The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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IAEA
International Atomic Energy Agency

1864-39

Ninth Workshop on Non-linear Dynamics and Earthquake Predictions

1 - 13 October 2007

Experiment in Prospective Earthquake Prediction Using Reverse Tracing of Precursors (RTP) Algorithm

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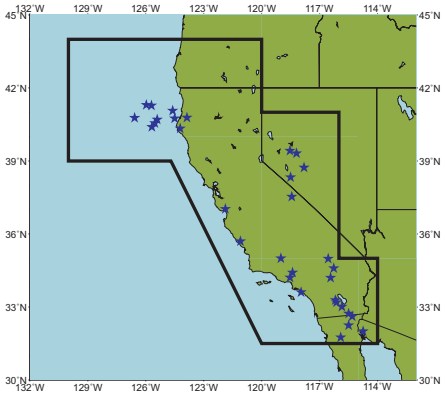
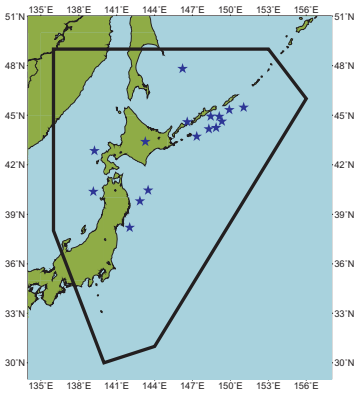
Experiment in month-in-advance earthquake prediction by RTP algorithm

http://www.igpp.ucla.edu/prediction/rtp/

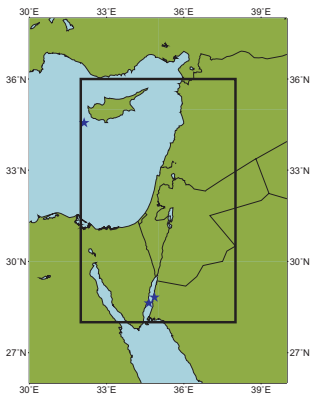
California and Western Nevada, M_{ANSS}>=6.4



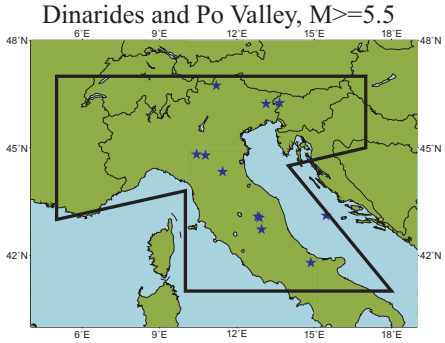
Honshu-Hokkaido-Southern Kuril, M_W>=7.2



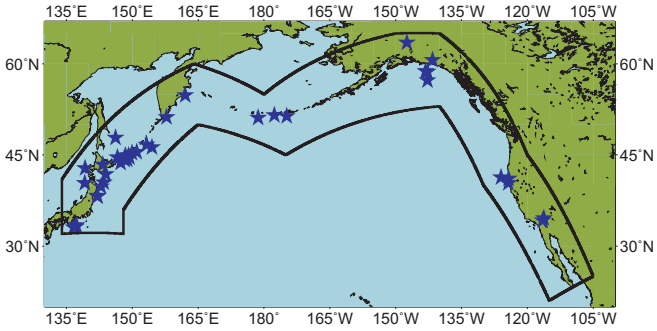
Eastern Mediterranean, M_W>=6.0



Central Apennines, Alps, Northern Dinarides and Po Valley, M>=5.5



North Pacific, M_W>=7.2; experiment started from November 10, 2006



Regions covered by prediction

Summary of the test in month-in-advance earthquake prediction by RTP algorithm

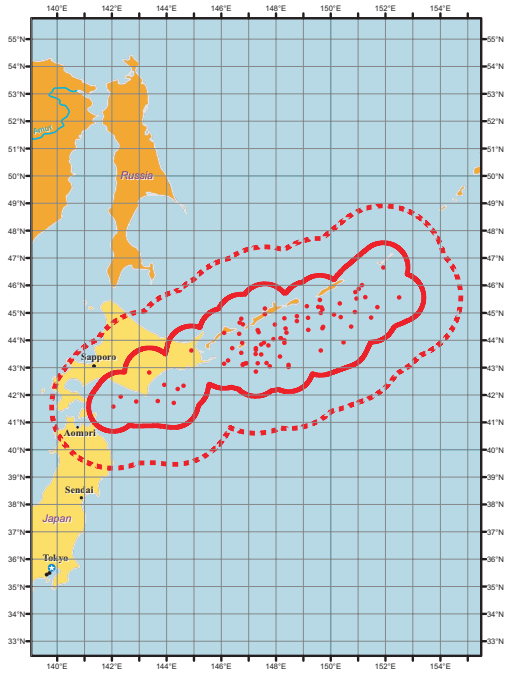
#	*Region/ target earthquakes*	*Period of alarm*	*Prediction was put on record on*	*Target earthquake*	*Prediction outcome*	*Probability of a success by chance*
1	Japan M_{JMA}>=7.0	Mar 27, 2003 - - Jan 27, 2004	July 1, 2003	**Sep 25, 2003, M_w=8.3** ***within the alarm***	**Correct**	0.32
2	California M_{ANSS}>=6.4	May 5, 2003 - - Feb 27, 2004	June 24, 2003	**Dec 22, 2004, M=6.5** ***within the alarm***	**Correct**	0.01
3	Southern California M_{ANSS}>=6.4	Oct 29, 2003 - - Sep 05, 2004	May 12, 2004		**False alarm**	0.08
4	Honsu, Japan M_w>=7.2	Feb 8, 2004 - - Nov 8, 2004	June 1, 2004	**Sep 5, 2004, M_w=7.4** ***outside the region; 127 km outside alarm***	**False alarm** (Near miss)	0.03
5	Northern Dinarides M_w>=5.5	Feb 29, 2004 - - Nov 29, 2004	May 12, 2004	**Jul 12, 2004, M_w=5.2, M_L=5.7** ***within the alarm***	**False alarm** (Near miss)	0.03
6, 6a 6b 6c 6d	Southern California M_{ANSS}>=6.4	Nov 14, 2004 - - Aug 14, 2005 - March 17, 2006 - Dec 24, 2006 - May 2, 2007	Nov 16, 2004, Oct 5, 2005 Mar 17, 2006 Mar 30, 2006 Dec 24, 2006		**False alarm**	0.23
7	Oregon off coast M_{ANSS}>=6.4	Nov 16, 2004 - - Aug 16, 2005	Jan 29, 2005	**Jun 15, 2005, M_w=7.2** ***60 km outside alarm***	**False alarm** (Near miss)	0.01
8, 8a	Central Italy M>=5.5	Jan 1, 2005 - Oct 1, 2005 - Feb 6, 2006	Jan 29, 2005, Oct 1, 2005		**False alarm**	0.14
9	Honsu, Japan M_w>=7.2	June 14, 2005 - - Mar 14, 2006	Oct 1, 2005	**Aug 16, 2005, M_w=7.2** ***within the alarm***	**Correct** (*)	0.03
10, 10a	Hokkaido-S. Kurils M_w>=7.2	May 11, 2006 - - Feb 11, 2007 - June 30, 2007	May 22, 2006 Oct 9, 2006	**Nov 15, 2006 M_w=8.3** ***within the alarm***	**Correct**	0.14
11	Italy, M>=5.5	May 2, 2006 - - Feb 3, 2007	June 12, 2006		**False alarm**	0.12
12	Oregon off coast M_{ANSS}>=6.4	Sept 23, 2006 - - June 23, 2007	Nov 10, 2006		**False alarm**	0.01

(*) Due to technical delay of data, the alarm was determined after the earthquake Aug 16, 2005

An alarm is turned on if the estimated probability that alarm is false is <50%

Example of a standard Issue posted on web

Experiment in prospective earthquake prediction using
Reverse Tracing of Precursors (RTP)
Prediction #10, May 22, 2006



Red circles show the earthquakes that formed precursory chain on May 11, 2006. Area of alarm is shown by red contour: solid line test A, dashed line test B.

Starting from October 1, 2005 we test in parallel two versions of the prediction algorithm. Test A concerns exactly the same algorithm as before. In test B we made one change: we increased by factor 2.5 the value of the numerical parameter, R, thus expanding the area of alarm.

An earthquake with magnitude M_w >= 7.2 is predicted to occur within the time interval 9 months, from 00:00 GMT May 11, 2006, to 00:00 GMT February 11, 2007 in the area shown in the figure: solid line shows the area of alarm in test A, dashed line in test B.

Estimated probability that a target earthquake will occur at random in the time-area of alarm is less than 20% in test A and less than 25% in test B. Estimated probability of a false alarm does not exceed 50% in both tests.

Reminder. As you know, earthquake predictions should be released to the public or media only by a proper disaster management authority. Otherwise, prediction may trigger profiteering and disruptive anxiety of population. Accordingly, we open an access to our predictions only to professionals who agreed to comply with the above limitation. This restriction is lifted and prediction becomes publicly available when a target earthquake occurs in the area of alarm, or when the alarm expires, independently of was it correct or wrong.

Example of a standard E-mail

Subject: Experiment in month-in-advance earthquake prediction by RTP algorithm: updating the web site, May 22, 2006

From: Vladimir Keilis-Borok

Date: 5/25/2006 5:10 AM

To: <list of 47 recipients>

.
Dear colleagues,

Please be informed that we have just updated the website with the experiment in month-in-advance earthquake prediction by RTP algorithm. A new current prediction (in Hokkaido-Southern Kurils area, Mw>=7.2) is added there.

As before the address is http://www.igpp.ucla.edu/prediction/rtp/

The access to the section Current predictions is password protected.
To access please use, as before,
Username: [redacted]
Password: [redacted]
Note: that the letters are CAPITAL.

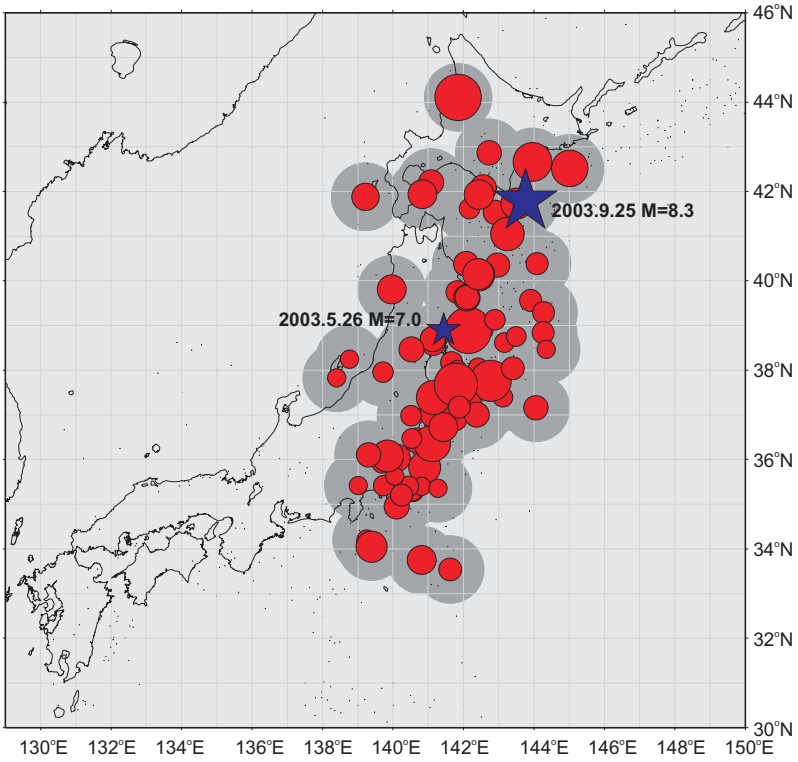
We remind you that the possibility of false alarms notwithstanding, predictions made in advance open for further research a unique opportunity: to apply different ideas, methods and data to the same area of alarm. We would be glad to help if you undertake such applications or independently use the RTP algorithm. We would be also grateful for any information on such applications.
Please inform us if you noticed the errors inevitable for a start.

Yours sincerely,

V. Keilis-Borok(1,2), vkb@ess.ucla.edu
P. Shebalin(2), shebalin@mitp.ru

(1) Institute of Geophysics and Planetary Physics and Department of Earth and Space Science, University of California, Los Angeles
(2) International Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Science

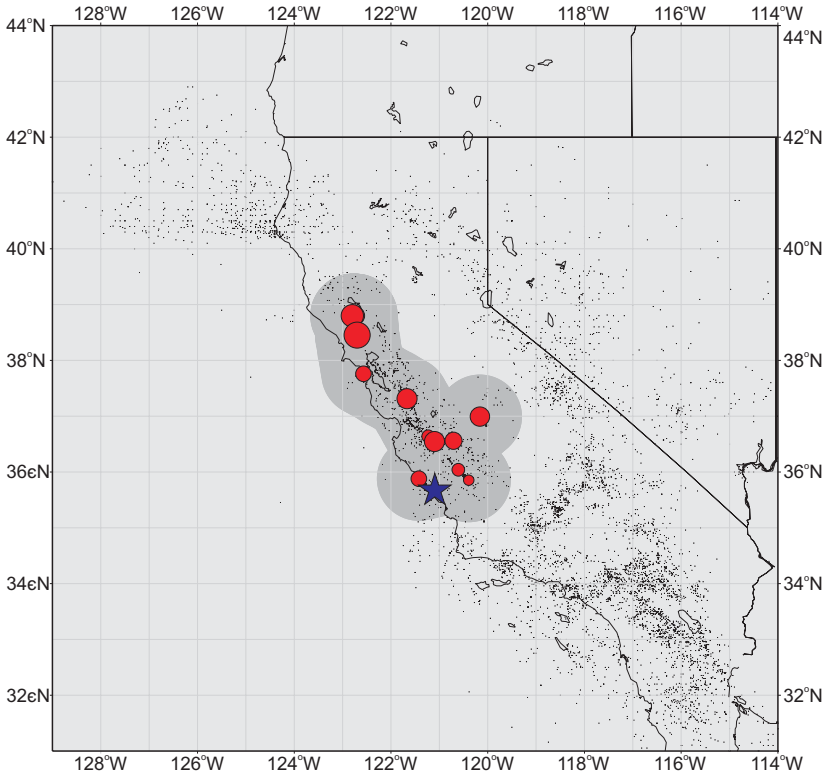
Advance prediction of Tokachi-oki earthquake, Japan, Sept. 25, 2003, M = 8.3



Dots show earthquakes, forming precursory chain. Stars - target earthquakes.

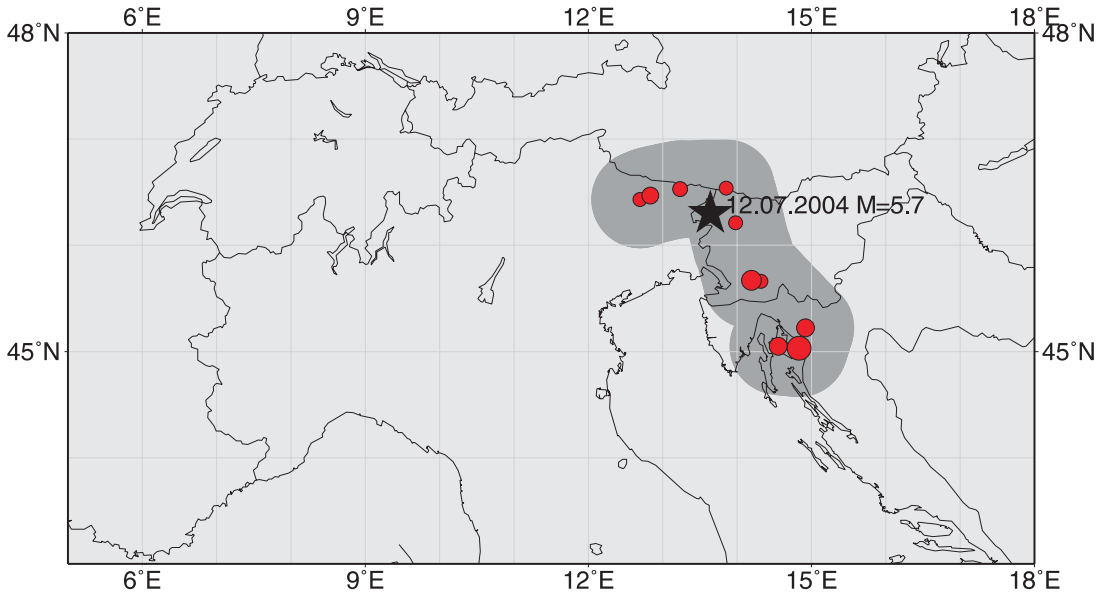
Case history, 2003
March 27: *Precursory chain* of earthquakes was formed. It indicates that an earthquake with magnitude 7 or more will occur in gray area within 9 months.
May 26: *Earthquake with magnitude 7.0* occurred in gray area; precursor was not reported in advance.
July 2: *Precursor reported* at IUGG (Sapporo, Japan).
Sept. 25: *Tokachi-oki earthquake* in gray area.

Advance prediction of San Simeon earthquake in central California, M=6.5



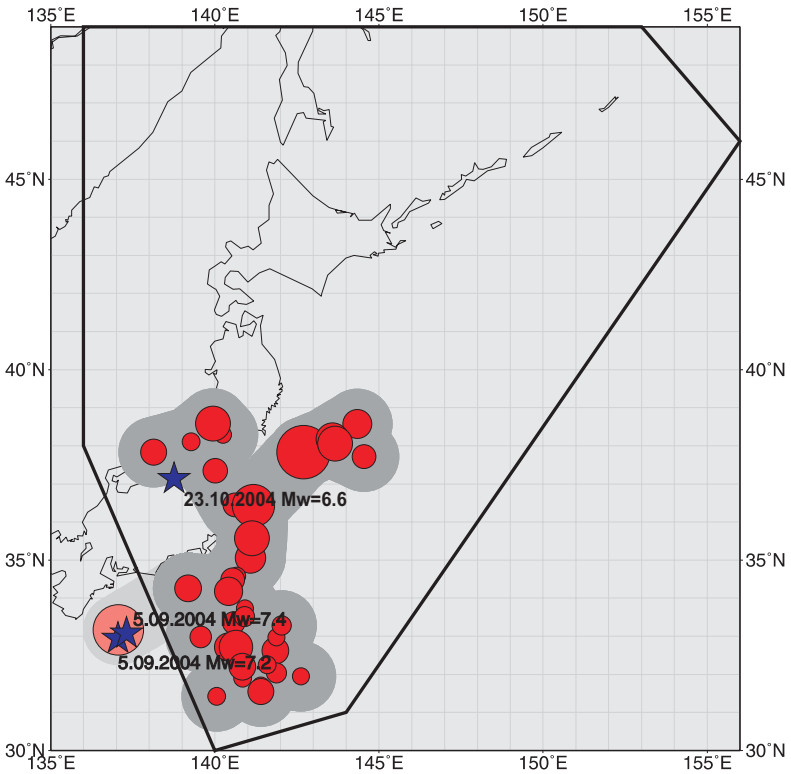
Case history, 2003
***May 5*:** *Precursory chain* of earthquakes was formed. It indicates that an earthquake with magnitude 6.4 or more will occur in gray area within 9 months.
June 21: *Prediction was distributed* among relevant scientists and administrators.
Dec. 22: *San Simeon earthquake* (star).

Bovec earthquake, Slovenia, M_L=5.7



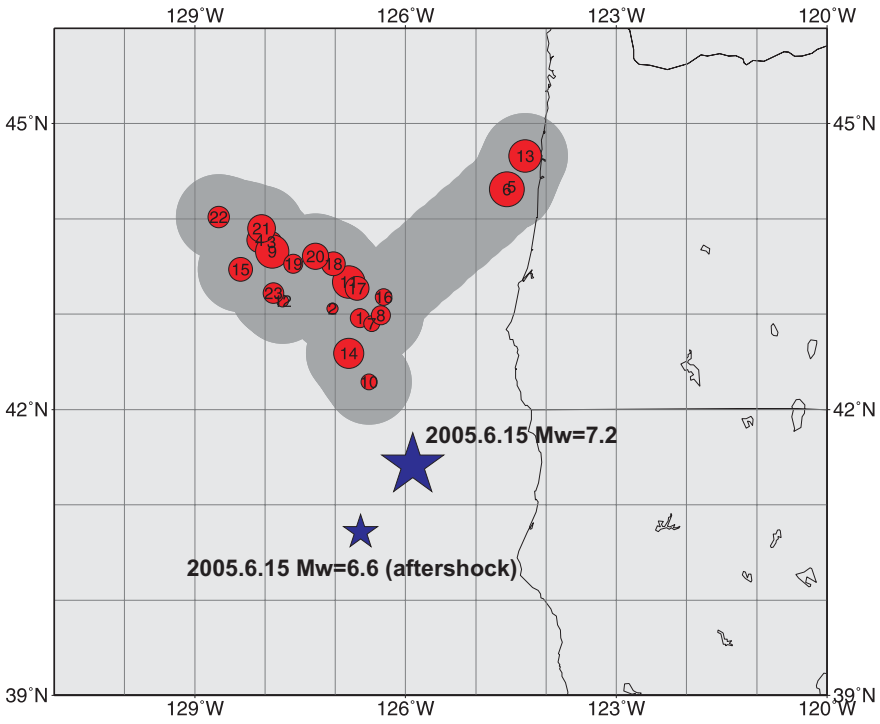
Case history, 2004
February, 29*: *Precursory chain of earthquakes was formed. It indicates that an earthquake with magnitude M_Wi5.5 or more will occur in gray area by November 29, 2004.
May, 12*: *Prediction was distributed among relevant scientists and administrators.
July, 12: Bovec earthquake, M_L=5.7(M_W=5.3) has occurred in the area of alarm.

Two earthquakes south to Honsu, M=7.2 and M=7.4. Near miss



Case history, 2004
February, 8*: *Precursory chain of earthquakes was formed. It indicates that an earthquake with M_w≥7.2 will occur in gray area by November 8, 2004.
June, 1*: *Prediction was distributed among relevant scientists and administrators.
September, 1: Two earthquakes, M_W=7.2 and M_W=7.4 have occurred ***near*** the area of alarm. Successful prediction is not scored.

Gorda plate earthquakes, M=7.2 and M=6.6. Near miss



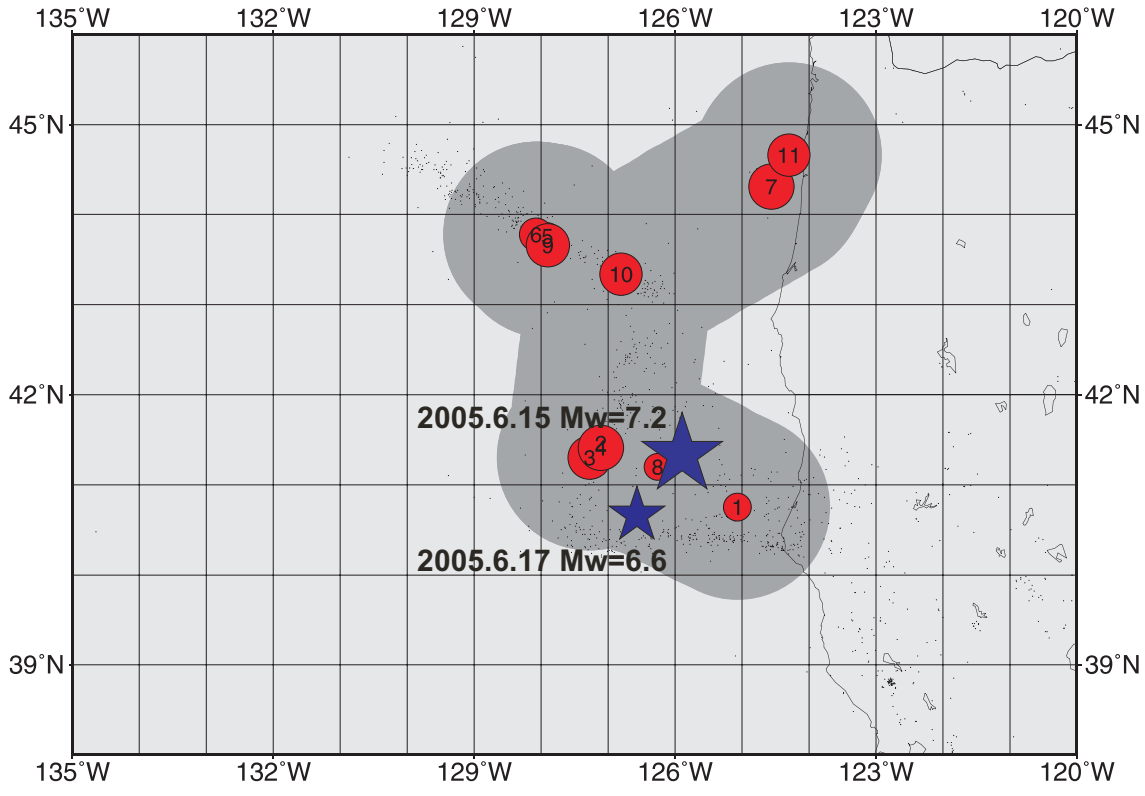
Case history

***November, 16, 2004*:** *Precursory chain* of earthquakes was formed. It indicates that an earthquake with M≥6.4 will occur in gray area by August 16, 2005.

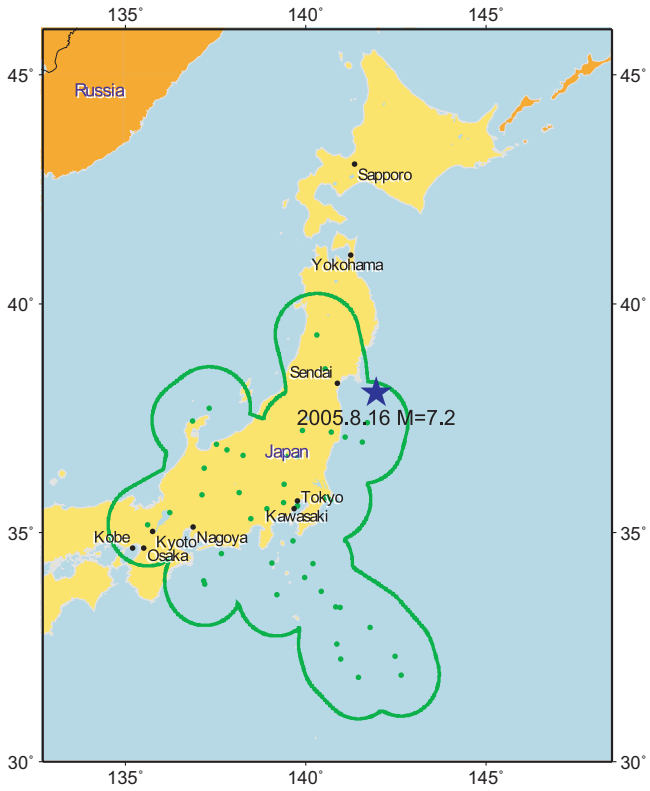
***January, 29, 2005*:** *Prediction was distributed* among relevant scientists and administrators.

June, 15 and 17, 2005: Two earthquakes, M=7.2 and M=6.6 have occurred ***near*** the area of alarm. Successful prediction is not scored.

RTP applied to $M_w \geq 7.2$ in North Pacific (Japan-Kurils-Kamchatka-Aleutians-Alaska-Canda-Oregon-California-N. Mexico). Alarm until 19 August, 2005

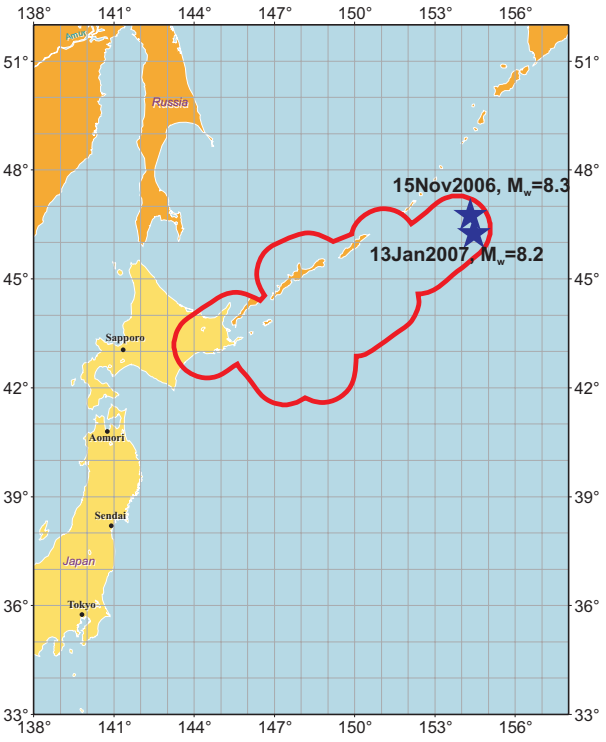


Prediction of the earthquake E of Honshu, Japan, August 16, 2005, M_w = 7.2

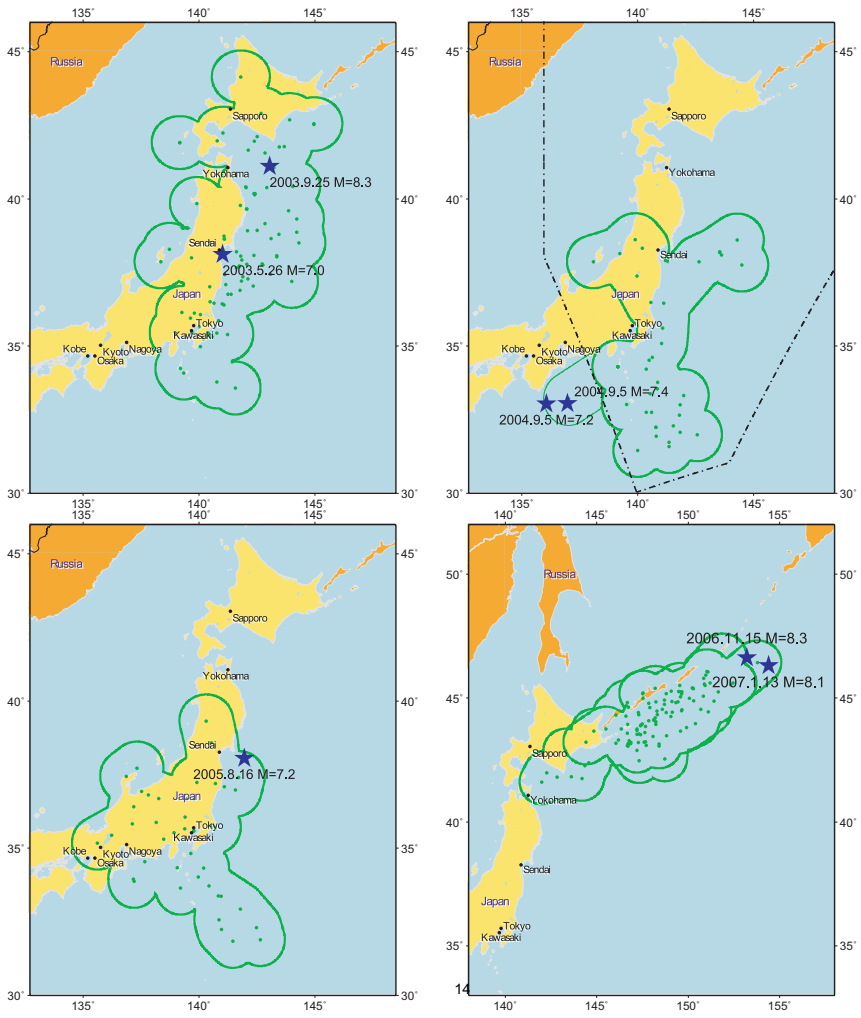


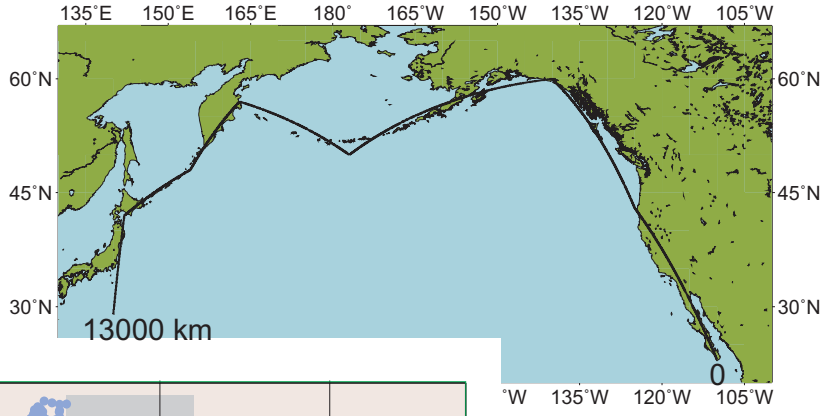
Green circles show the earthquakes that formed precursory chain on June 1, 2005. Area of alarm is shown by green contour: solid line test A, dashed line test B. Blue star shows the epicenter of the earthquake that has occurred on August 16, 2005, M_w=7.2 within the area of alarm. Due to technical delay of data the complete RTP analysis was made after the earthquake. According to the RTP rules the prediction remained current until March 2, 2006.

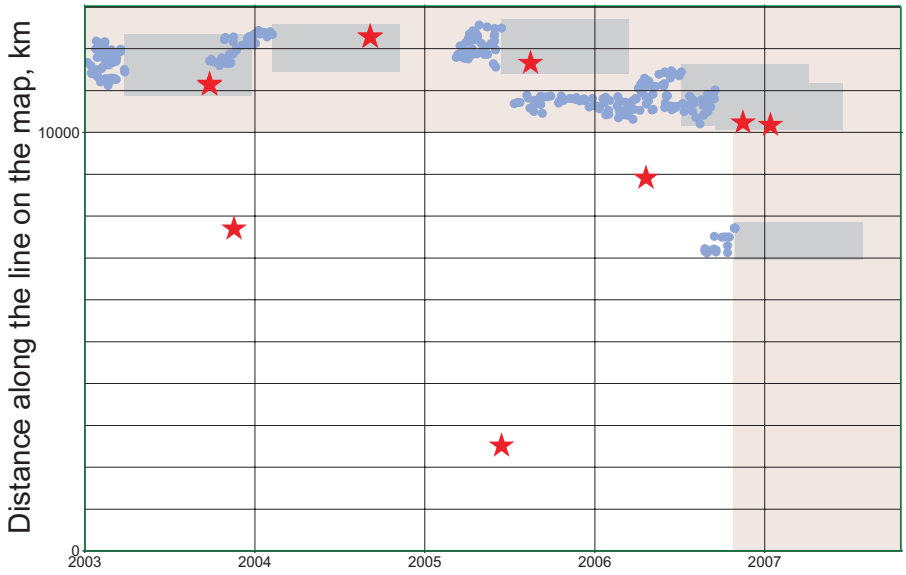
Advance prediction of Simushir earthquake, Kuril islands, Russia, Nov. 15, 2006, M_w = 8.3 and second large earthquake, Jan. 13, 2007, M_w = 8.2

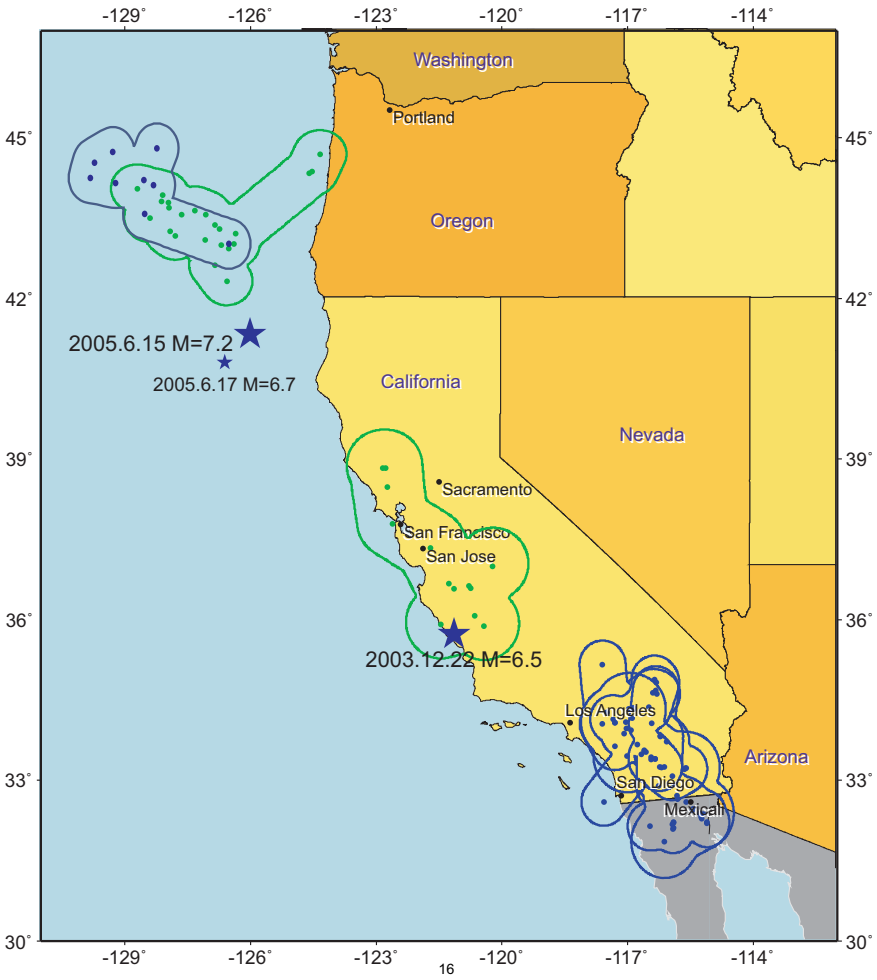


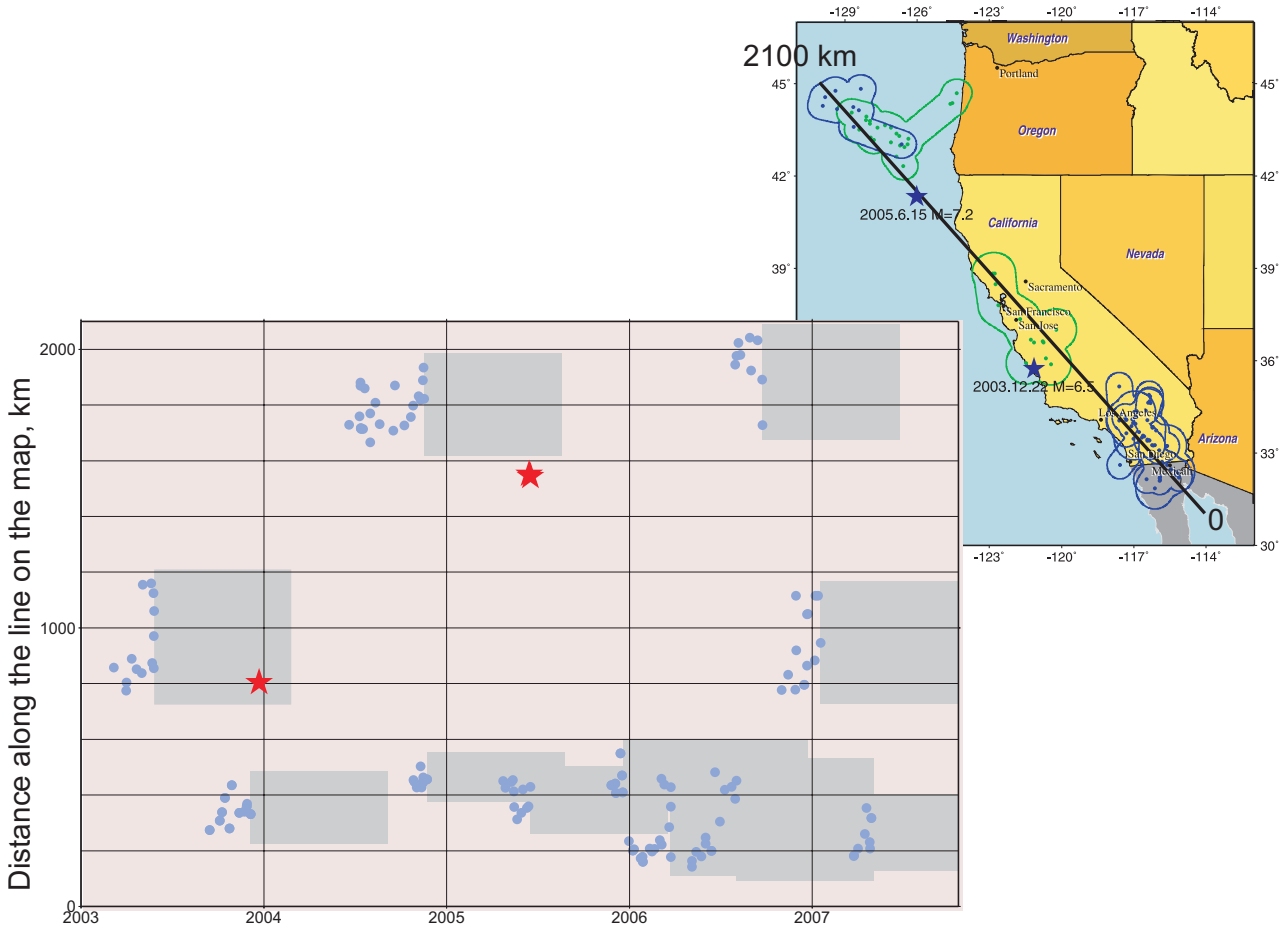
Case history, 2006-2007
Septemer 30, 2006: *Precursory chain* of earthquakes was formed. It indicates that an earthquake with magnitude 7.2 or more will occur in an area shown by red contour within 9 months.
October 9, 2006: *Precursor is reported* on the RTP web site (http://www.igpp.ucla.edu/prediction/rtp2/RTP10a.pdf)
Nov. 15, 2006 and Jan. 13, 2007: *Simushir earthquake,* M_W=8.3, and a second strong earthquake, M_W=8.2, have occured, their epicenters in the area shown by blue stars.

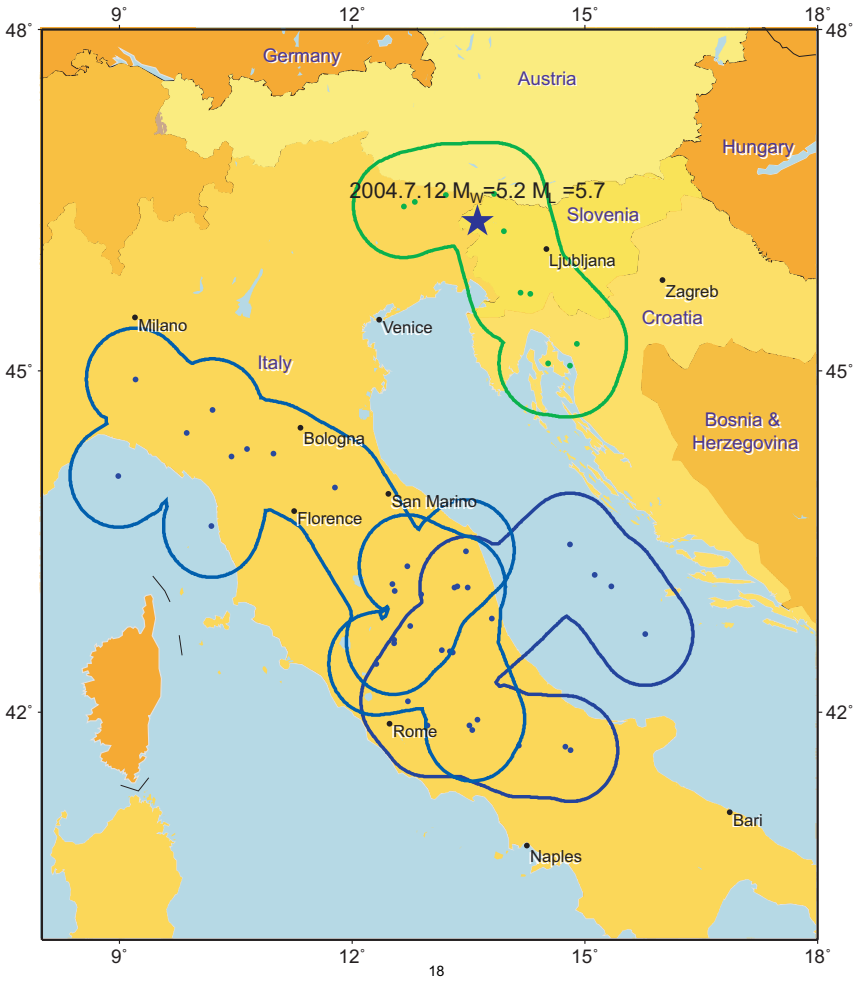

Russia
Sapporo
Yokohama
Sendai
Japan
Tokyo
Kawasaki
Kobe
Kyoto
Osaka
Nagoya
2003.9.25 M=8.3
2003.5.26 M=7.0
2004.9.5 M=7.4
2004.9.5 M=7.2
2005.8.16 M=7.2
2006.11.15 M=8.3
2007.1.13 M=8.1


13000 km
0

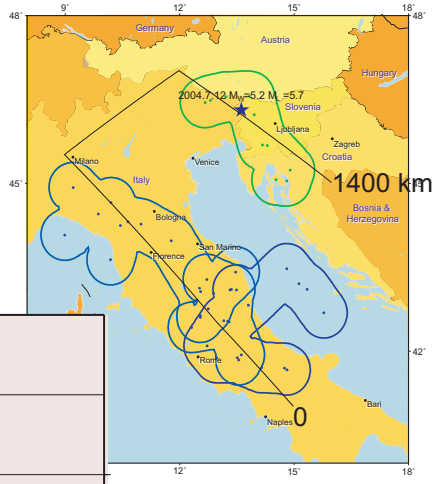

Distance along the line on the map, km
10000
0
2003
2004
2005
2006
2007

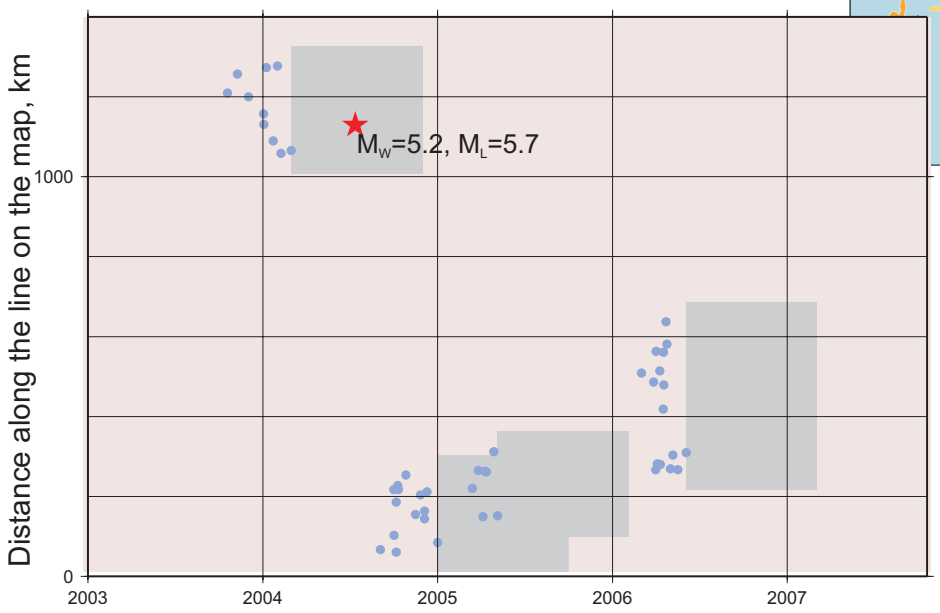

-129°
-126°
-123°
-120°
-117°
-114°
45°
42°
39°
36°
33°
30°
Washington
Portland
Oregon
California
Nevada
Sacramento
San Francisco
San Jose
Los Angeles
San Diego
Mexicali
Arizona
2005.6.15 M=7.2
2005.6.17 M=6.7
2003.12.22 M=6.5


2100 km
0
2005.6.15 M=7.2
2003.12.22 M=6.5
Distance along the line on the map, km
2000
1000
0
2003
2004
2005
2006
2007


9˚
12˚
15˚
18˚
48˚
45˚
42˚
Germany
Austria
Hungary
2004.7.12 M_W=5.2 M_L =5.7
Slovenia
Ljubljana
Zagreb
Croatia
Milano
Venice
Italy
Bologna
Bosnia &
Herzegovina
San Marino
Florence
Rome
Bari
Naples

18


1400 km
0


Distance along the line on the map, km
1000
0
M_W=5.2, M_L=5.7
2003
2004
2005
2006
2007

19

Statistical significance is hardly appropriate value for alarm-based prediction experiments

1. Statistical significance does not reflect efficiency of the tested algorithm.

Explaining example, imperfect roulette test. 1.000.000 spins, 490.000 times red (18/37*1.000.000=486486 expected). Statistical significance that the roulette is imperfect is 10^{-12}, but statistically, putting on red, one will loose 2%.

2. Statistical significance is not appropriate to accept or to decline a prediction method.

Srtandard models imply constant conditions of the experiment, independent alarms, independent targets, unambiguous outcomes. None of those conditions actually can be insured in a real experiment.

What instead?

Stability, within a large period of the test, of some efficiency characteristics, for example loss functions ($\eta+\tau$) or max(η,τ) (Molchan) or probability gain (1-η)/τ (Aki, Gusev).

After a period of fluctuations at the beginning of the experiment, this value should stabilize around some value. In case this value is acceptable, the method may be accepted.

η is the fraction of failures to predict to the number of targets.

τ is the probability of successful predictions obtained by chance, estimated from known seismicity

Summary of the test in month-in-advance earthquake prediction by RTP algorithm

#	Region/ target earthquakes	Period of alarm	Prediction was put on record on	Target earthquake	Prediction outcome	Probability of a success by chance
1	Japan M_{JMA}>=7.0	Mar 27, 2003 - - Jan 27, 2004	July 1, 2003	**Sep 25, 2003, M_w=8.3** *within the alarm*	**Correct**	0.32
2	California M_{ANSS}>=6.4	May 5, 2003 - - Feb 27, 2004	June 24, 2003	**Dec 22, 2004, M=6.5** *within the alarm*	**Correct**	0.01
3	Southern California M_{ANSS}>=6.4	Oct 29, 2003 - - Sep 05, 2004	May 12, 2004		**False alarm**	0.08
4	Honsu, Japan M_w>=7.2	Feb 8, 2004 - - Nov 8, 2004	June 1, 2004	**Sep 5, 2004, M_w=7.4** *outside the region; 127 km outside alarm*	**False alarm** (Near miss)	0.03
5	Northern Dinarides M_w>=5.5	Feb 29, 2004 - - Nov 29, 2004	May 12, 2004	**Jul 12, 2004, M_w=5.2, M_L=5.7** *within the alarm*	**False alarm** (Near miss)	0.03
6, 6a 6b 6c 6d	Southern California M_{ANSS}>=6.4	Nov 14, 2004 - - Aug 14, 2005 - March 17, 2006 - Dec 24, 2006 - May 2, 2007	Nov 16, 2004, Oct 5, 2005 Mar 17, 2006 Mar 30, 2006 Dec 24, 2006		**False alarm**	0.23
7	Oregon off coast M_{ANSS}>=6.4	Nov 16, 2004 - - Aug 16, 2005	Jan 29, 2005	**Jun 15, 2005, M_w=7.2** *60 km outside alarm*	**False alarm** (Near miss)	0.01
8, 8a	Central Italy M>=5.5	Jan 1, 2005 - Oct 1, 2005 - Feb 6, 2006	Jan 29, 2005, Oct 1, 2005		**False alarm**	0.14
9	Honsu, Japan M_w>=7.2	June 14, 2005 - - Mar 14, 2006	Oct 1, 2005	**Aug 16, 2005, M_w=7.2** *within the alarm*	**Correct** (*)	0.03
10, 10a	Hokkaido-S. Kurils M_w>=7.2	May 11, 2006 - - Feb 11, 2007 - June 30, 2007	May 22, 2006 Oct 9, 2006	**Nov 15, 2006 M_w=8.3** *within the alarm*	**Correct**	0.14
11	Italy, M>=5.5	May 2, 2006 - - Feb 3, 2007	June 12, 2006		**False alarm**	0.12
12	Oregon off coast M_{ANSS}>=6.4	Sept 23, 2006 - - June 23, 2007	Nov 10, 2006		**False alarm**	0.01

(*) Due to technical delay of data, the alarm was determined after the earthquake Aug 16, 2005

An alarm is turned on if the estimated probability that alarm is false is <50%

RTP predictions summary, 24 June 2003 to 5 October 2007

a) formal statistics

	Expected rate of targets in alarms k	Predicted n	Number of alarms	Expected rate of targets in regions K	Occurred N	τ=k/K	τ+η	probability gain n/k/(N/K)
California	0.39	1	5	1.76	2	0.22	0.72	2.26
Honshu to Kurils	0.61	3	4	2.06	3	0.30	0.30	3.35
Italy+	0.35	0	3	1.10	0	0.32	0.32	
E. Mediterranean	0	0	0	0.37	0	0	0	
N. Pacific (without Honshu to Kurils)	0.03	0	1	0.10	0	0.33	0.33	
total	**1.38**	**4**	**13**	**5.93**	**5**	**0.23**	**0.43**	**3.48**

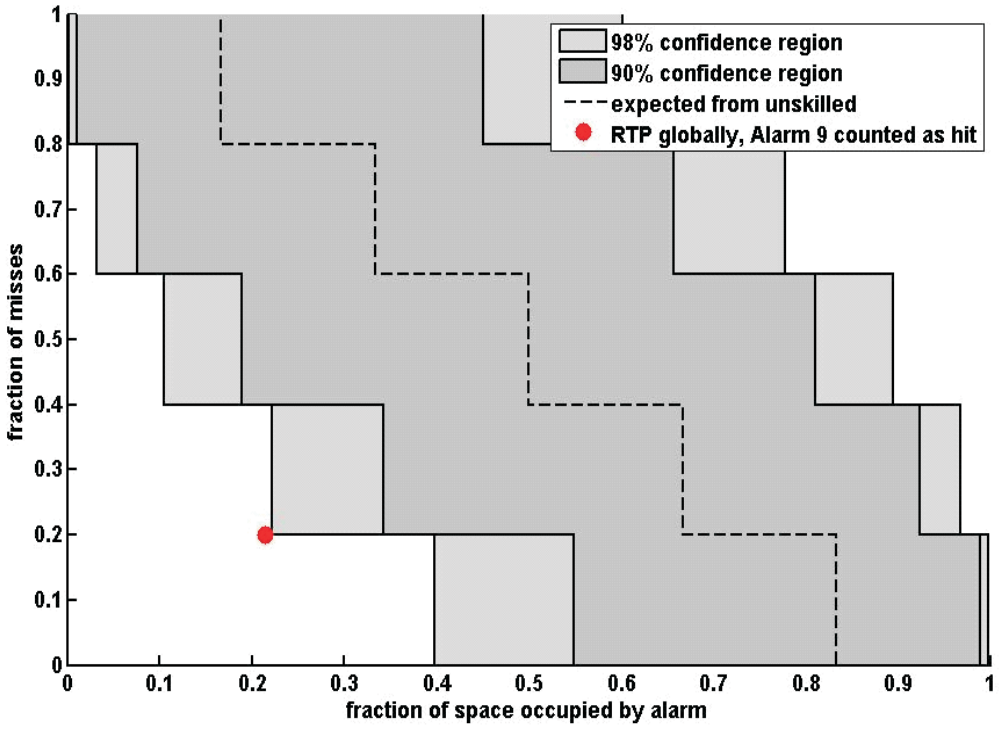
Statistics k includes three current alarms

b) informal complementary details

Three false alarms are "near misses". In one case target magnitude was documented as M_w>=5.5, and the earthquake within time and space of alarm had magnitude M_w=5.2 and M_L=5.7. In two other cases the target earthquakes occurred within time of prediction, but outside its area, at a distance much smaller than the alarm size.

Large earthquakes during the test

25-Sep-03	Japan	M_{JMA}= 8.0	**predicted**
22-Dec-03	Central CA	M=6.5	**predicted**
12-Jul-04	N. Dinarides	M_W=5.2	not applied: small magnitude (**near miss**, M_L = 5.7)
5-Sep-04	Japan	M_W = 7.4	not applied: outside region; (**near miss**, 140 km outside alarm)
15-Jun-05	CA Offshore	M_W = 7.2	**failure to predict** (near miss, 60 km outside alarm)
17-Jun-05	CA Offshore	M_W = 6.6	not applied: aftershock (outside prediction)
16-Aug-05	sea near Japan	M_W = 7.2	**predicted** (due to technical delay of data, the alarm was determined after the earthquake)
15-Nov-06	Kuriles	M_W = 8.3	**predicted**
13-Jan-07	Kuriles	M_W = 8.1	not applied: aftershock (within prediction)



J. Zechar (USC/SCEC). Presentation at the meeting “Earthquake predictability and time dependent forecasting” Ruschlikon, Switzerland, 28-31 January 2007.