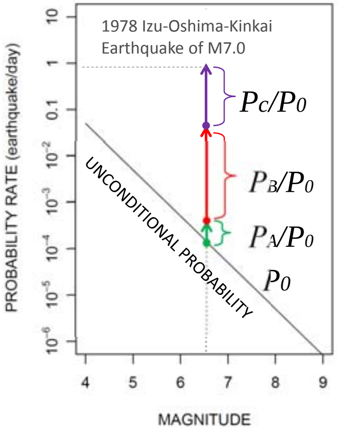
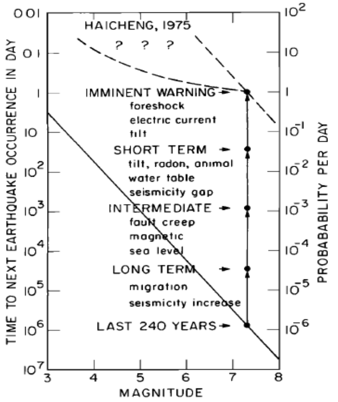
統計モデルによる地震活動異常のモニタリング
Monitoring seismicity anomalies by statistical models

統計数理研究所
尾形良彦

$$P(M \mid A,B,C,\cdots,S) = \frac{1}{1+\left(\frac{1}{P_A}-1\right)\left(\frac{1}{P_B}-1\right)\left(\frac{1}{P_C}-1\right)\cdots\left(\frac{1}{P_S}-1\right)\Big/\left(\frac{1}{P_0}-1\right)^{N-1}} \approx P_0 \cdot \boxed{\frac{P_A}{P_0}}\,\frac{P_B}{P_0}\,\frac{P_C}{P_0}\cdots\frac{P_S}{P_0}$$

$$確率利得 = \frac{\boxed{異常現象}が大地震の前兆である確率}{大地震の基礎確率}$$





宇津 (1977). 地震予知の適中率と予知率，地震 II, 30

予報の適中率（success rate, truth rate）：　ある予報が当たる確率 p

$1-p$　空振り率 (false alarm rate)

予知率（alarm rate）：　ある地震が予知（異常が認知）される確率 q

$1-q$　見逃し率 (failure rate)

異常地震活動の監視（monitoring）

地震活動活発化:

M8-MSc algorithms: Keilis-Borok & Kossobokov (1986), IASPEI Software Library, 1997
RTP（Reverse Tracing of Precursors）algorithm ; Shebalin et al., 2003, *EPS*）
先行群発地震 (precursory swarm) (関谷, 1976; Evison, 1977) →
EEPAS モデル(Every Earthquake a Precursor According to Scale; Rhoades & Evison, 2004)
前震の識別：Jones (1985, *BSSA*), Agnew&Jones(1991, *JGR*), Console他 (1993, *BSSA*),
前田 (1993, 地震), Maeda (1996, *BSSA*), Ogata et al. (1995, 1996 *GJI*)

地震活動静穏化：

空白域（第1種，Gap）
静穏化（井上, 1965 **験震時報**）
相対的静穏化 (Ogata, 1992 *JGR*)

b値：

空間 Gutenberg・Richter (1949BSSA) etc., **時間** Suyehiro etc. (1964, PAGEPH) etc.

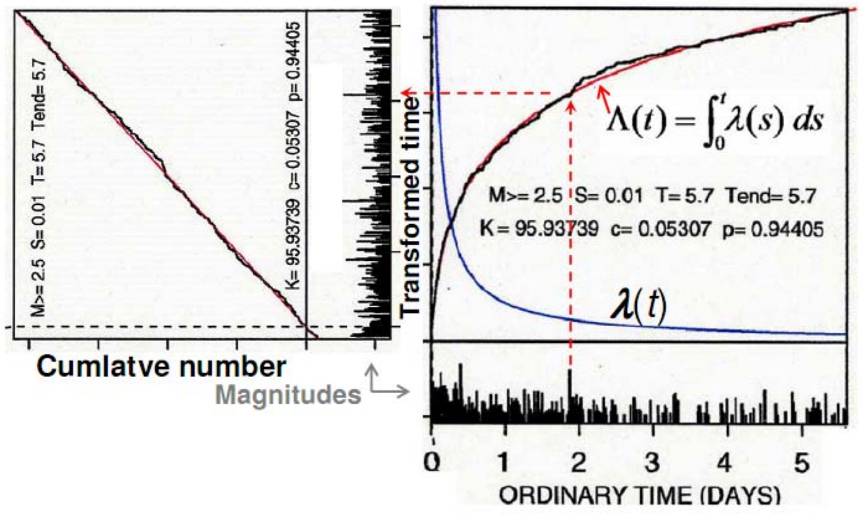
Coda Q:　Aki (1967), Jin&Aki (1986, *JGR*, etc.), Sato (1986, JGR), etc.

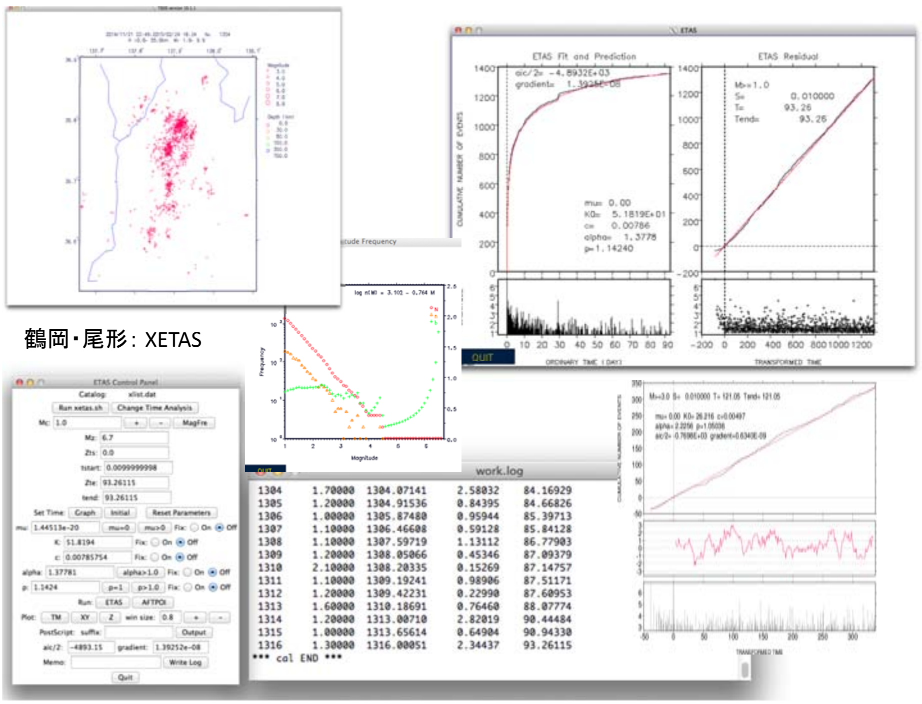
地球潮汐とのシンクロ：

Load/Unload Response Ratio (LURR): Y値, Yin et al. (1995 , 2000, 2006, *PAGEOPH*)
Y値*ETAS; Thang & Zhuang (2011, *tectonophysics*)
Shuster test: Tsuruoka et al. (1995, *GJI*); Tanaka et al. (2002 *JGR*, *GRL*, etc.)
Fourier series +/x ETAS:　Iwata & Katao (2006a, GRL; 2006b, 地震学会）

Theoretical cumulative number of the events:

$$\Lambda(t) = \int_0^t \lambda(s)\, ds$$





鶴岡・尾形: XETAS

Catalog: xlist.dat
Mc: 1.0
Mz: 6.7
Zts: 0.0
tstart: 0.0099999998
Zte: 93.26115
tend: 93.26115
mu: 1.44513e-20 Fix: ○ On ● Off
K: 51.8194 Fix: ○ On ● Off
c: 0.00785754 Fix: ○ On ● Off
alpha: 1.37781 Fix: ○ On ● Off
p: 1.1424 Fix: ○ On ● Off
win size: 0.8
PostScript: suffix:
aic/2: -4893.15 gradient: 1.39252e-08
Memo:

```
 1304      1.70000  1304.07141    2.58032    84.16929
 1305      1.20000  1304.91536    0.84395    84.66826
 1306      1.00000  1305.87480    0.95944    85.39713
 1307      1.10000  1306.46608    0.59128    85.84128
 1308      1.10000  1307.59719    1.13112    86.77903
 1309      1.20000  1308.05066    0.45346    87.09379
 1310      2.10000  1308.20335    0.15269    87.14757
 1311      1.10000  1309.19241    0.98906    87.51171
 1312      1.20000  1309.42231    0.22990    87.60953
 1313      1.60000  1310.18691    0.76460    88.07774
 1314      1.20000  1313.00710    2.82019    90.44484
 1315      1.00000  1313.65614    0.64904    90.94330
 1316      1.30000  1316.00051    2.34437    93.26115
*** cal END ***
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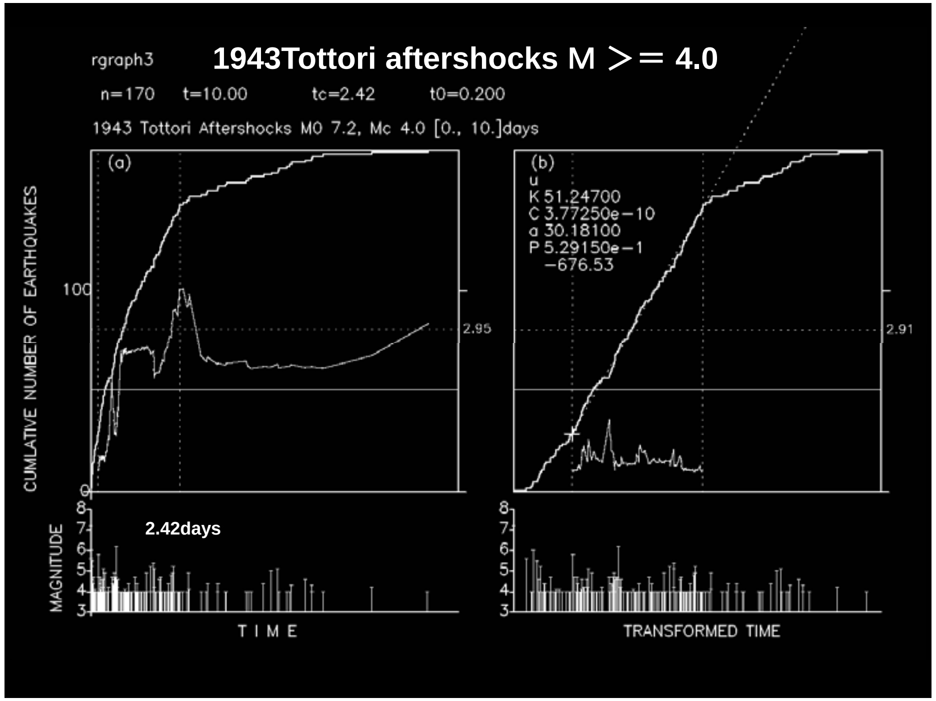
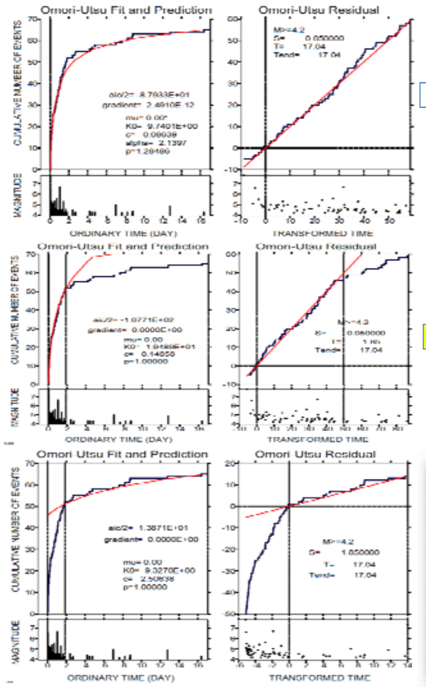
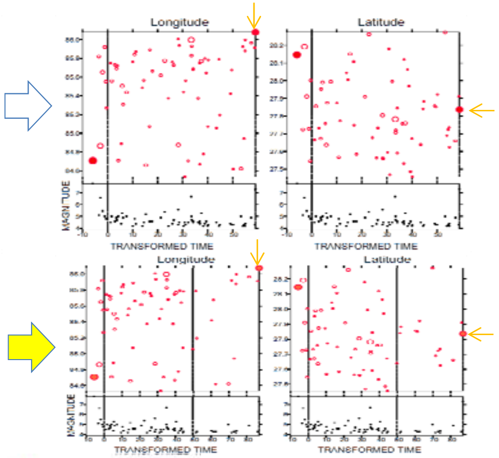


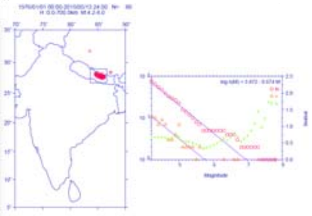
Inland earthquakes	Mag.	Threshold magnitudes
1925 Tajima	6.8	Felt 5.0
1927 North-Tango	7.3	0.0 4.5
1943 Tottori East	6.2	Felt 3.6
1943 Tottori	7.4	Felt 4.4 4.7 5.0
1945 Mikawa	6.8	Felt 0.0 4.4 4.8
1948 Fukui	7.1	Felt 0.0 3.5 4.0 4.5 4.7
1955 Tokushima S.	6.4	0.0 3.0
1961 North Mino	7.0	0.0
1963 Echizen Pen.	6.9	0.0
1968 Ehime W coast	6.6	3.5 4.0
1969 Gifu Pref. Central	6.6	0.0 3.9
1978 Shimane Pref. C.	6.1	0.0 3.3 3.7

Great Events in Nankai trough

Orange color represents aftershock sequence of the threshold magnitude with Relative Quiescence, otherwise white color.
“Felt” represents felt shocks, and “0.0” represents all the located events in the catalog







1984年 長野県西部地震 (M6.8)

Ogata (1989, Tectonophysics)

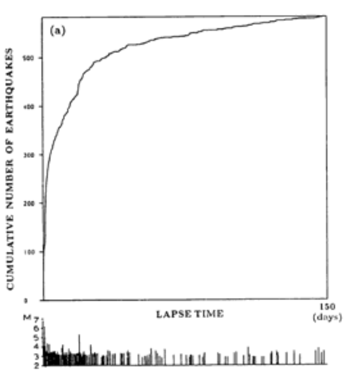
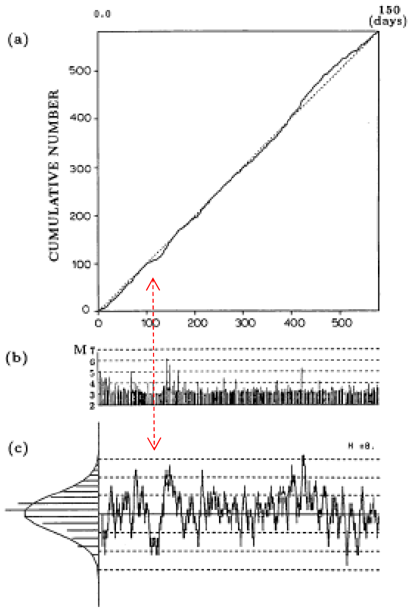


Fig. 12. Series of events and their cumulative numbers for the aftershocks of the Western Nagano Prefecture earthquake (*M* = 6.8) of 1984.

Fig. 13. Residual point process of the aftershock occurrences of the Western Nagano Prefecture earthquake: (a) cumulative numbers versus the transformed time; (b) magnitudes versus the transformed time; and (c) time series of the number of points on a moving interval with *h* = 8 (see the caption to Fig. 10 for a more detailed explanation of the graph).



1978～1984年 長野県西部の群発型地震

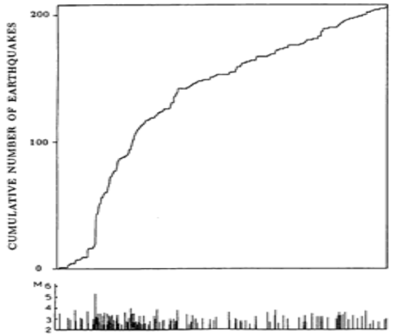


Fig. 14. Cumulative numbers and magnitudes of the swarm activity before the Nagano Prefecture earthquake versus lapse time from 1978 to the occurrence time of the main shock: events are selected with a cut-off magnitude of 2.5 from the JMA catalog.

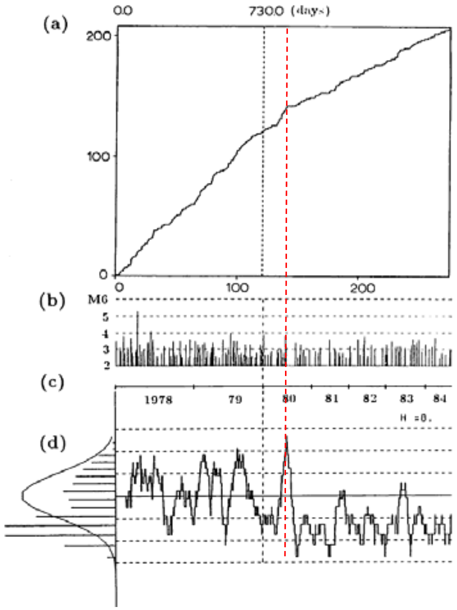


Fig. 16. (a, b) Cumulative number and magnitudes, respectively, versus occurrence time of the residual process of the swarms obtained by the epidemic-type model with the estimated parameters in the text for the data of the first time span, 1978–1979. The vertical dotted line shows the end of 1979. (c, d) Similar to (c) and (d) in Fig. 14, respectively, but extrapolated for the last time span from the beginning of 1980 to the occurrence time of the main shock.

宇津 地震活動総説

図10.9 ETASモデルによる解析（表10.11）に使った日本付近の地域分け

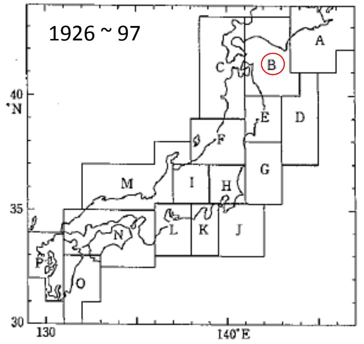


表10.12 日本の各地域(図10.9)に対するETASパラメーター等(1926～97年，JS4使用)

地域	N	M_{max}	M_z	b	η	μ	K	α	p	c	r
A	180	8. 2	5. 45	1. 006	1. 986	0. 003576	0. 006985	2. 4583	1. 1990	0. 15693	0. 522
B	677	7. 9	4. 95	0. 860	1. 860	0. 011914	0. 006652	2. 2683	1. 0689	0. 13163	0. 463
C	126	7. 7	4. 95	1. 065	2. 791	0. 001147	0. 017203	1. 7462	1. 2449	0. 04257	0. 239
D	262	8. 1	5. 45	0. 934	1. 748	0. 002336	0. 035755	1. 5709	1. 2406	0. 06241	0. 234
E	163	7. 5	4. 95	0. 758	1. 883	0. 003937	0. 010727	1. 1496	0. 9543	0. 00647	0. 635
F	160	7. 5	4. 45	0. 883	1. 886	0. 002749	0. 005351	2. 2434	1. 2109	0. 03010	0. 452
G	624	7. 5	4. 95	0. 771	1. 695	0. 011968	0. 005173	2. 3350	1. 0785	0. 03001	0. 504
H	599	6. 9	4. 45	0. 877	1. 742	0. 011383	0. 007783	1. 5908	0. 8801	0. 01795	0. 500
I	185	6. 8	4. 45	1. 014	1. 912	0. 001426	0. 038264	0. 6281	0. 9581	0. 01155	0. 203
J	181	7. 4	4. 95	0. 986	1. 765	0. 003430	0. 011408	2. 5049	1. 2194	0. 35193	0. 498
K	136	7. 3	4. 95	0. 902	1. 953	0. 002170	0. 047888	0. 4545	1. 0627	0. 01397	0. 420
L	77	7. 9	4. 95	0. 905	2. 019	0. 000427	0. 014656	1. 6515	1. 0078	0. 02113	0. 146
M	311	7. 3	4. 45	0. 797	1. 882	0. 003791	0. 007026	1. 9752	1. 0830	0. 00885	0. 321
N	429	8. 0	4. 45	0. 820	1. 975	0. 008766	0. 002354	2. 1181	0. 9617	0. 09936	0. 537
O	210	7. 5	4. 95	0. 959	2. 174	0. 003843	0. 019777	0. 9560	0. 9833	0. 00793	0. 481
P	95	6. 1	4. 45	0. 805	1. 650	0. 001819	0. 006655	1. 9279	0. 9391	0. 00188	0. 504

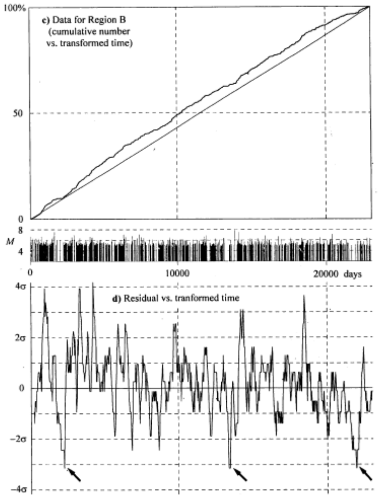
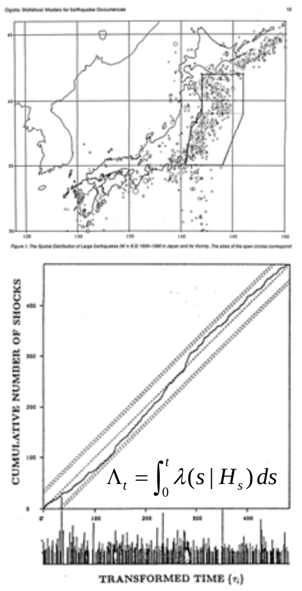


図10.10 ETASモデルによる解析結果の例（表10.11，図10.9のB地域）

5個のパラメーターの最尤推定値は図中に示す．上の図は累積地震度数図でCは理論値，Oは観測値を示す．横軸は理論曲線が直線になるように変換した時間．中央はM-T図．下の図は残差曲線．宇津ほか（1996, *JPE* 43, 1）の図に5年分のデータを追加して再解析したもの（深さは60 km以内に変更）．残差曲線の解釈については宇津ほか（1996↑）に一部が記されている．

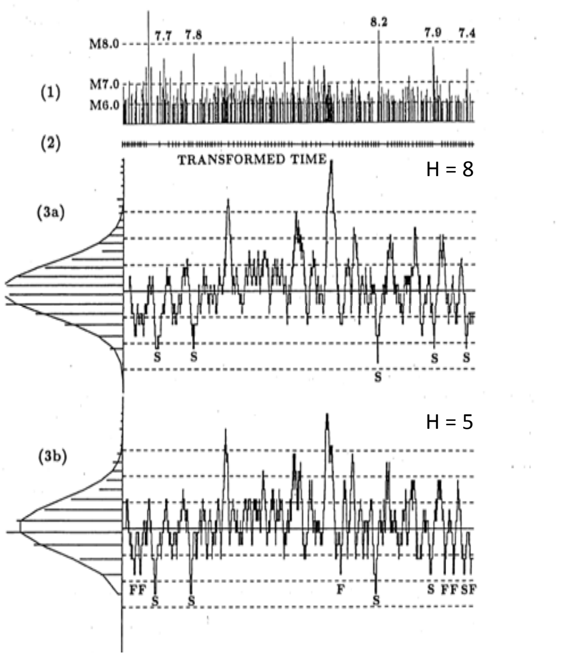
Ogata (1988, *J. Amer. Stats. Assoc.*)

宇津カタログ 1885 ~ 1980 M>=6.0

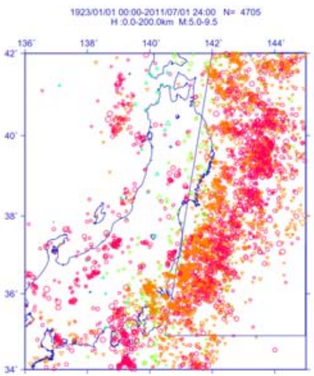


$$\Lambda_t = \int_0^t \lambda(s\,|\,H_s)\,ds$$

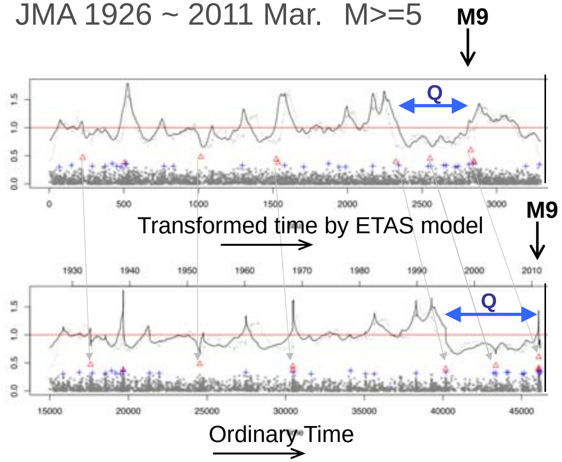
Journal of the American Statistical Association, March



熊澤 (2011)

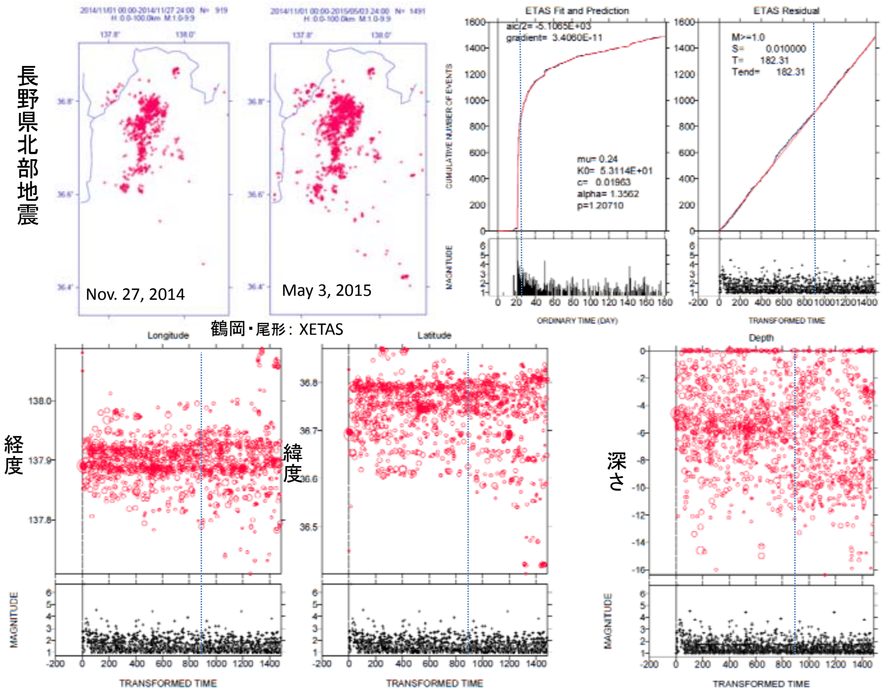


JMA 1926 ~ 2011 Mar.   M>=5



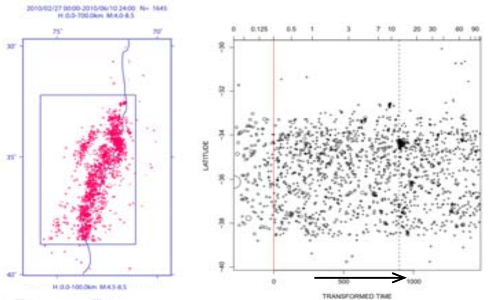
$$\frac{\text{実際の発生率}}{ETAS\,\text{の発生率}}$$

長野県北部地震

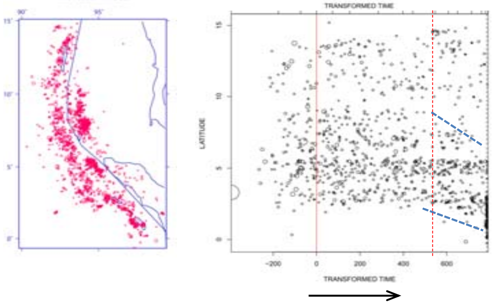


鶴岡・尾形: XETAS

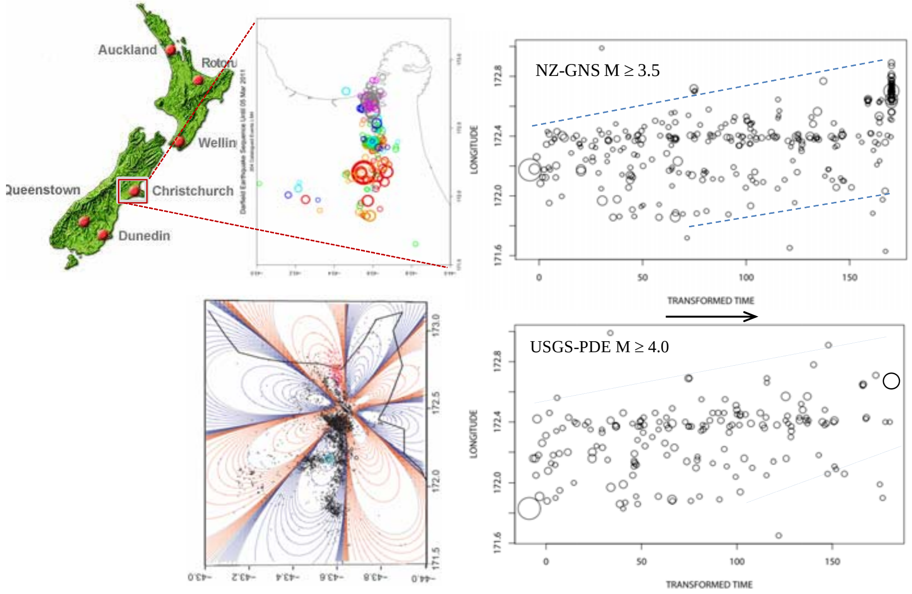
2010 Chili Earthquake
（Mw8.8）Aftershocks

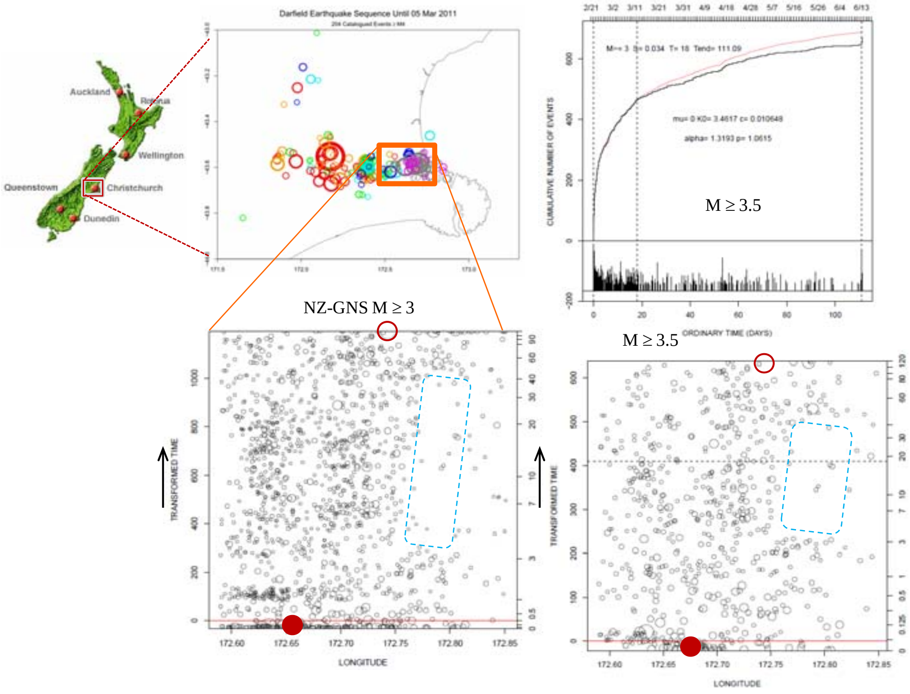


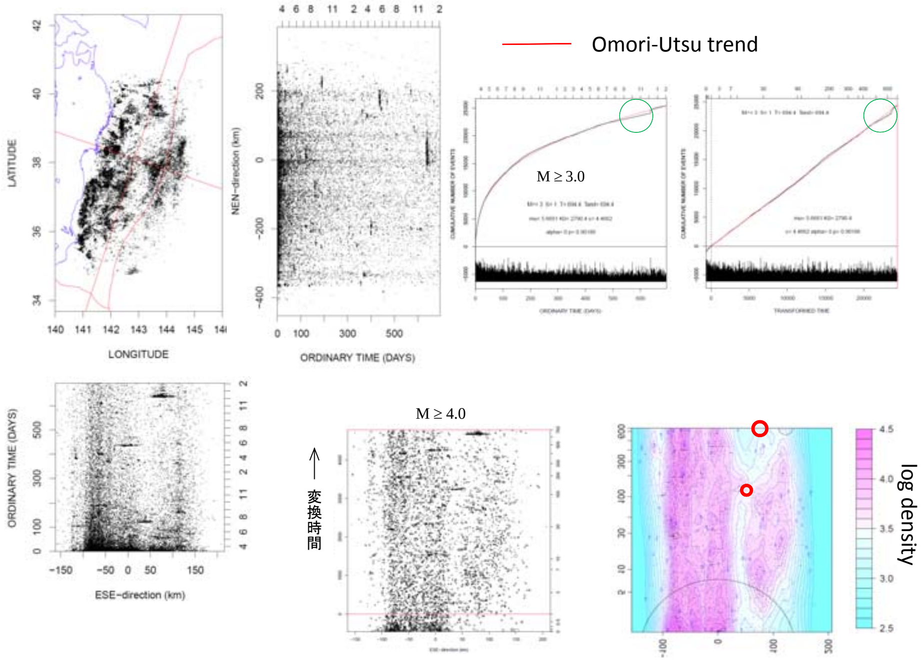
2004 Sumatra Earthquake
（Mw9.0） Aftershocks

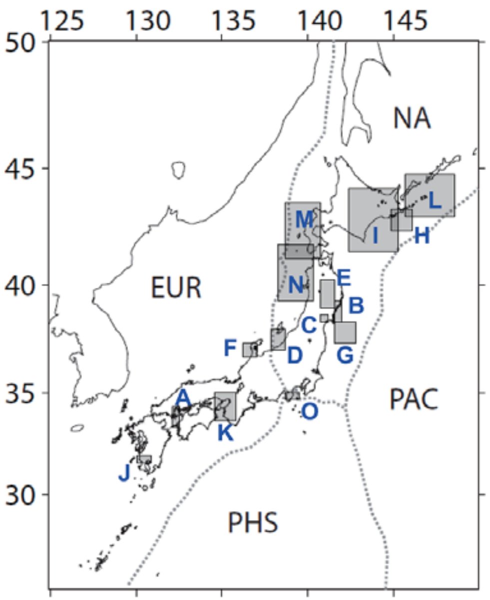


New Zealand Darfield 地震の余震活動とChristchurch地震の関係



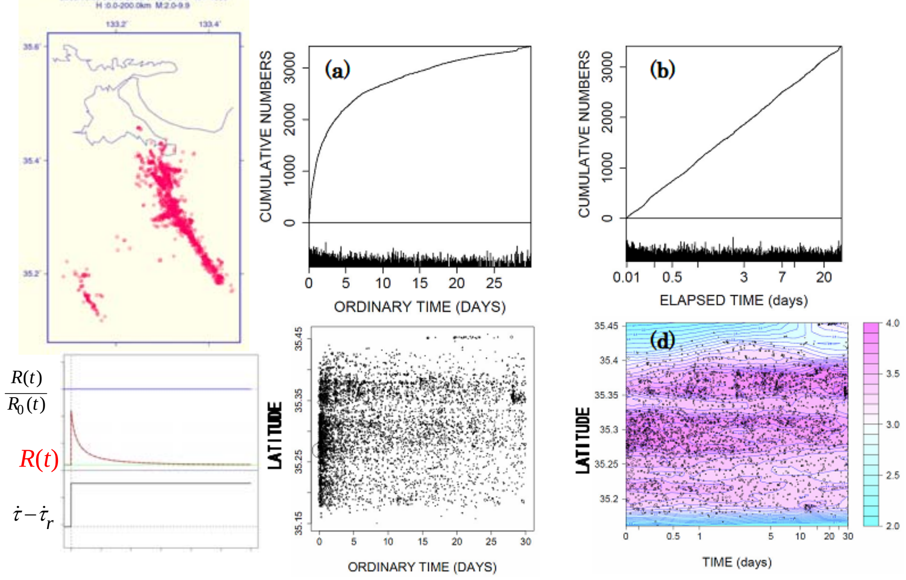




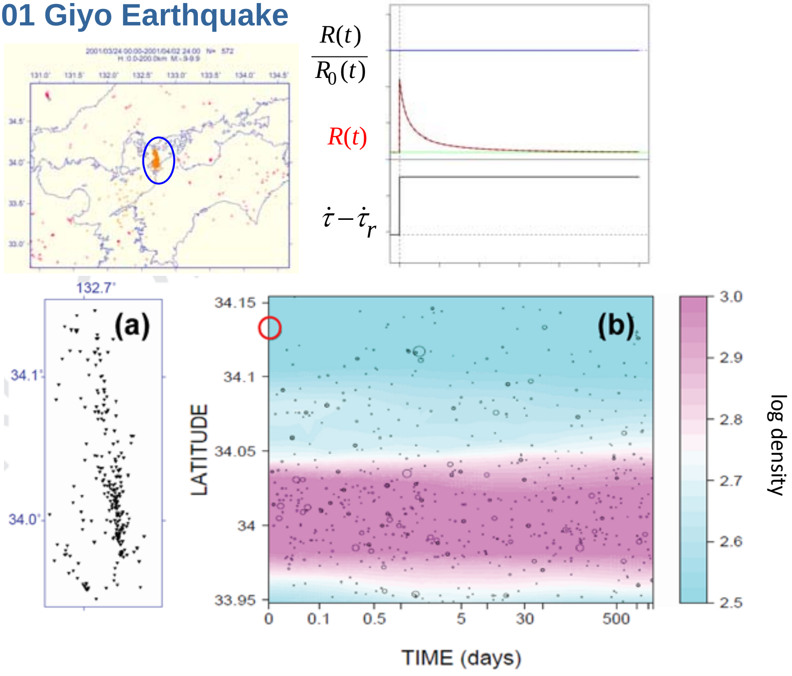


2000 WesternTottori earthquake

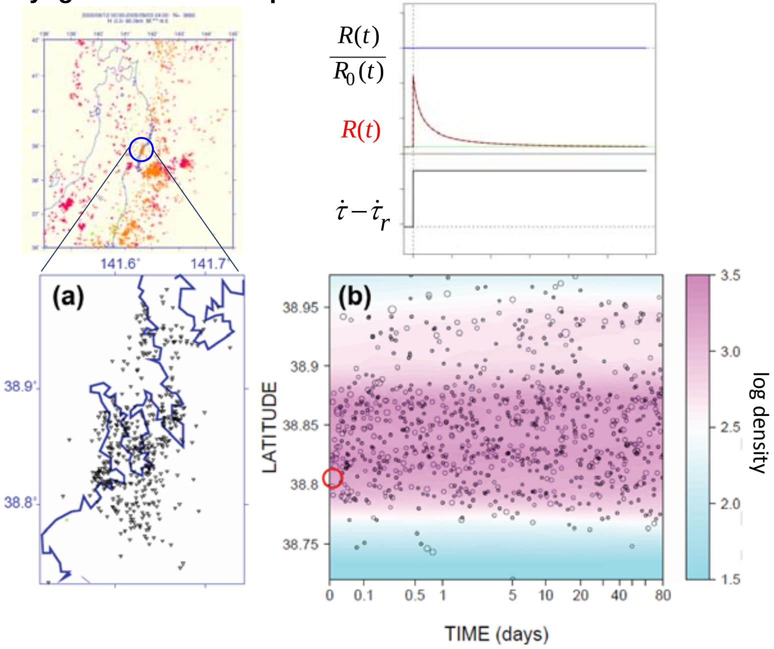
M >= 2.0



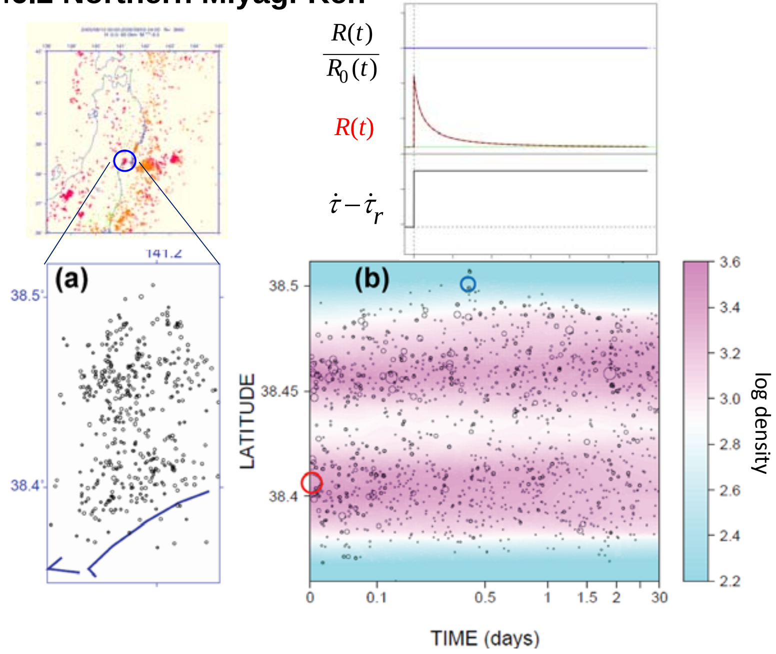
2001 Giyo Earthquake



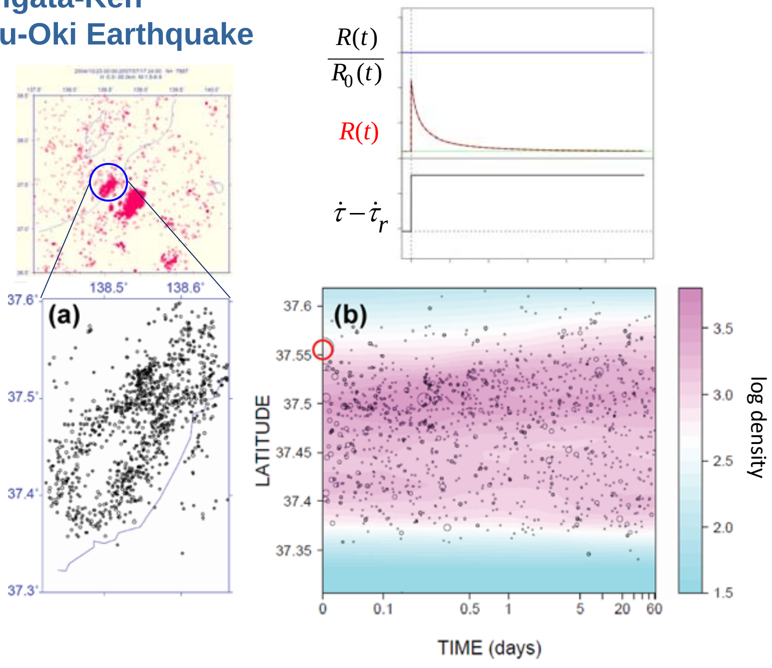
2003 M7.1 Miyagi-Ken-Oki Earthquake

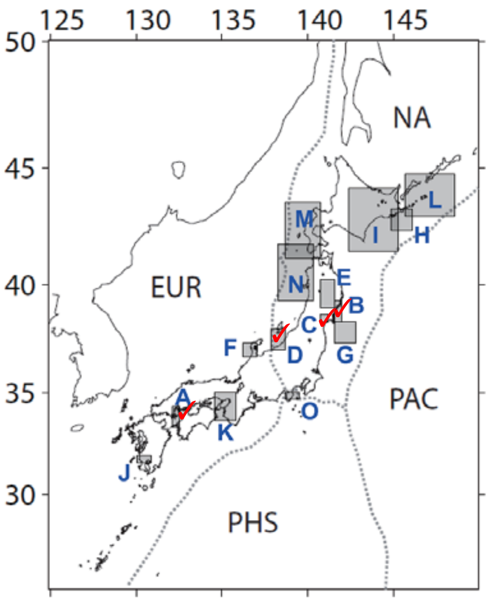


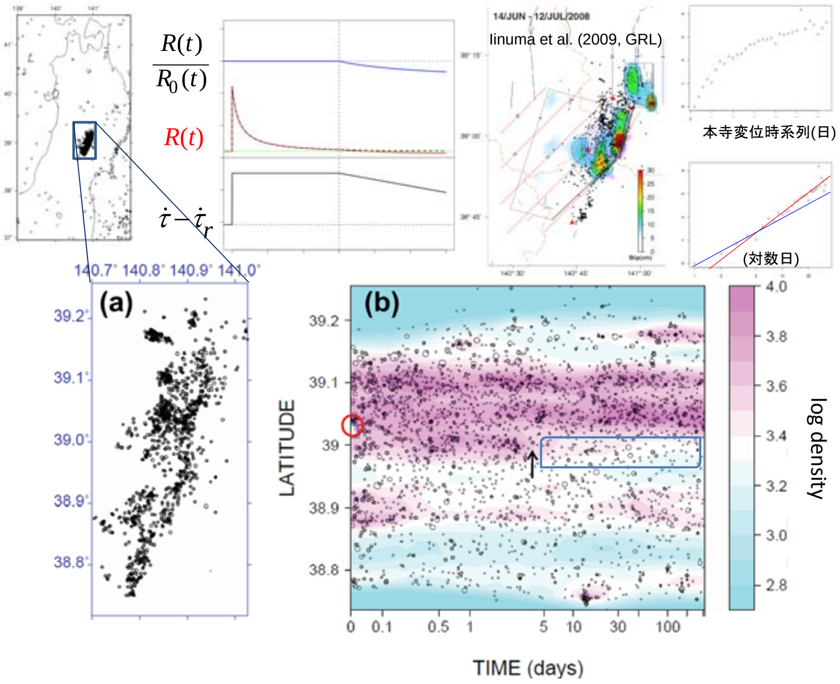
2003 M6.2 Northern Miyagi-Ken



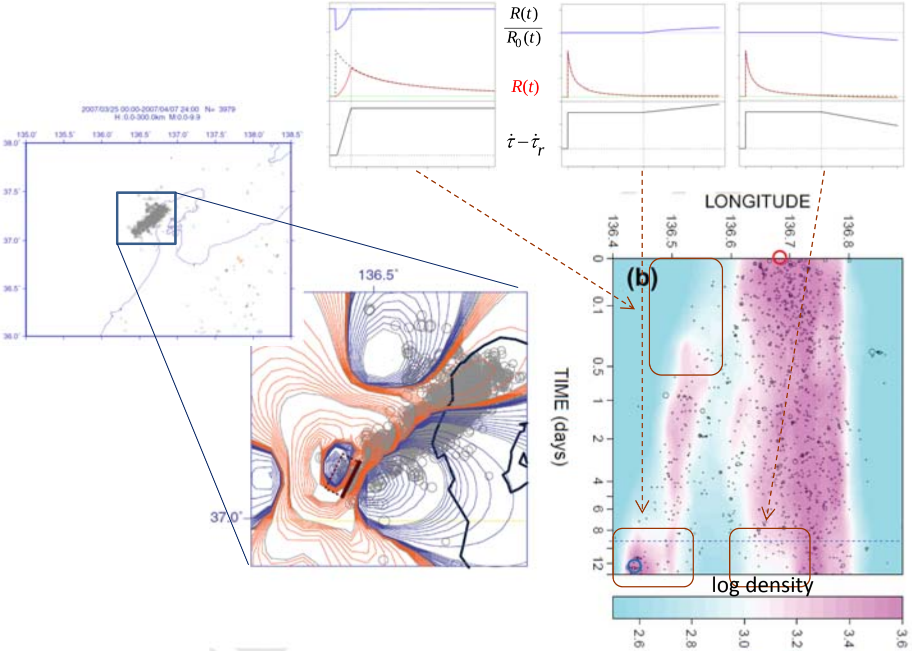
2007 Niigata-Ken Chuetsu-Oki Earthquake

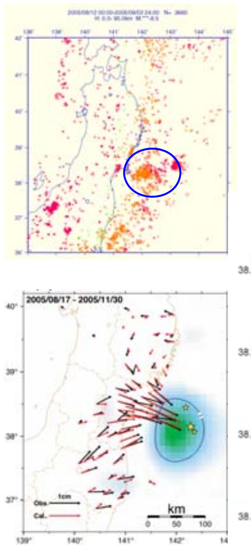




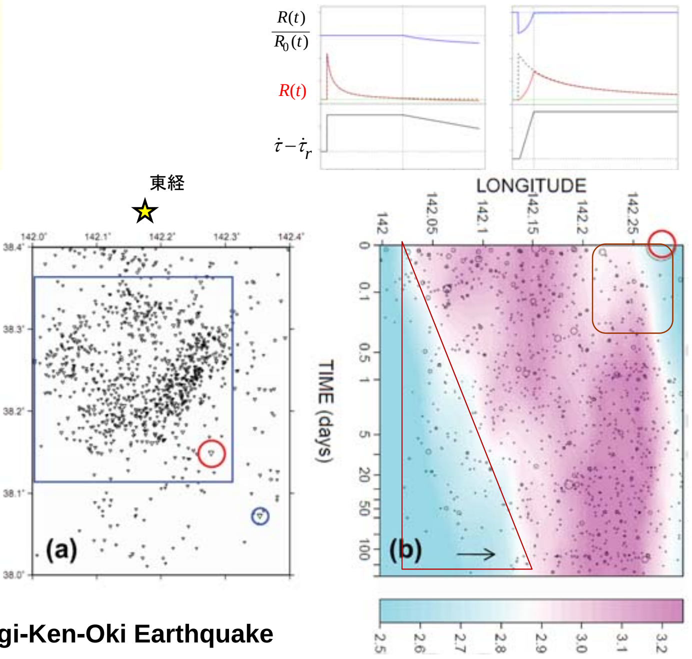


2007 Noto Peninsula Earthquake of M6.9



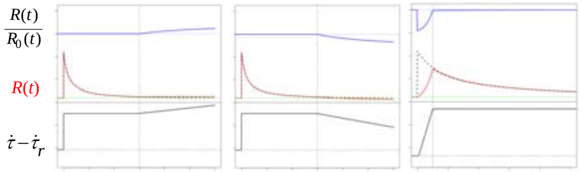


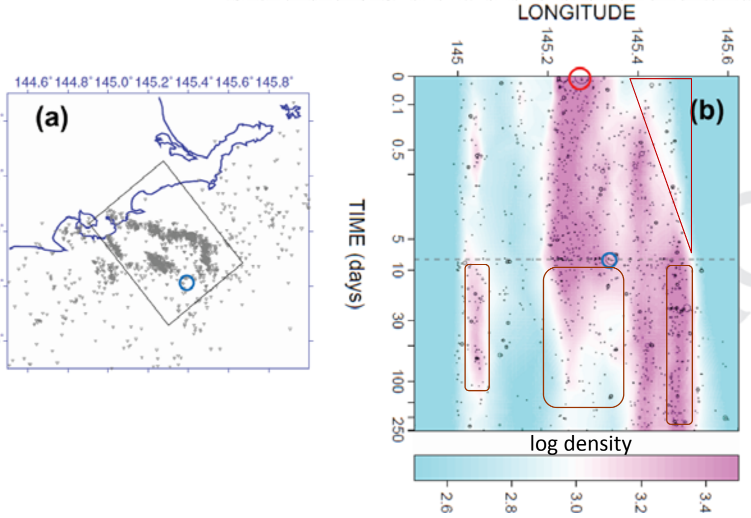
Miura et al. (2006 EPS)



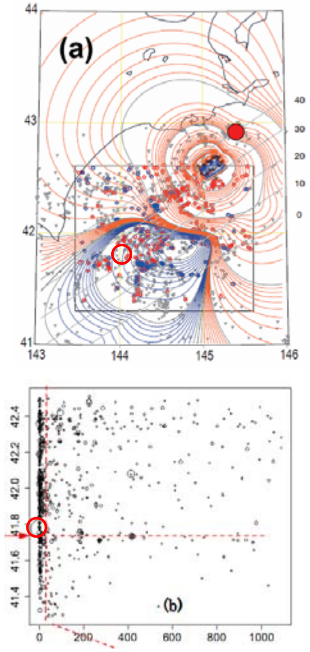
2005 M7.2 Miyagi-Ken-Oki Earthquake

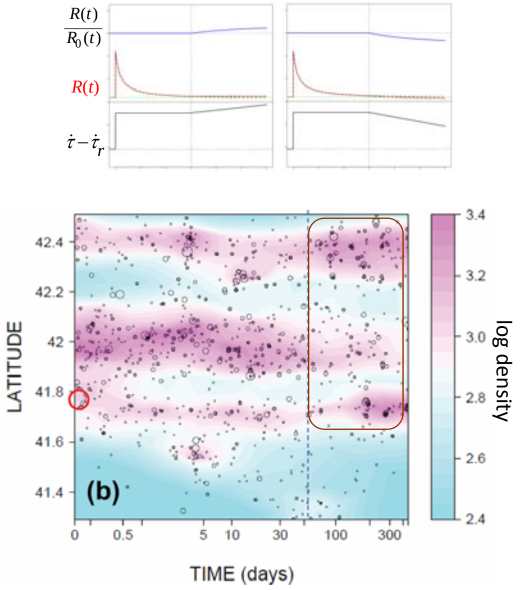
2004 M7.1 Kushiro-Oki Earthquake

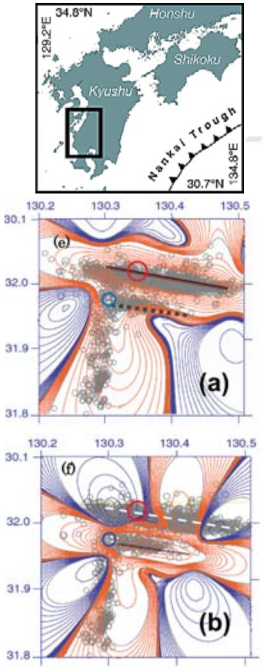




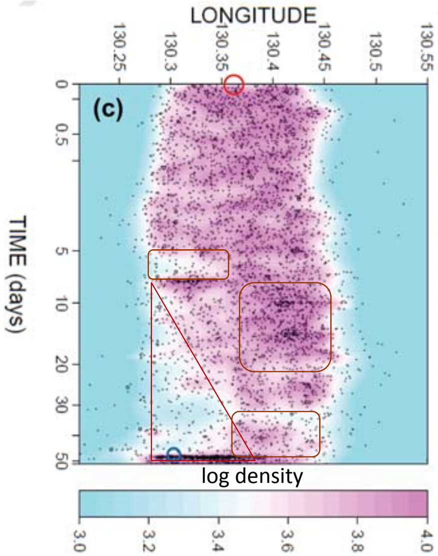
2003 M8.0 Tokachi-Oki Earthquake

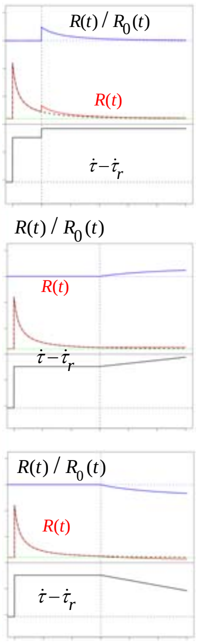




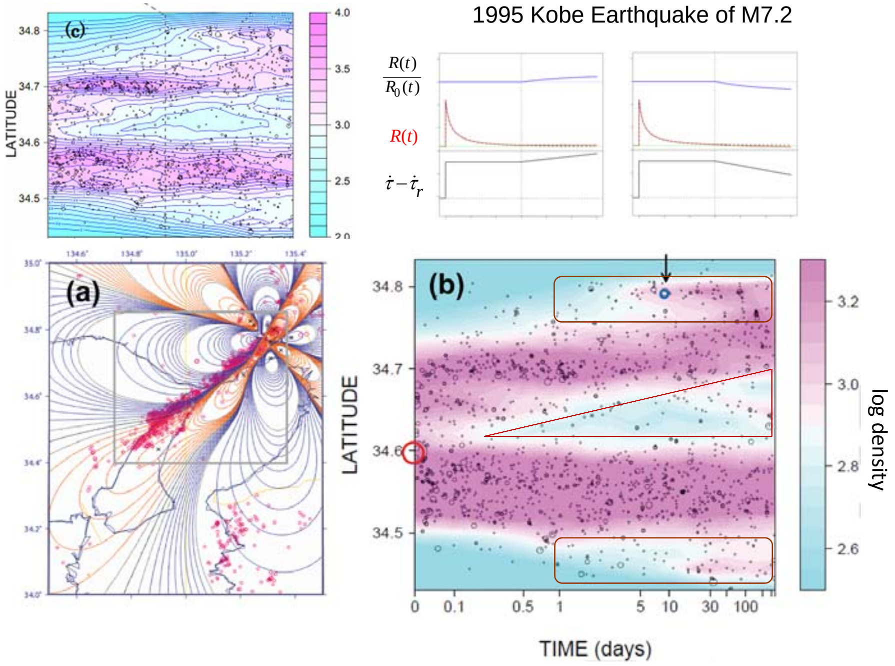


1997 Western Kagoshima-Ken Earthquake of M6.4

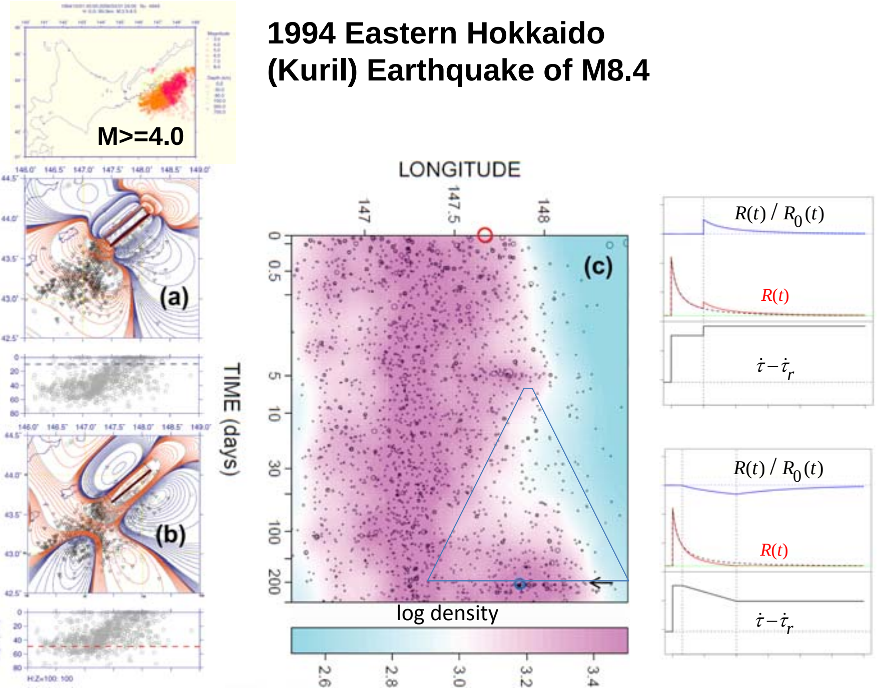




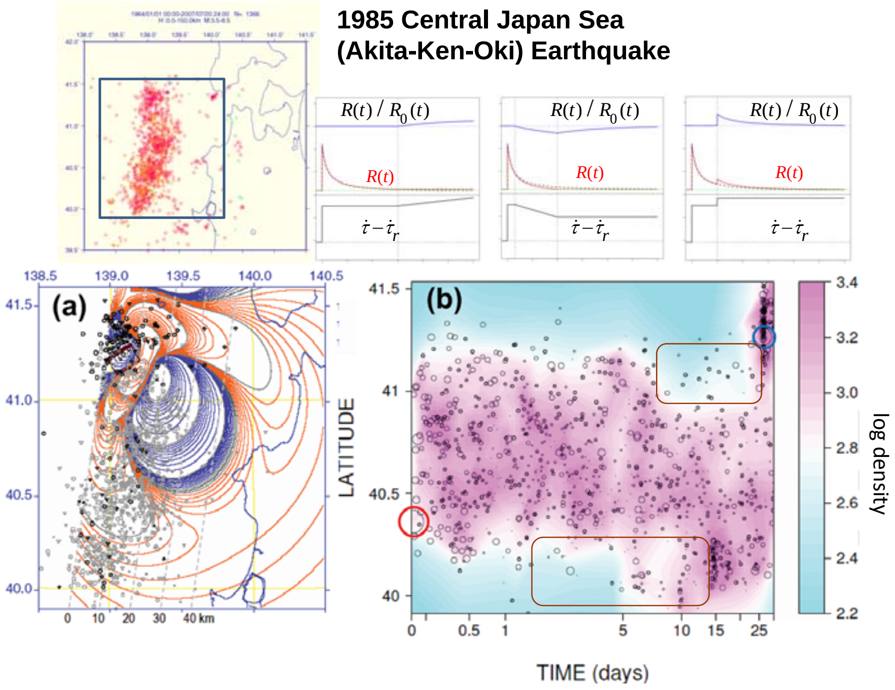
1995 Kobe Earthquake of M7.2



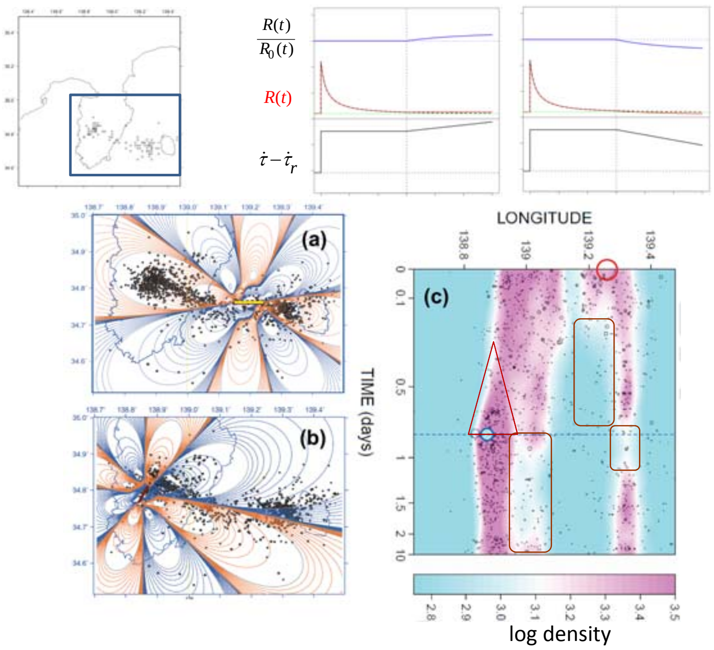
1994 Eastern Hokkaido (Kuril) Earthquake of M8.4



1985 Central Japan Sea (Akita-Ken-Oki) Earthquake



1978 Izu Oshima Kinkai Earthquake



Rate/state dependent friction law of Dietrich (1994, JGR)

$$R_n = \frac{r}{\gamma_n \dot{\tau}_r}$$

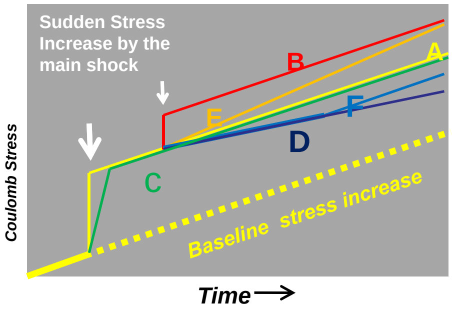
$$\gamma_n = \gamma_{n-1} \exp\left[-\frac{\Delta CFS}{A\sigma}\right]$$

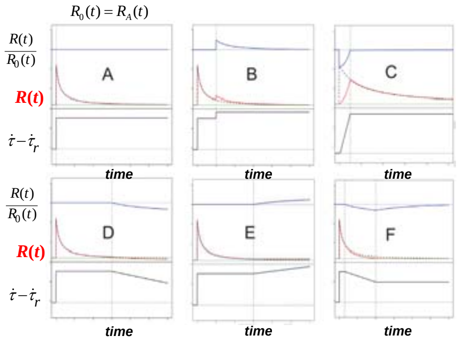
coseismic stress change

$$\gamma_{n+1} = \left[\gamma_n - \frac{1}{\dot{\tau}_n}\right] \exp\left[-\frac{\dot{\tau}_n}{A\sigma}\Delta t\right] + \frac{1}{\dot{\tau}_n}$$

Stressing rate change

$\dot{\tau}_r$	secular shear stressing rate
$\dot{\tau}$	shear stressing rate
r	background seismicity rate
γ_n	state variable (n time steps)
Δt	time increment to relocate γ
$A\sigma$	constitute parameter x normal stress

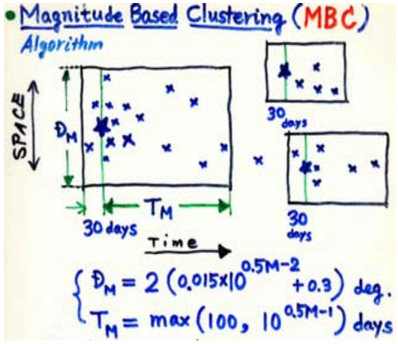




Clustering algorithms

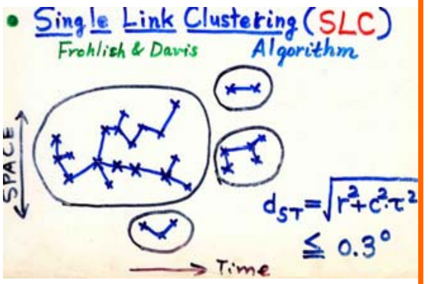
Magnitude-based

Utsu (1969,*GBHU*)



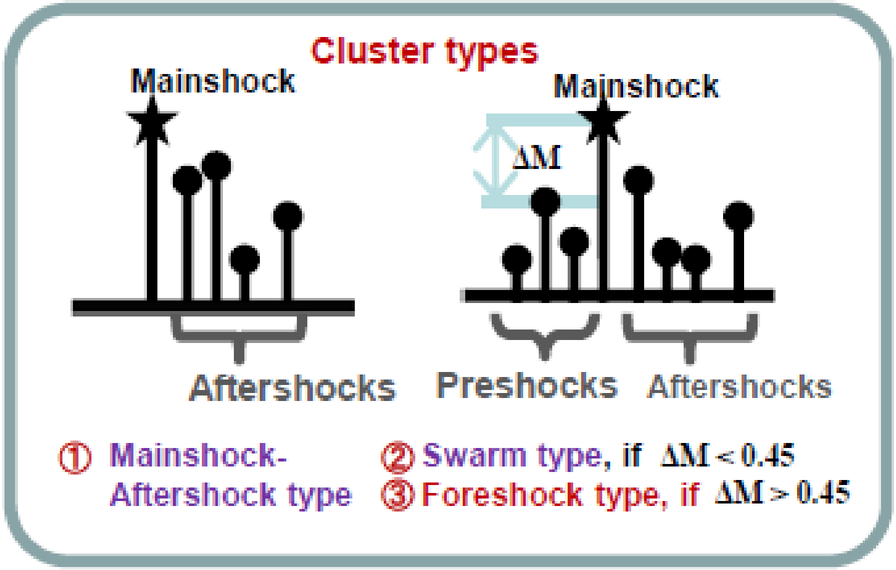
Single-Link

Frohlich & Davis



$$d_{ST} = \sqrt{\Delta^2_{space} + (c\Delta_{time})^2} \leq 0.3^\circ \text{(or 33.33km)}$$

$$c = 1^\circ / month \approx 1\ km / day$$



① Mainshock-Aftershock type

② Swarm type, if $\Delta M < 0.45$

③ Foreshock type, if $\Delta M > 0.45$

JMA 1926−1993

Multiple earthquakes in a cluster

Stacked inter-event times, distances and magnitude increments in a cluster

Time difference:

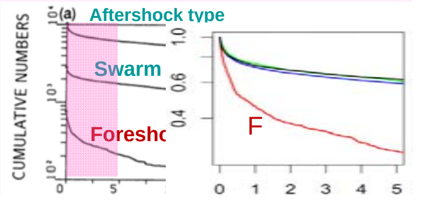
$$t^c_{i,j} = t^c_j - t^c_i$$

Epicenter separation:

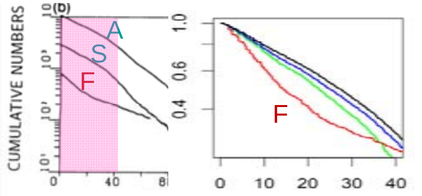
$$r^c_{i,j} = \sqrt{(x^c_i - x^c_j)^2 + (y^c_i - y^c_j)^2}$$

Magnitude difference:

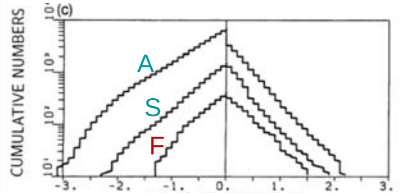
$$g^c_{i,j} = M^c_j - M^c_i$$



Time differences between earthquakes（days）



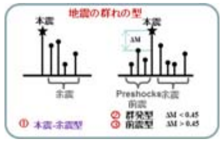
Distances between earthquakes（KM）



Magnitude difference between earthquakes

時間間隔、相互距離、マグニチュード差の単位立方体への非線形変換

Ogata, Utsu & Katsura, *GJI*, 1996



時間間隔: $t_{i,j}^c = t_j^c - t_i^c$

相互距離: $r_{i,j}^c = \sqrt{(x_i^c - x_j^c)^2 + (y_i^c - y_j^c)^2}$

マグニチュードの差: $g_{i,j}^c = M_j^c - M_i^c$

$$\left(t_{i,j}^c,\ r_{i,j}^c,\ g_{i,j}^c\right)$$

$$\Downarrow$$

$$\left(\tau_{i,j}^c,\ \rho_{i,j}^c,\ \gamma_{i,j}^c\right) \in [0,1]^3$$

① 時間間隔の変換: $t \rightarrow \tau$

$$\tau = \begin{cases} 0 & \text{for} \quad t \le 0.01 \\ \log(100t)/\log(3000) & \text{for } 0.01 < t \le 30 \\ 1 & \text{for} \quad 30 \le t \end{cases}$$

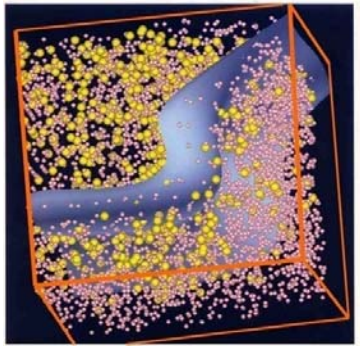
② 相互距離の変換: $r \rightarrow \rho$

$$\rho = 1 - \exp\{-\min(r, 50)/20\}$$

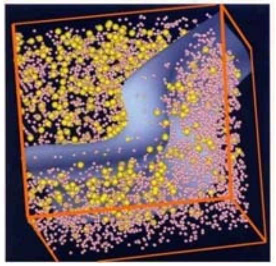
③ マグニチュード差の変換: $g \rightarrow \gamma$

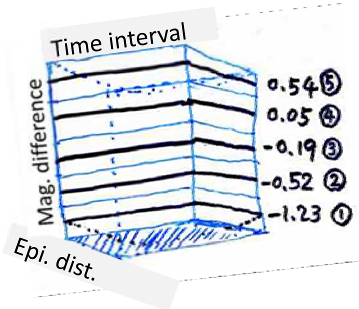
$$\gamma = \begin{cases} (2/3)\exp\{g/\sigma_1\} & \text{for } g \le 0 \\ (2/3) + (1/3)[1 - \exp\{-g/\sigma_2\}] & \text{for } g > 0 \end{cases}$$

ただし　$\sigma_1 = 6709, \sigma_2 = 0.4456$

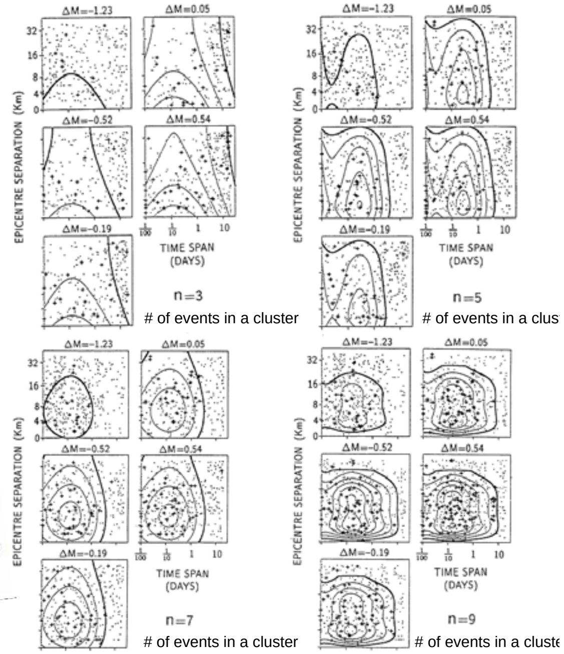


Normalized time, distance
& magnitude difference
in the unit cube





Foreshock probab. on sliced planes of mag-difference



Global Forecasting using NEIC-PDE catalog ($M \geqq 4.7$)

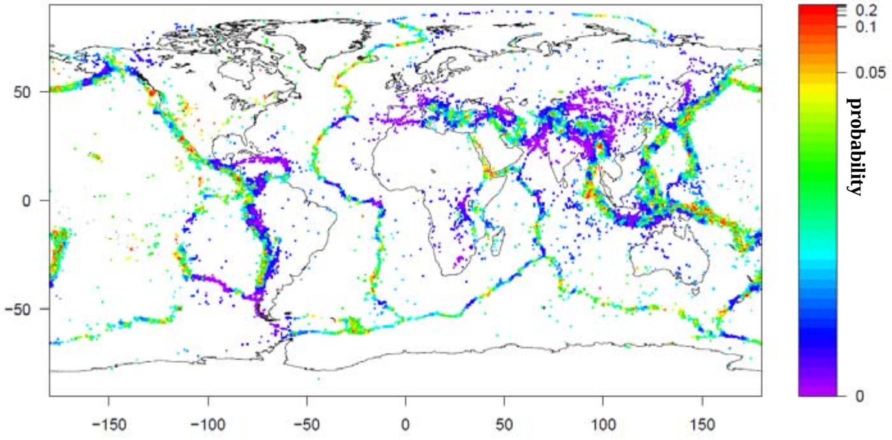
Single-link-clustering by connecting the space-time distance $d_{ST} = \sqrt{\Delta_{space}^2 + (c\Delta_{time})^2} \le 0.45^\circ$ (or 50km)

1973 ~ 1993: learning period, calibrating the forecasting parameters in Ogata et al. (1993, GJI)

1994 ~ 2013 April: forecasting period

Foreshock probability for isolated or the 1st quake estimated from the NEIC data from 1973 – 1993

Given location of a future earthquake, probability is calculated by the interpolation using the including Delaunay triangle.

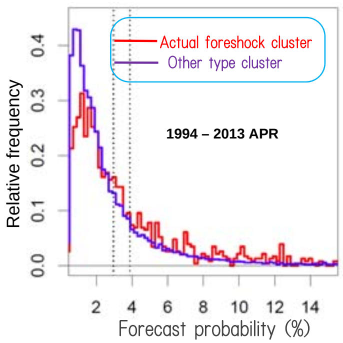


Global Forecast Result using NEIC-PDE catalog ($M \geqq 4.7$)

1973 ~ 1993: learning period, calibrating the forecasting parameters in Ogata et al. (1993, GJI)

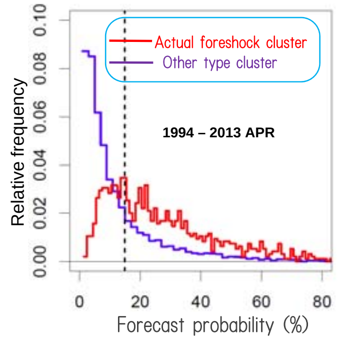
1994 ~ 2013 April: forecasting period

Isolated or 1st quake in a cluster



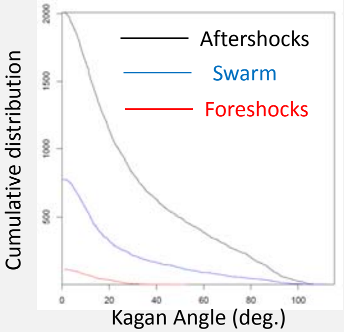
Predicted probability	2.5%	5.0%	+	all
Foreshock	18610	6154	3721	28485
Others	580	304	267	1151
	19190	6458	3988	29636
Frequency ratio	3.0	4.7	6.7	3.9

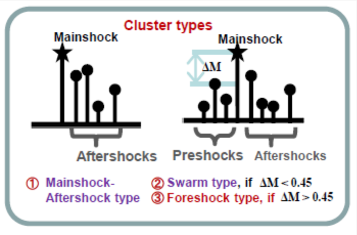
Plural earthquakes within a cluster

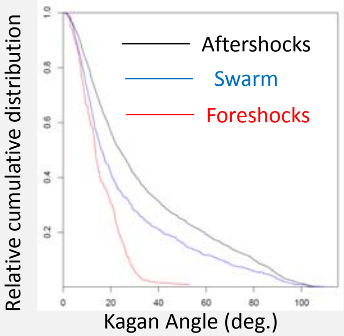


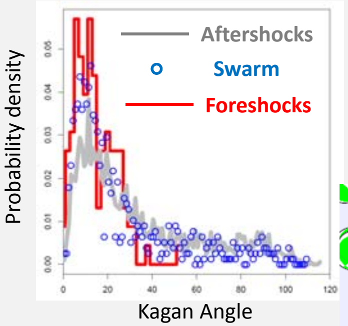
Predicted probability	5%	10%	20%	30%	+	all
Foreshock	32	115	207	156	440	950
Others	1684	1237	1246	552	707	5426
	1716	1352	453	708	1147	6376
Frequency ratio	1.9	8.5	14.2	22.0	38.4	14.9

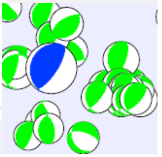
Magnitude Based Clusters (MBC)



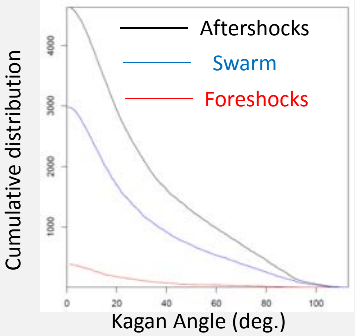


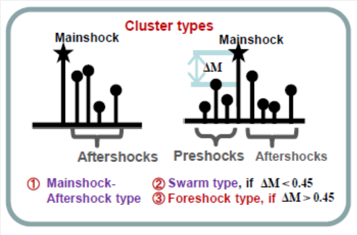


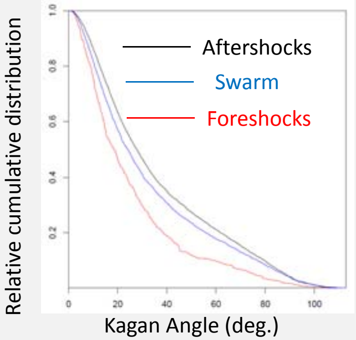


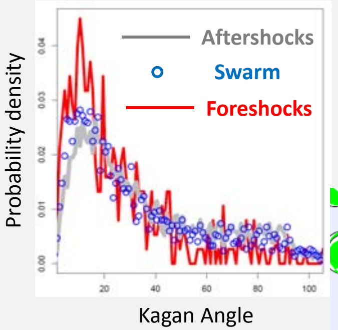


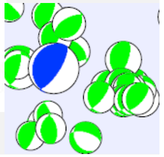
Single Link Clusters (SLC)



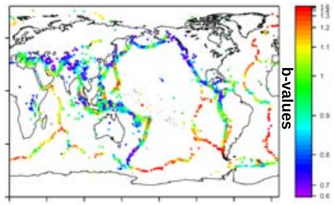


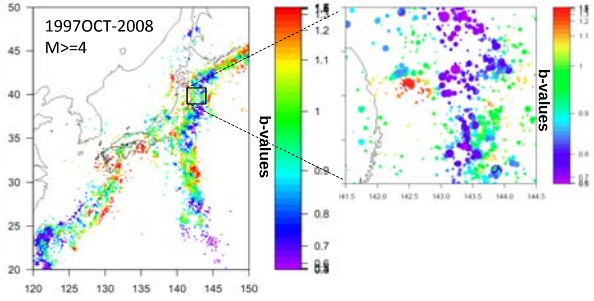




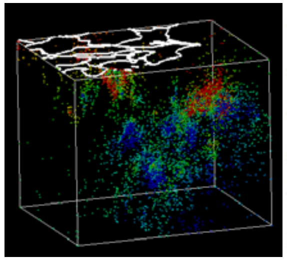


Global CMT Catalog, M>=5.4

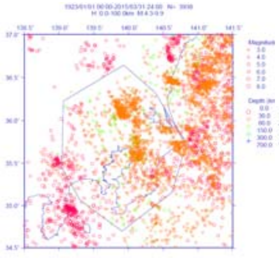


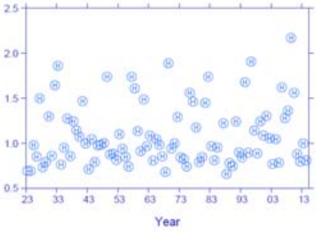


b値



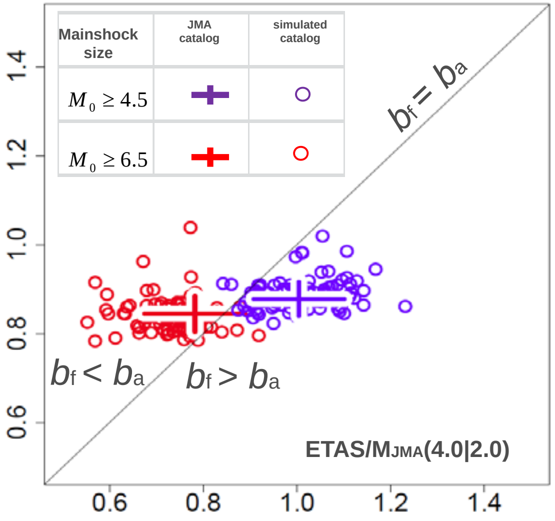
1985 ~ 2011.3.10, M>=3.0



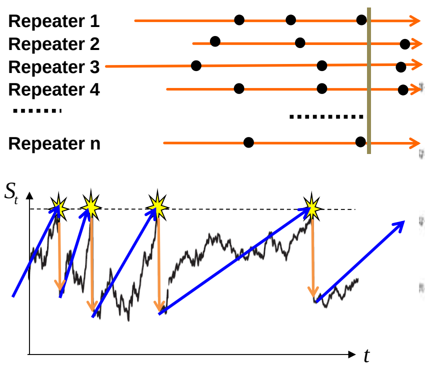


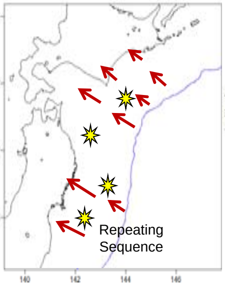
b-value of each year 1923 ~ 2014

b-values of stacked aftershocks vs foreshocks

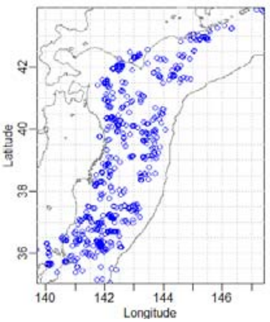


繰り返し小地震の時空間 Brownian Passage Time (BPT) 点過程モデル



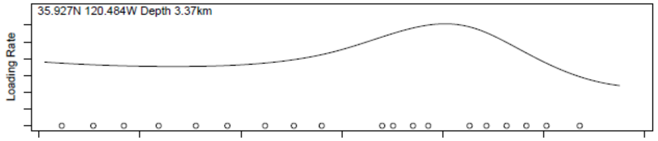


Uchida catalog 1994-2011



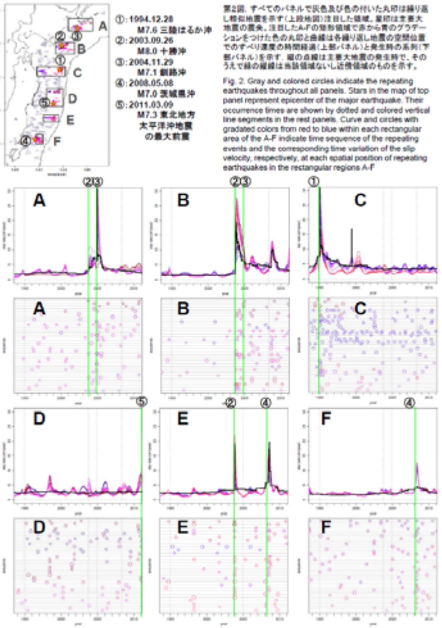
$$dS_t = \lambda \cdot v(x,y,t)dt + \sigma\sqrt{v(x,y,t)}dW_t$$

$v(x,y,t)$: Slip rate around the hypocenter



繰り返し小地震の時空間 BPT モデル

野村・内田・尾形 (2014, 連絡会報)

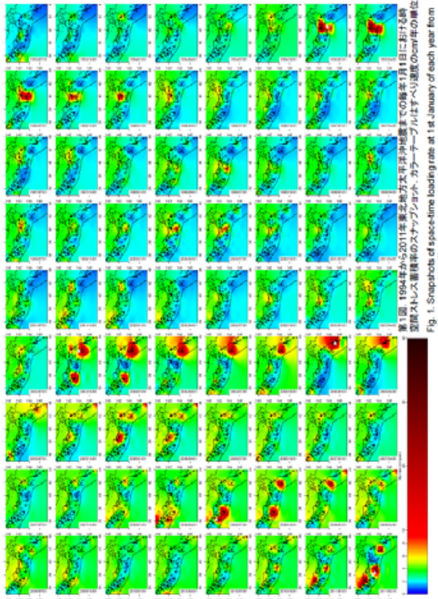


①: 1994.12.28 M7.6 三陸はるか沖
②: 2003.09.26 M8.0 十勝沖
③: 2004.11.29 M7.1 釧路沖
④: 2008.05.08 M7.0 茨城県沖
⑤: 2011.03.09 M7.3 東北地方太平洋沖地震の最大前震

第2図. すべてのパネルで灰色及び色の付いた丸印は繰り返し相似地震を示す(上段地図)注目した領域。星印は主要大地震の震央。注目したA-Fの矩形領域で赤から青のグラデーションをつけた色の丸印と曲線は各繰り返し地震の空間位置でのすべり速度の時間経過(上部パネル)と発生時の系列(下部パネル)を示す。縦の点線は主要大地震の発生時で、そのうえで緑の縦線は当該領域ないし近傍領域のものを示す。

Fig. 2. Gray and colored circles indicate the repeating earthquakes throughout all panels. Stars in the map of top panel represent epicenter of the major earthquake. Their occurrence times are shown by dotted and colored vertical line segments in the rest panels. Curve and circles with gradated colors from red to blue within each rectangular area of the A-F indicate time sequence of the repeating events and the corresponding time variation of the slip velocity, respectively, at each spatial position of repeating earthquakes in the rectangular regions A-F

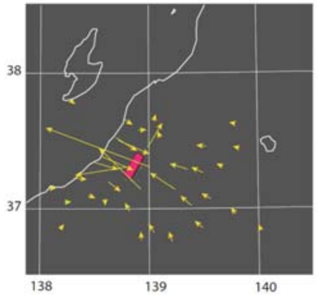
1994.1.1 →

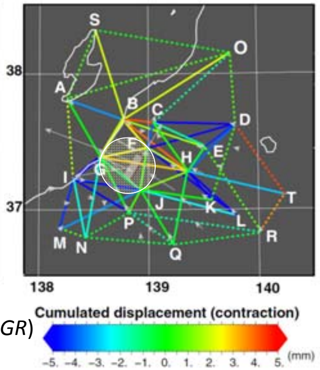


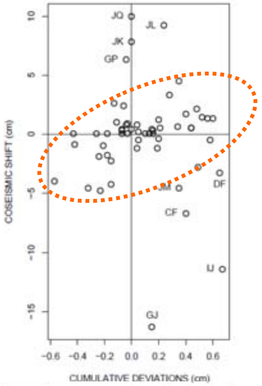
第1図. 1994年から2011年東北地方太平洋沖地震までの毎年1月1日における時空間ストレス蓄積率のスナップショット。カラーテーブルはすべり速度のcm/年の単位

Fig. 1. Snapshots of space-time loading rate at 1st January of each year from 1994 till the 2011 Tohoku earthquake. Color table in bottom right shows slip-rate with unit of cm/year (cf., reference 3).

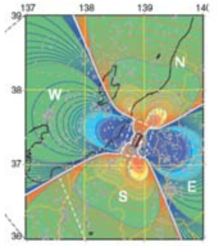
→ 2011.3.10



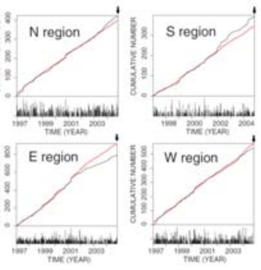


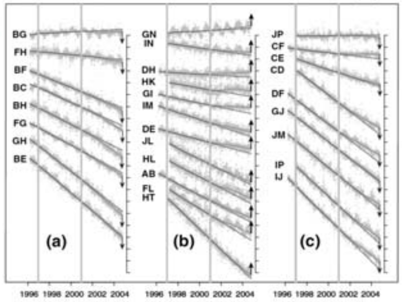


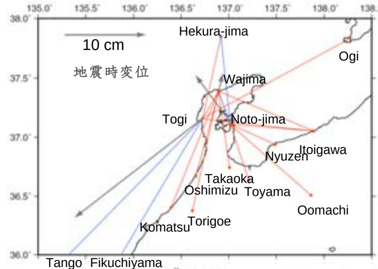
尾形(2005 連絡会報) Ogata (2007, *JGR*)



ΔCFS



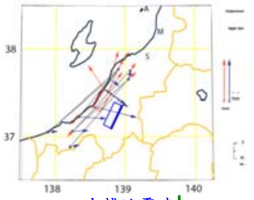


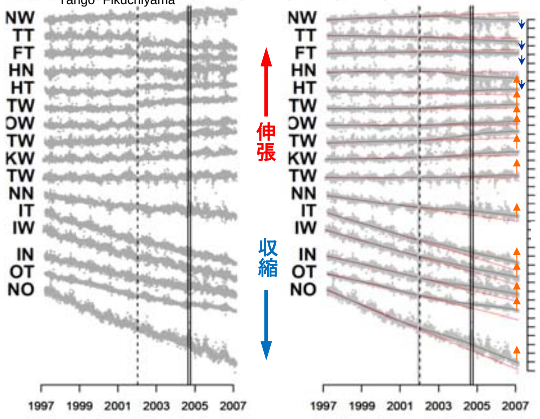


Ogata (2011, *GJI*)

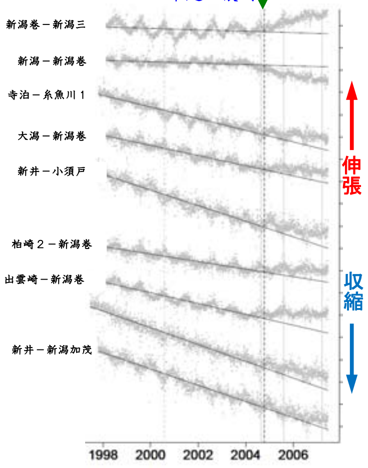
伸張の加速化
又は収縮の減速

伸張の減速化

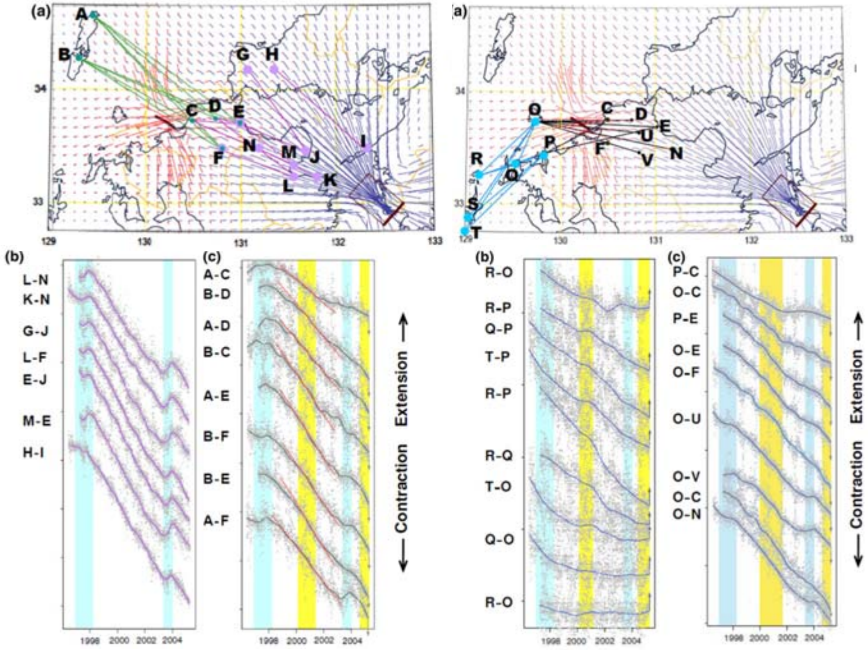




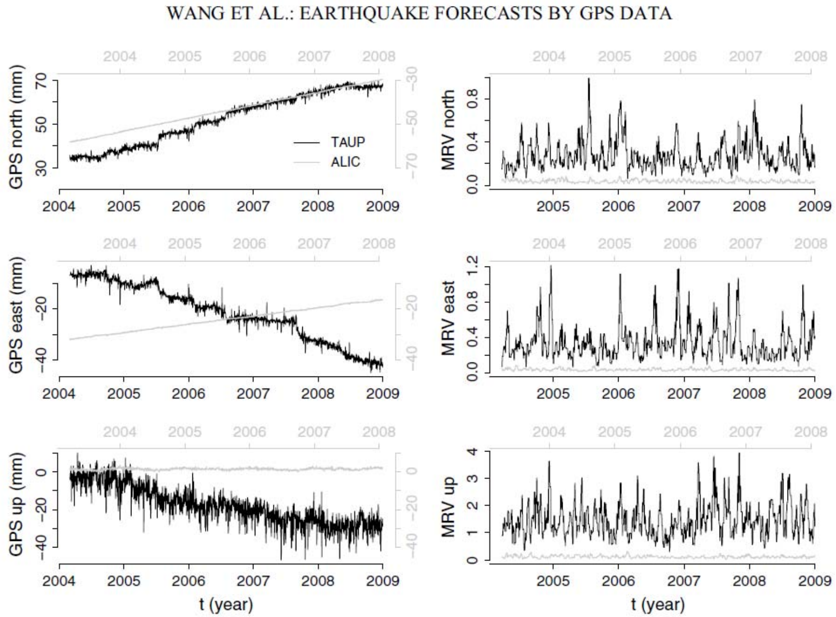
中越地震時

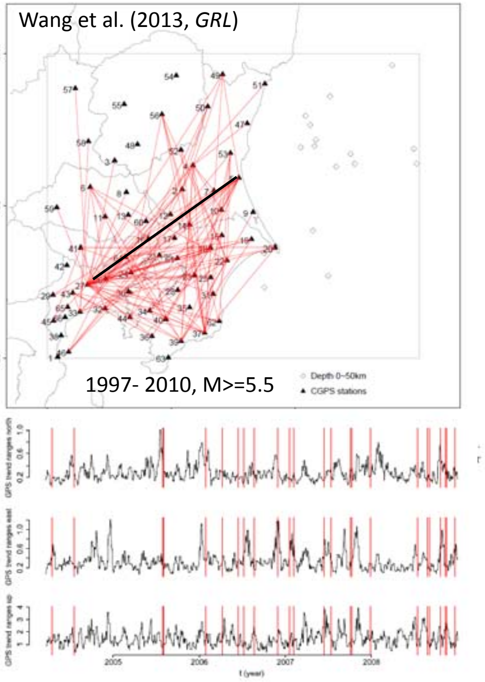


Ogata (2010, PAGEOPH)



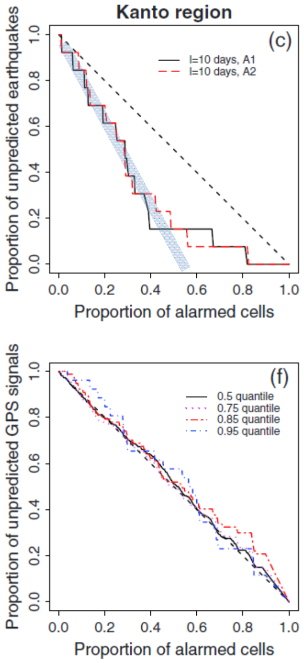
Wang & Bebbington (2013) *Computational and Stastical Data Analysis*





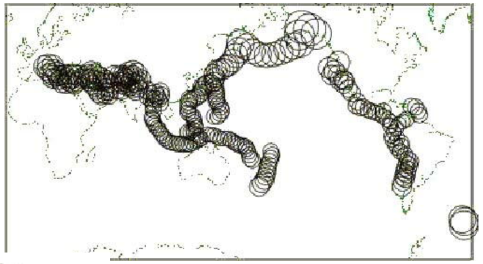
Wang et al. (2013, *GRL*)

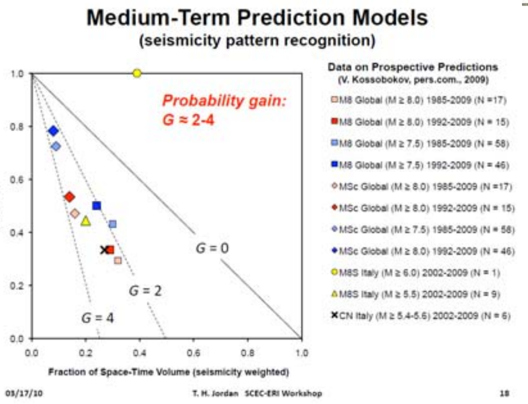
1997- 2010, M>=5.5



Jordan et al. (2010, SCEC-ERI workshop；
2011, ANNALS OF GEOPHYSICS）

M8-MSc algorithm outputs provided
by Kossobokov





Medium-Term Prediction Models
(seismicity pattern recognition)

Data on Prospective Predictions
(V. Kossobokov, pers.com., 2009)

- □ M8 Global (M ≥ 8.0) 1985-2009 (N =17)
- ■ M8 Global (M ≥ 8.0) 1992-2009 (N = 15)
- □ M8 Global (M ≥ 7.5) 1985-2009 (N = 58)
- ■ M8 Global (M ≥ 7.5) 1992-2009 (N = 46)
- ◇ MSc Global (M ≥ 8.0) 1985-2009 (N =17)
- ◆ MSc Global (M ≥ 8.0) 1992-2009 (N = 15)
- ◇ MSc Global (M ≥ 7.5) 1985-2009 (N = 58)
- ◆ MSc Global (M ≥ 8.0) 1992-2009 (N = 46)
- ○ M8S Italy (M ≥ 6.0) 2002-2009 (N = 1)
- △ M8S Italy (M ≥ 5.5) 2002-2009 (N = 9)
- ✕ CN Italy (M ≥ 5.4-5.6) 2002-2009 (N = 6)

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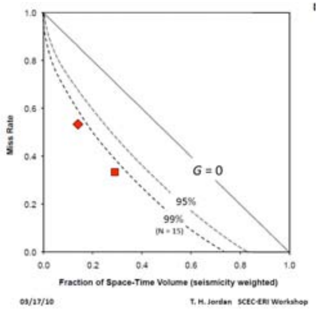
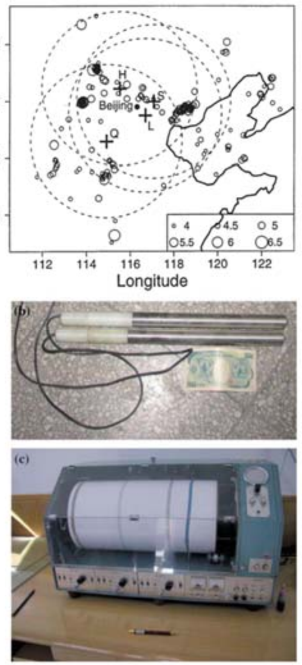
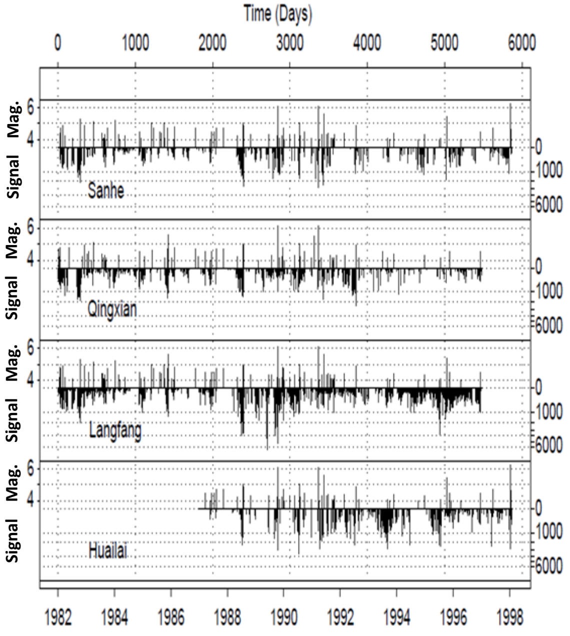
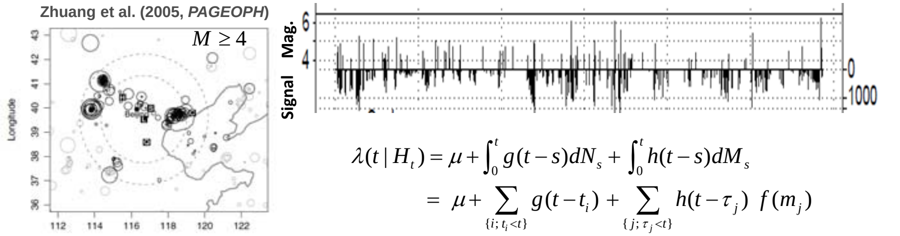


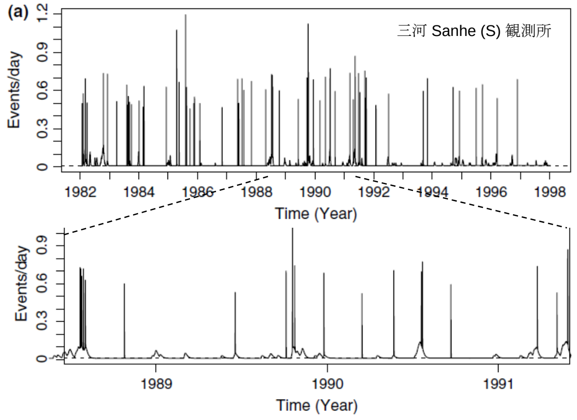


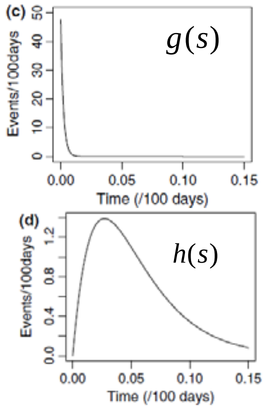




$$\lambda(t \mid H_t) = \mu + \int_0^t g(t-s)dN_s + \int_0^t h(t-s)dM_s$$
$$= \mu + \sum_{\{i;\, t_i<t\}} g(t-t_i) + \sum_{\{j;\, \tau_j<t\}} h(t-\tau_j)\ f(m_j)$$

1日当たりのM4以上の地震の発生率





結語：予知率の向上を目指すモニタリング

- 各種のビッグデータの解析・研究によって，前兆かもしれない異常事象を精力的に探し出すことが予知率の向上につながる。例え適中率が低くてもそのような異常事象を発掘すべきである.
- 自明な異常現象もあれば観測データの基礎モデルに対する残差解析に基づいてやっと認められる微妙な異常現象もある.
- 警告型予知についても、あらためて回顧的なサーベイで、確率利得や切迫性を定量的に研究し確率予測につなげることが大事である。
- 地震活動異常を炙り出すために地域性に合った地震活動の標準予測モデルを開発したように，GPS観測の時空間データも先ず地殻特性や歪の蓄積などの地域性に合った標準予測モデルを目指す必要がある.

「統計数理」 特集号　地震予測と統計モデル（2015年6月頃発行予定）

尾形良彦：　地震の確率予測の研究 ― その展望

庄　建倉・尾形良彦：　地震予測の評価法について

熊澤貴雄：　地震活動の異常性とモデリング

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野村俊一：　活断層で繰り返される地震の点過程モデルとその長期確率予測

松浦充宏：　GPSデータの逆解析と地震の発生予測

岩田貴樹：　地球潮汐と地震活動との相関を用いた地震活動予測