAL FOCAL MECHANISM FORECAST

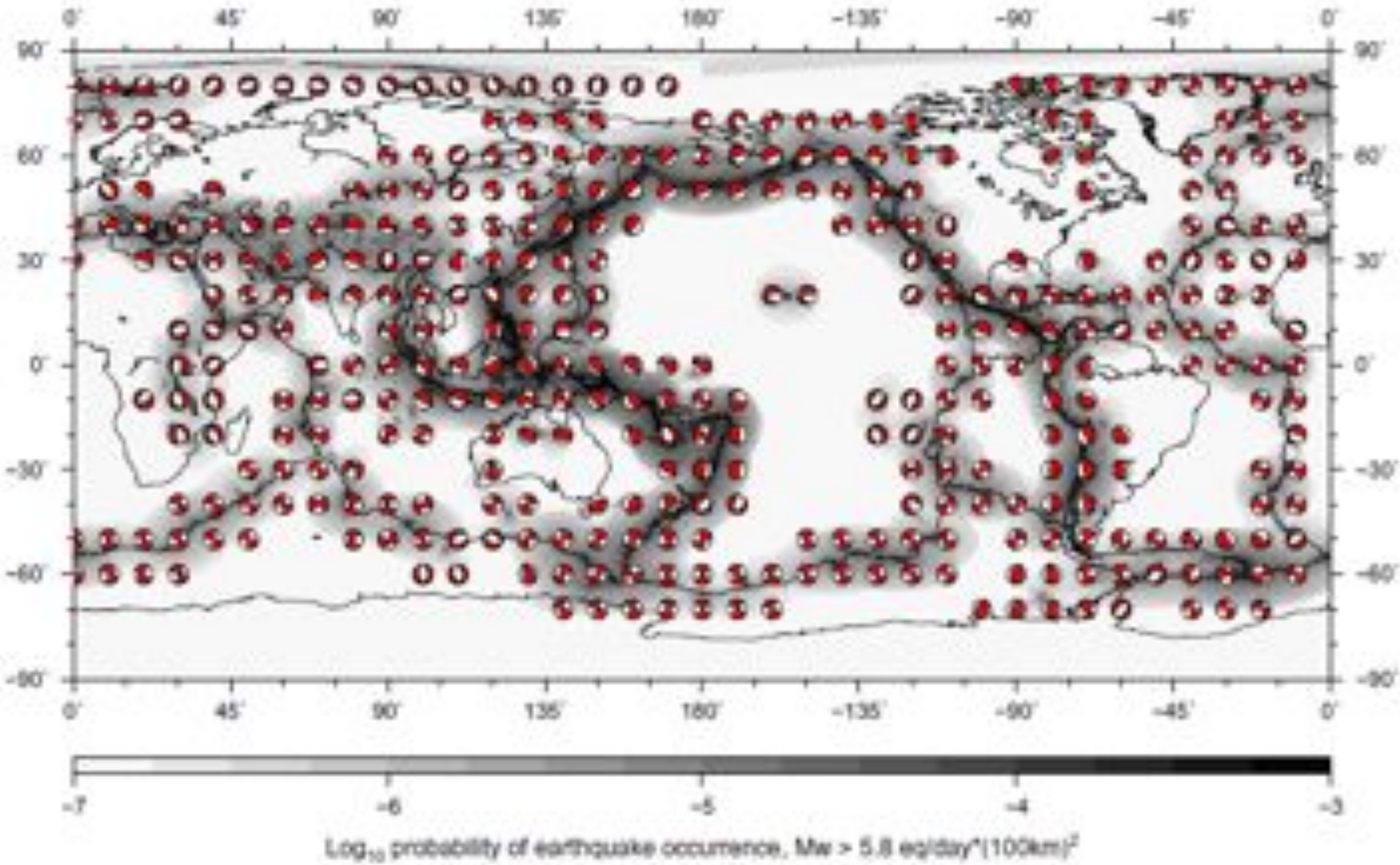
- 1. Focal mechanisms are necessary to calculate seismograms due to forecasted events.
- 2. Forecast must be GLOBAL, i.e. available everywhere where earthquakes occur (Kagan & Jackson, JGR, 1994).
- 3. Forecast uncertainty should be estimated (K&J_1994).
- 4. Forecast skill should be evaluated by prospective testing (K&J_2014, K&J_2015).

Kagan & Jackson, GJI, 2000.

Table 1. Example of long- and short-term forecasts, 1999 February 11, north of the Philippines.

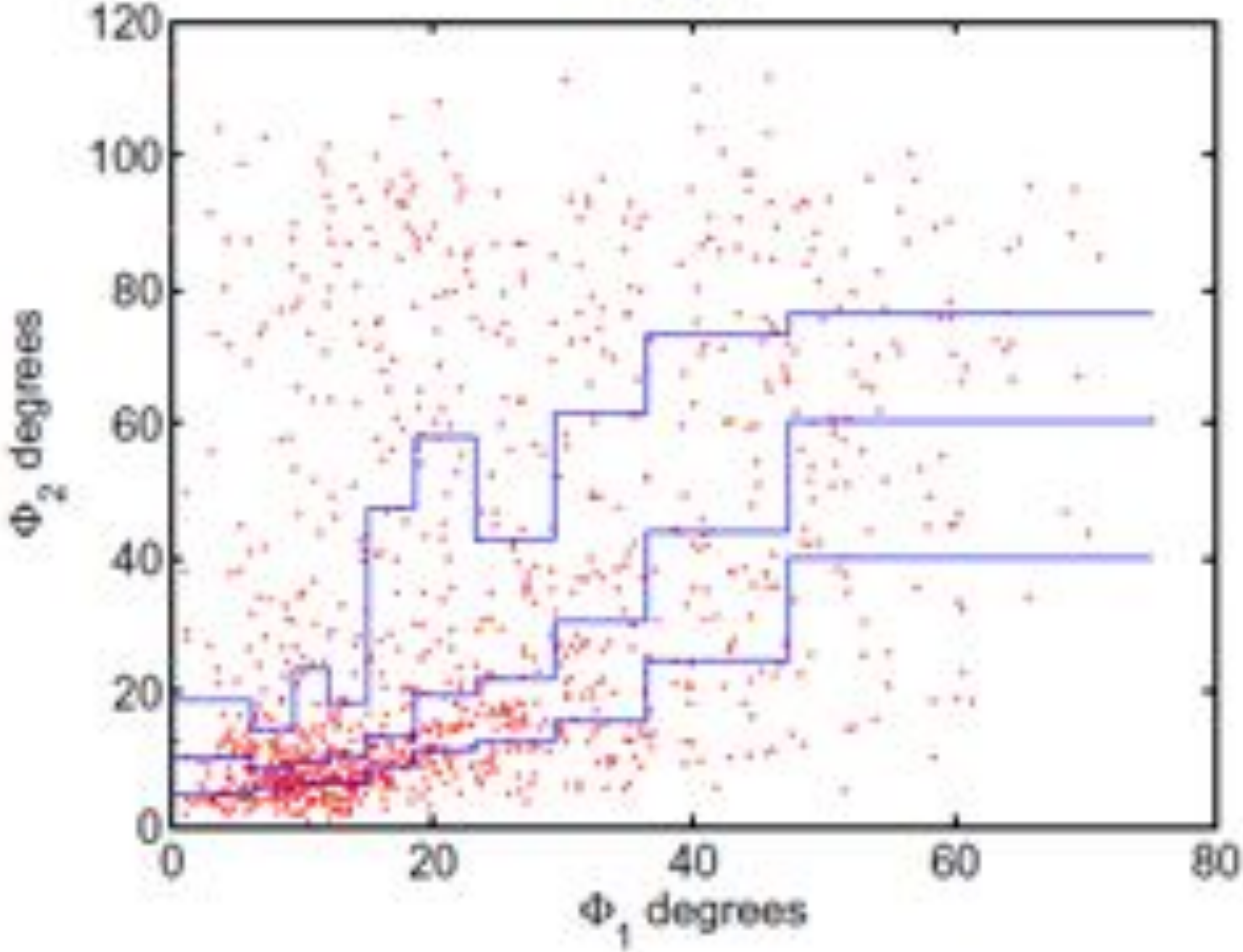
Latitude	Longitude	Long-term forecast						Short-term forecast	
		Probability $m \geq 5.8$ eq/day*km^2	Focal mechanism T-axis Pl	T-axis Az	P-axis Pl	P-axis Az	Rotation angle degree	Probability $m \geq 5.8$ eq/day*km^2 time-dependent	Probability ratio time-dependent/ independent
119.5	19.5	3.18E-09	31	208	10	304	64.8	1.79E-14	5.62E-06
120.0	19.5	5.23E-09	17	213	32	314	68.8	1.40E-10	2.71E-02
120.5	19.5	4.28E-08	7	93	75	335	21.4	2.12E-07	5.0
121.0	19.5	3.02E-08	69	135	21	302	28.2	2.84E-07	9.4
121.5	19.5	1.82E-08	77	106	13	296	40.9	6.14E-08	3.4
122.0	19.5	7.81E-09	60	32	3	297	48.4	1.13E-10	1.45E-02
122.5	19.5	4.15E-09	81	228	4	113	51.8	1.00E-12	2.41E-04
123.0	19.5	3.01E-09	78	251	9	110	50.3	7.70E-16	2.56E-07
123.5	19.5	2.43E-09	76	273	13	107	49.5	1.08E-20	4.43E-12

Focal mechanism forecast is calculated by summing seismic moment tensors in 1000 km distance area and evaluating eigenvectors of the sum tensor. We compare this source forecast with other mechanisms to measure degree of uncertainty (\Phi_1).



Focal mechanism forecast 2008-2012, based on 1977-2007

Fig. 1



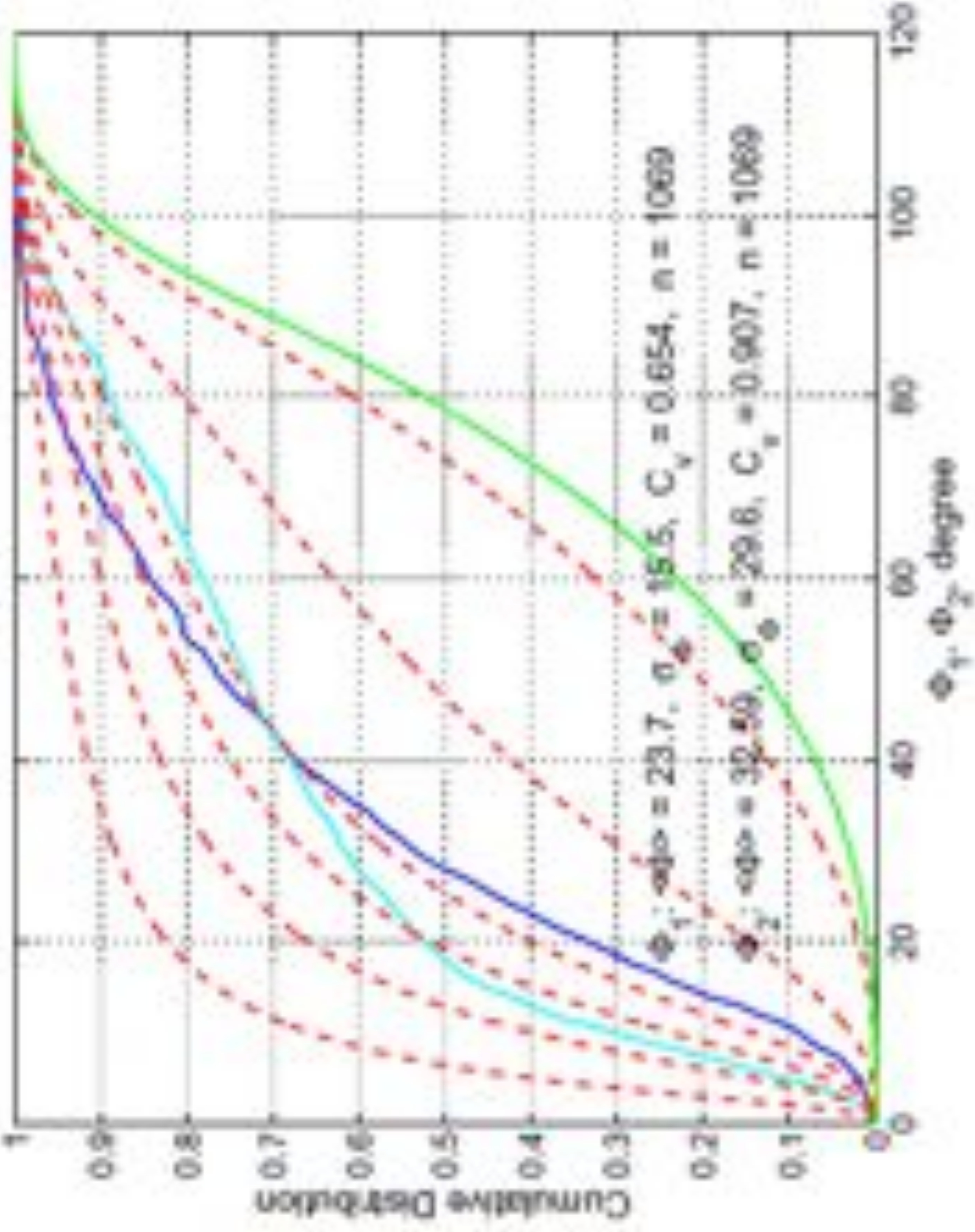

Cumulative Distribution
Φ_1: $\langle\phi\rangle$ = 23.7, σ_ϕ = 15.5, C_v = 0.654, n = 1069
Φ_2: $\langle\phi\rangle$ = 32.59, σ_ϕ = 29.6, C_v = 0.907, n = 1069
Φ_1, Φ_2, degree

Fig. 2

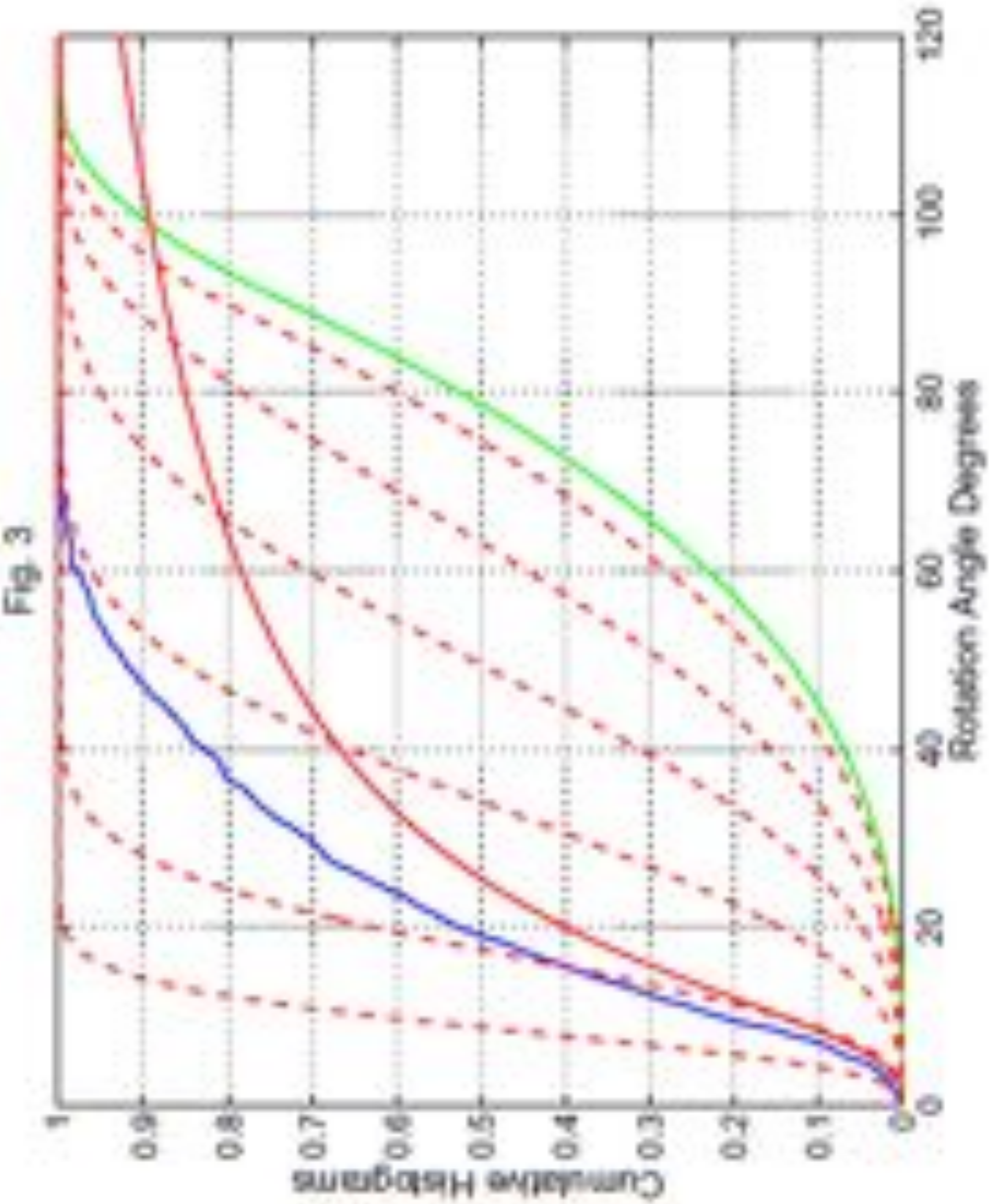
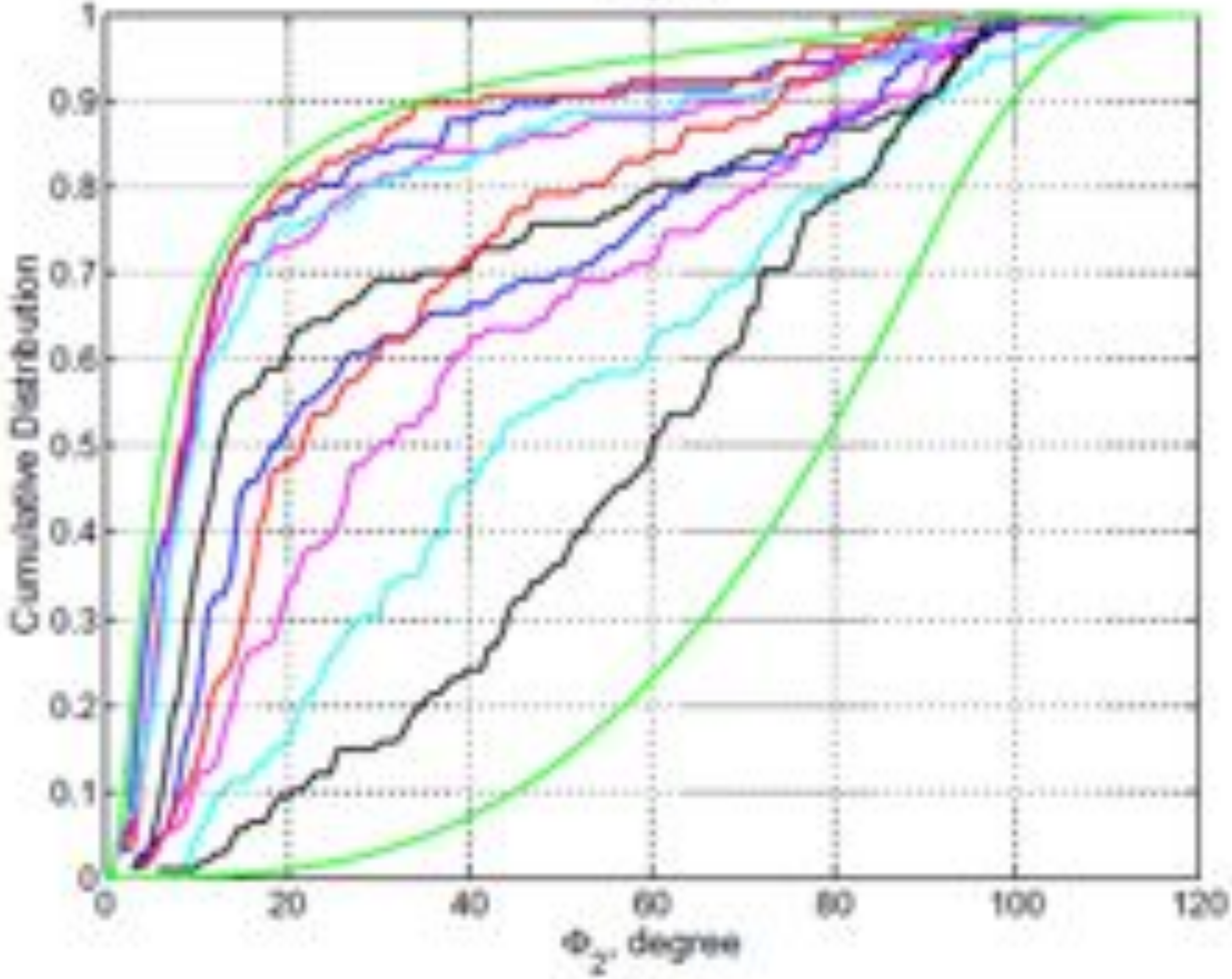


Fig. 3
Cumulative Histograms
Rotation Angle Degrees
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120

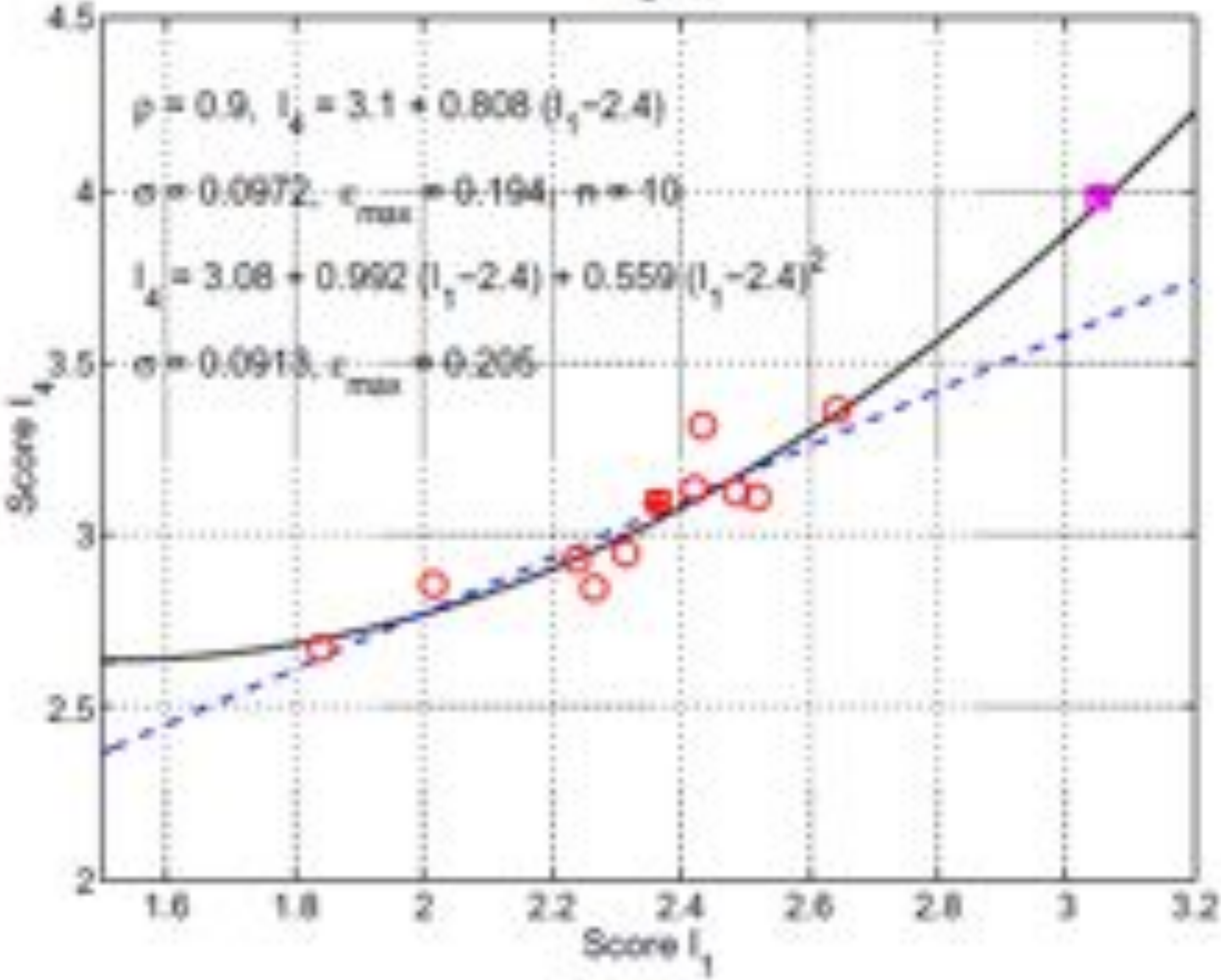
Fig. 4



I_4 bits
C 7.5

1 6.56
2 6.47
3 5.93
4 5.85
5 4.32
6 3.35
7 3.42
8 2.36
9 1.45
10 .77

Fig. 5



ρ = 0.9, I4 = 3.1 + 0.808 (I1−2.4)
σ = 0.0972, εmax = 0.194, n = 10
I4 = 3.08 + 0.992 (I1−2.4) + 0.559 (I1−2.4)2
σ = 0.0913, εmax = 0.206
4.5
4
3.5
3
2.5
2
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
Score I4
Score I1

CONCLUSIONS

1. We apply a likelihood method to measure the skill of an earthquake focal mechanism forecast. The advantage of such an approach is that the likelihood scores for the earthquake rate prediction can quantitatively be combined with the focal mechanism forecast, resulting in a general forecast optimization.
2. We compare actual forecasts or occurrences of event source properties with the null hypothesis that the mechanism's 3-D orientation is random.
3. We calculate the information (likelihood) score for two rotational distributions (Cauchy and von Mises-Fisher) which are used to approximate a source orientation pattern.
4. We calculate the likelihood score for earthquake source forecasts based on the GCMT catalog and their validation by future seismicity data. We explored the dependence of the results on data resolution, internal dependence of scores on forecasted angle, and a random variability of likelihood scores.

END

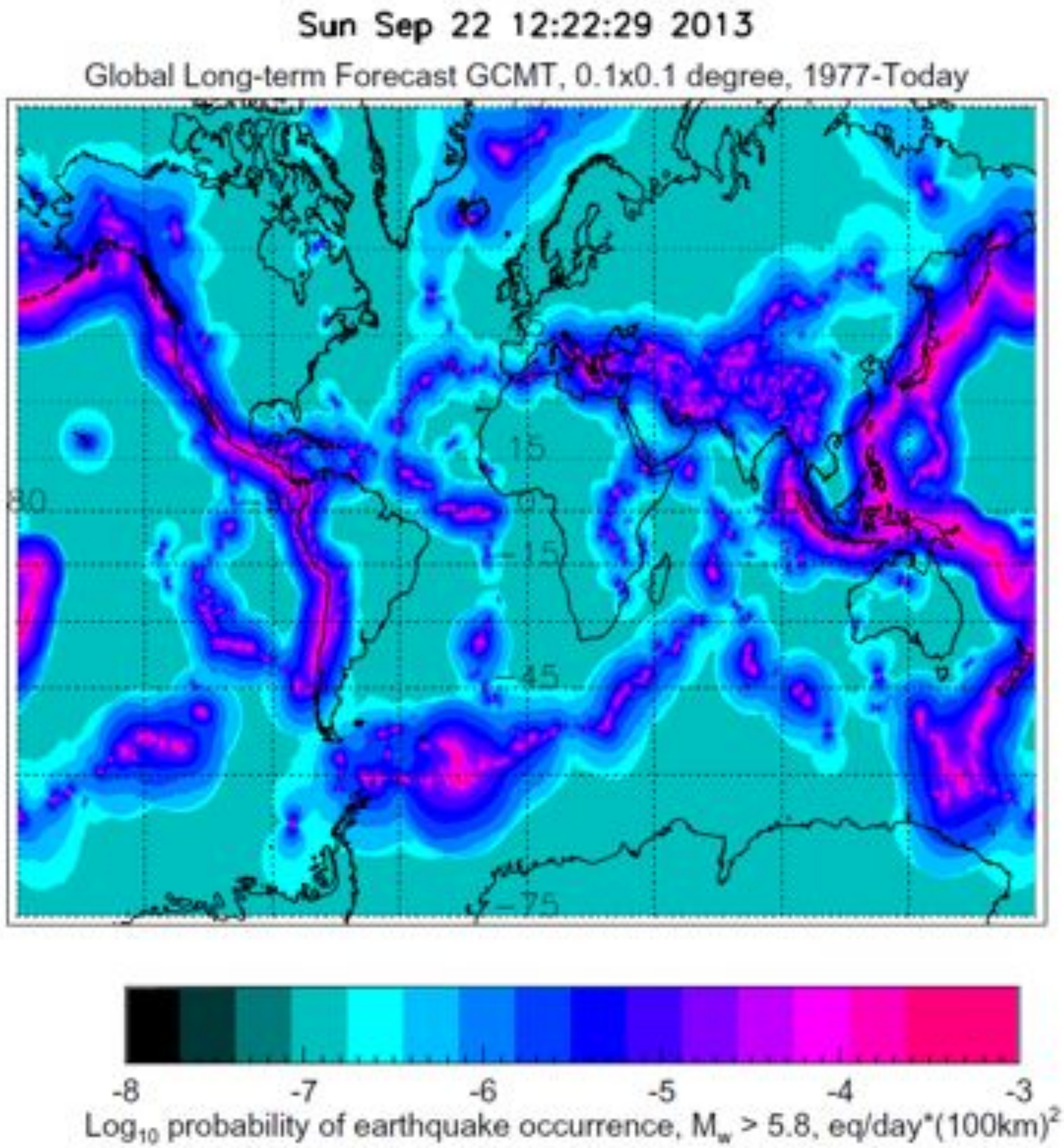
Thank you

Abstract

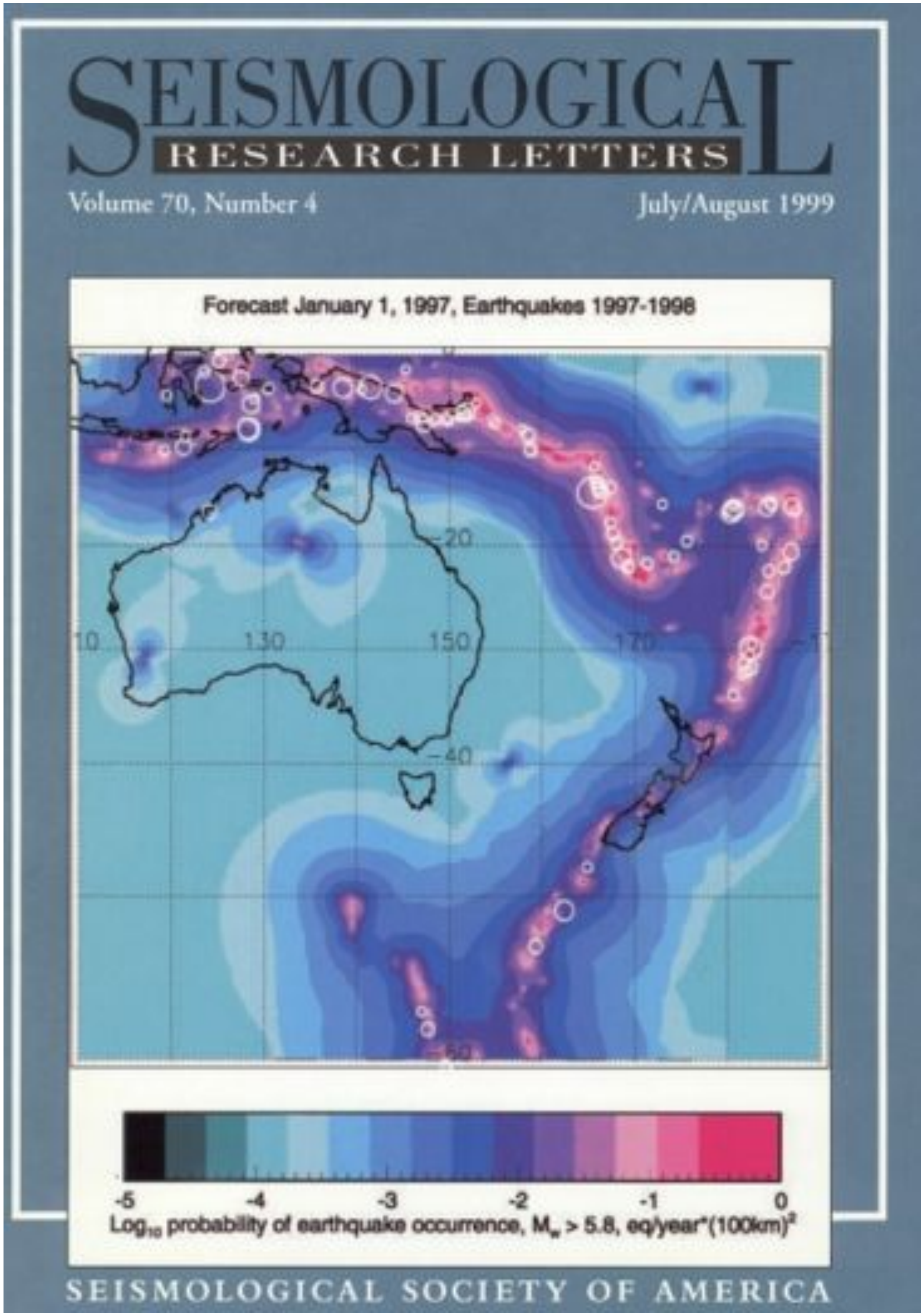
In our paper published earlier we discussed forecasts of earthquake focal mechanism and ways to test the forecast efficiency. Several verification methods were proposed, but they were based on ad-hoc, empirical assumptions, thus their performance is questionable. In this work we apply a conventional likelihood method to measure a skill of forecast. The advantage of such an approach is that earthquake rate prediction can in principle be adequately combined with focal mechanism forecast, if both are based on the likelihood scores, resulting in a general forecast optimization. To calculate the likelihood score we need to compare actual forecasts or occurrences of predicted events with the null hypothesis that the mechanism's 3-D orientation is random. For double-couple source orientation the random probability distribution function is not uniform, which complicates the calculation of the likelihood value. To better understand the resulting complexities we calculate the information (likelihood) score for two rotational distributions (Cauchy and von Mises-Fisher), which are used to approximate earthquake source orientation pattern. We then calculate the likelihood score for earthquake source forecasts and for their validation by future seismicity data.

Abstract (cont.)

Several issues need to be explored when analyzing observational results: their dependence on forecast and data resolution, internal dependence of scores on forecasted angle, and random variability of likelihood scores. In this work we propose a preliminary solution to these complex problems, as these issues need to be explored by a more extensive theoretical and statistical analysis.

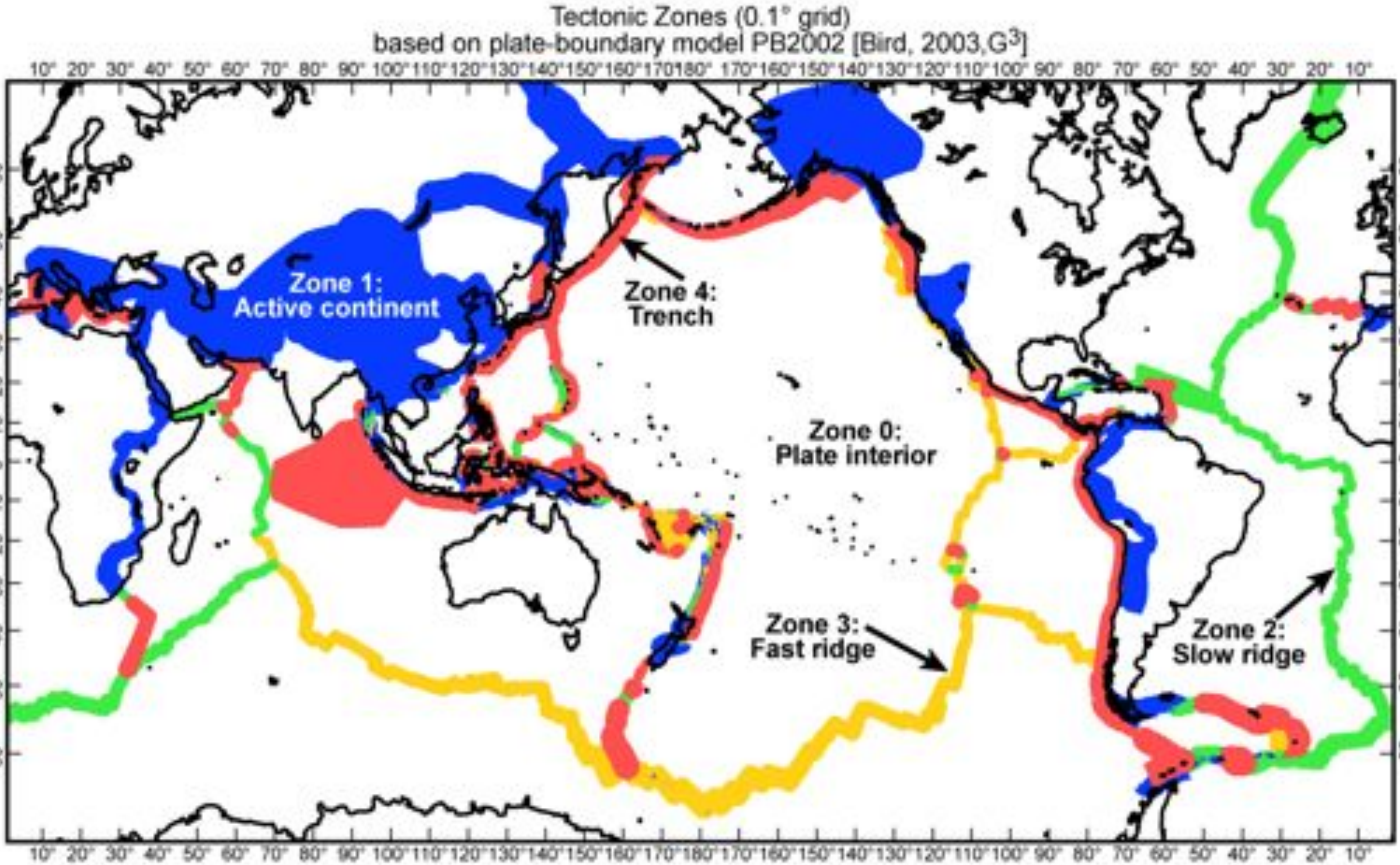


Forecast: Long-term earthquake rate based on GCMT catalog 1977-present. 0.1 x 0.1 degree, Magnitude M>=5.8

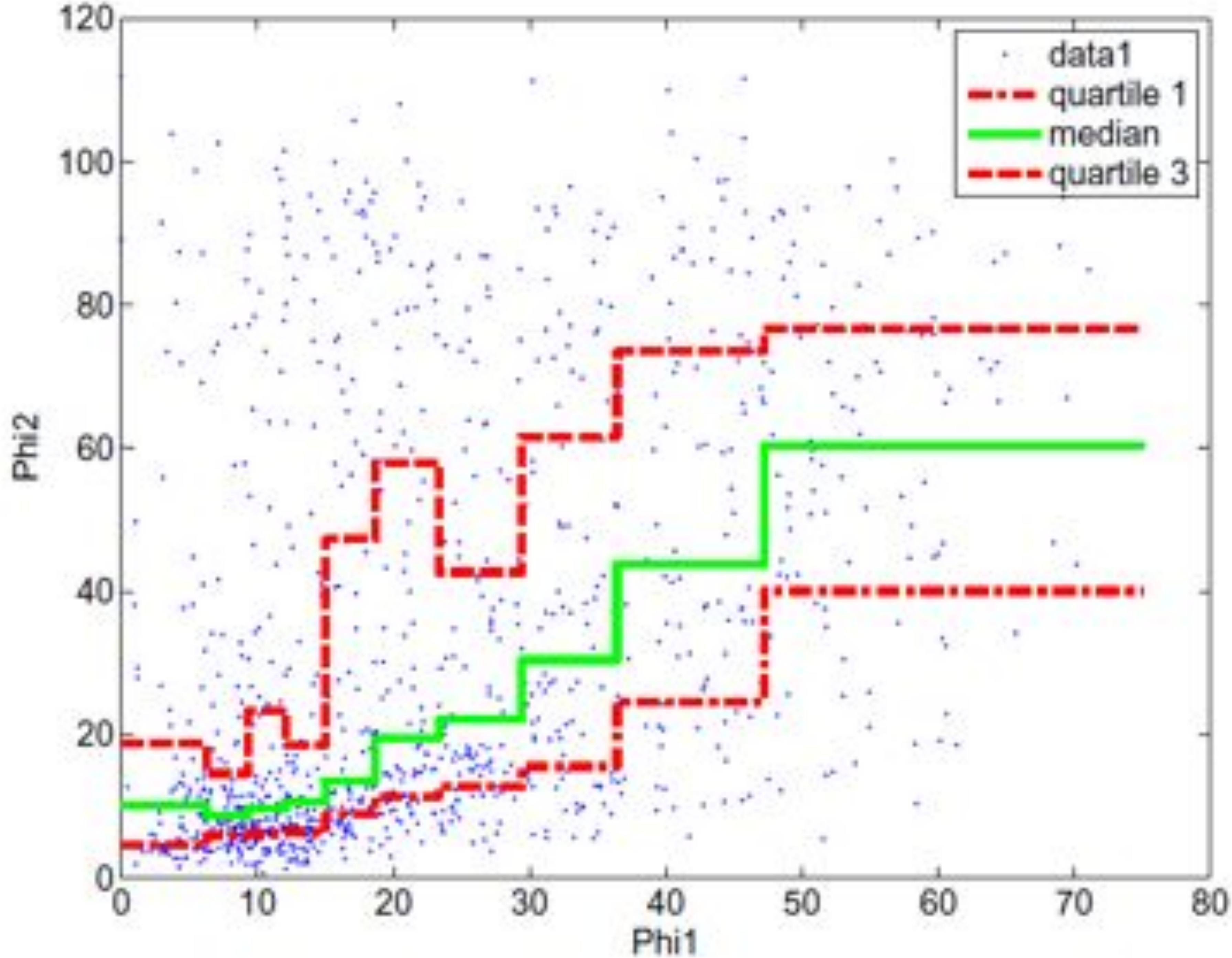


Jackson, D. D., and Y. Y. Kagan, 1999. Testable earthquake forecasts for 1999, Seism. Res. Lett., 70, 393-403.

Combined long- and short-term forecast for north- and south-western Pacific area



http://bemlar.ism.ac.jp/wiki/index.php/Bird%27s_Zones


data1
quartile 1
median
quartile 3
Phi2
Phi1
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
80