

Testing physical simulator models

David D. Jackson

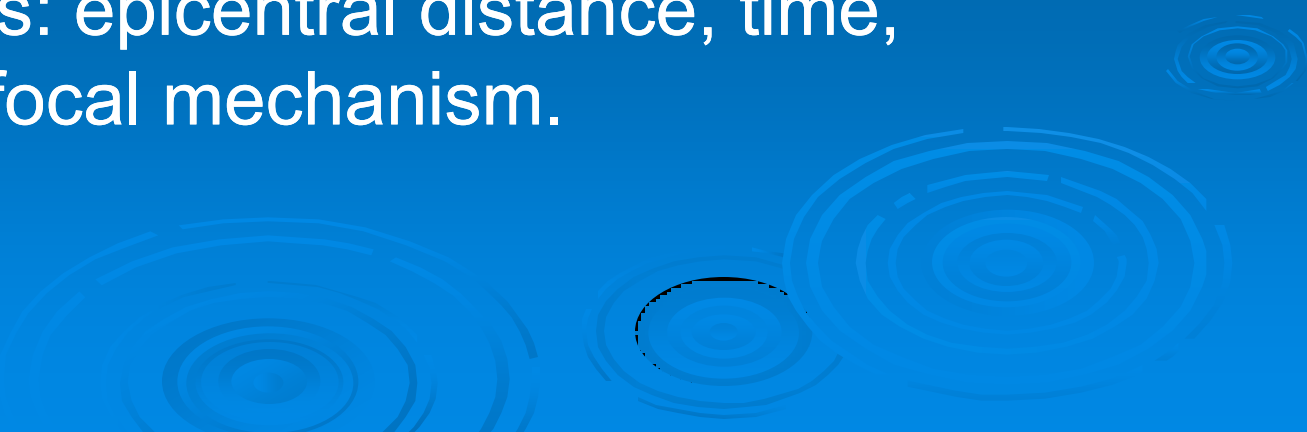


Why?

➤ Test hypotheses

- Characteristic earthquakes, seismic gaps, elastic rebound, segmentation
- Earthquakes triggered by static or dynamic Coulomb stress
- Earthquake rate proportional to deformation rate
- Earthquakes clustered in space and time
- Maximum size limited by fault dimensions
- Fault-based simulators can identify ripe faults

What to test?

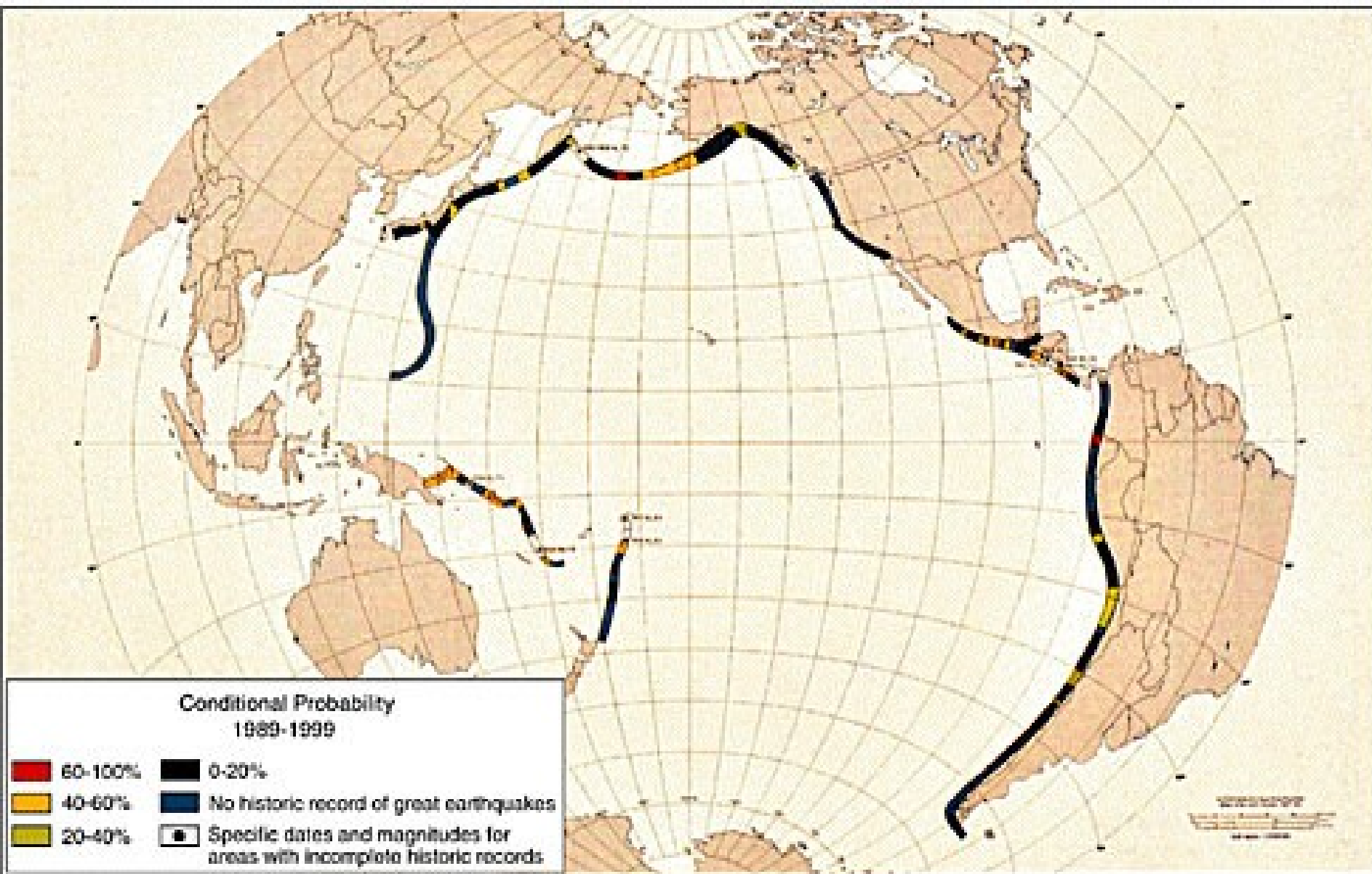
- Future Catalog: Hypocenter Probability vs location, time, magnitude, other?
 - Magnitude-Frequency distribution
 - Recurrence time of displacement at a point
 - Recurrence time of events over magnitude threshold
 - Pair statistics: epicentral distance, time, magnitude, focal mechanism.
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Requirements for testing

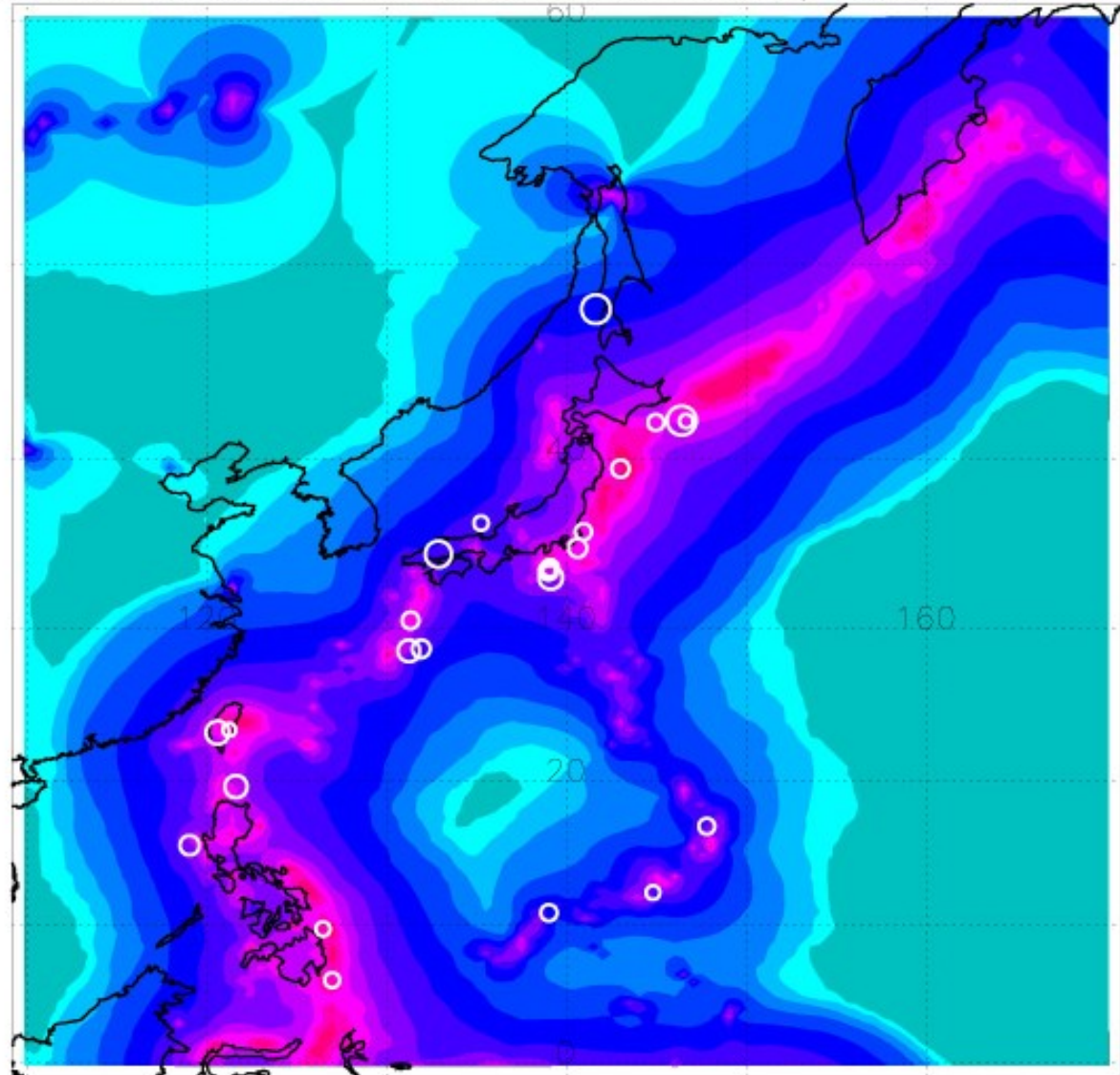
- Clear definitions:
 - Magnitude: which scale
 - Segment boundaries; uncertainty
 - Rupture; lower threshold?
 - Recurrence;
- Authoritative data:
 - Will exist for location, time, magnitude, focal mechanism
 - Will not exist (?) for rupture extent and amount
- Association rules: probability, or probability density, for every possible future event.
- Treat data limitations:
 - Incompleteness
 - Hidden aftershocks and temporal resolution of catalog

Nishenko's Circum-Pacific Seismic Gap Model, 1991

Tables included characteristic magnitudes and probability estimates.



“Smoothed Seismicity”
earthquake forecast
(probability per unit time,
per unit area, above a given
magnitude threshold).



-5 -4 -3 -2 -1 0
 Log_{10} probability of earthquake occurrence, $M_w > 5.8$, eq/year*(100km)²

Why worry about testing now?

- Thinking about testing is thinking about science:
 - What is the scope of my model?
 - What are my assumptions
- Avoid ambiguous definitions
 - “System level earthquake”
 - “Characteristic earthquake”
 - “Earthquake Potential”
 - “Aftershock”
 - “Background” earthquake



Fault assignments of California earthquakes, M6.5+, 1850+

From UCERF2

Table 10. Assignment of likely source faults to the historic M = 6.5 California earthquakes.

ID	Date	Lat	Lon	Mag	Loc Err	Fault	Source Type
1	January 1, 1852	39.5	-119.5	7.3	NA		B or C?
2	November 29, 1852	32.5	-115	6.5	100		B?
3	January 9, 1857	36.2	-120.8	7.9	25	San Andreas	A
4	March 15, 1860	39.5	-119.5	6.5	100	Olinghouse?	B or C?
5	October 8, 1865	37.2	-121.9	6.5	25		background, possibly A
6	October 21, 1868	37.7	-122.1	7	25	Hayward	A
7	March 26, 1872	36.7	-118.1	7.6	25	Owens Valley	B
8	March 26, 1872*	36.9	-118.2	6.8	100	Owens Valley	B
9	April 11, 1872*	37.5	-118.5	6.8	100		B
10	November 23, 1873	42	-124.2	6.9	100		Gorda plate background
11	May 9, 1878	40.4	-125.2	7	100		background
12	April 12, 1885	36.2	-120.8	6.5	100	San Andreas	A
13	June 3, 1887	39.2	-119.8	6.5	50		B or C?
14	February 9, 1890	33.4	-116.3	6.8	NA		B or C?
15	February 24, 1892	32.55	-115.65	7.3	50	Laguna Salada?	B
16	April 19, 1892	38.4	-122	6.6	25	Great Valley ?	B
17	May 28, 1892*	33.2	-116.2	6.5	NA		A or C?
18	September 30, 1894	40.3	-124.5	6.5	100		Gorda plate background
19	April 15, 1898	39.2	-123.8	6.7	50	San Andreas?	A or background
20	December 25, 1899	33.8	-117	6.7	25	San Jacinto?	A

21	April 18, 1906	37.7	-122.5	7.8	25	San Andreas	A
22	November 21, 1915	32	-115	6.6	NA	Cerro Prieto?	background
23	April 21, 1918	33.75	-117	6.8	25	San Jacinto?	A
24	July 15, 1918	41	-125	6.5	NA		Gorda plate background
25	January 22, 1923	40.4	-124.9	7.2	NA		Gorda plate background
26	June 29, 1925	34.3	-119.8	6.8	25		B
27	November 4, 1927	34.6	-120.9	7.1	30		background
28	December 30, 1934 ^a	32.77	-115.604	6.5	25	Cerro Prieto?	B or background
29	December 31, 1934	32.51	-115.533	7	5	Cerro Prieto?	B or background
30	May 19, 1940	32.85	-115.52	6.9	5	Imperial	B
31	April 10, 1947	34.983	-116.331	6.5	5	Manix	C
32	July 21, 1952	34.958	-118.998	7.5	5	White Wolf	B
33	December 21, 1954	40.78	-123.87	6.6	NA		background
34	February 9, 1956	31.75	-115.917	6.5	25	San Miguel	background
35	April 9, 1968	33.17	-116.087	6.6	5	San Jacinto - Borrego section	A
36	February 9, 1971	34.42	-118.37	6.6	5	Sierra Madre San Fernando	B
ID	Date	Lat	Lon	Mag	Loc Err	Fault	Source Type
37	October 15, 1979	32.61	-115.318	6.51	5	Imperial	B
38	November 8, 1980	41.08	-124.62	7.3	5		Gorda plate background
39	November 24, 1987	33.02	-115.852	6.51	1	San Jacinto - Superstition Hills section	A
40	October 18, 1989	37.04	-121.88	6.89	1	San Andreas?	background or A
41	April 25, 1992	40.33	-124.23	7.15	5	Cascadia ?	Gorda plate background
42	April 26, 1992 ^a	40.42	-124.832	6.6	5		Gorda plate background
43	June 28, 1992	34.2	-116.437	7.29	1	Johnson Valley, Homeslead Valley, Emerson, Camp Rock	B
44	January 17, 1994	34.21	-118.537	6.65	1	Northridge	B
45	October 16, 1999	34.59	-116.271	7.12	1	Lavic Lake, Bullion	B
46	December 22, 2003	35.7	-121.097	6.55	2		background

^a Probable aftershock

Comparing simulation models with paleoseismic data

What counts as a "recurrence"?

- a. rupture initiates on the named segment?
- b. rupture includes all of named segment?
- c. rupture includes any part of named segment?



Comparing simulation models with paleoseismic data

➤ What are the rules for magnitude rounding?

- Does a magnitude 6.95 event count as 6.5+, or 7.0+?
- If paleo data are rounded off, then simulated events should be treated the same.
- Important issue in GR world; 0.5 magnitude units implies factor of 3 in frequency

Sceptic's Doubts

- Real earthquakes frequently off known faults
- Earthquake clustering is major feature
 - Aftershocks an important feature
 - Depends on unknown rheology and fault geometry
- The primary source of triggering stress may be small earthquakes, not large ones.