



**The Abdus Salam
International Centre for Theoretical Physics**



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**Advanced School on Understanding and Prediction of Earthquakes and
other Extreme Events in Complex Systems**

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**Predicting Predictable:
Accuracy and Natural Limitations of Seismic Forecasts**

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Predicting Predictable: Accuracy and Natural Limitations of Seismic Forecasts



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Stage accuracies of earthquake prediction

- Term-less prediction of earthquake-prone areas
- Prediction of time and location of an earthquake of certain magnitude

Temporal, <i>in years</i>		Spatial, <i>in source zone size L</i>	
Long-term	10	Long-range	up to 100
Intermediate-term	1	Middle-range	5-10
Short-term	0.01-0.1	Narrow	2-3
Immediate	0.001	Exact	1

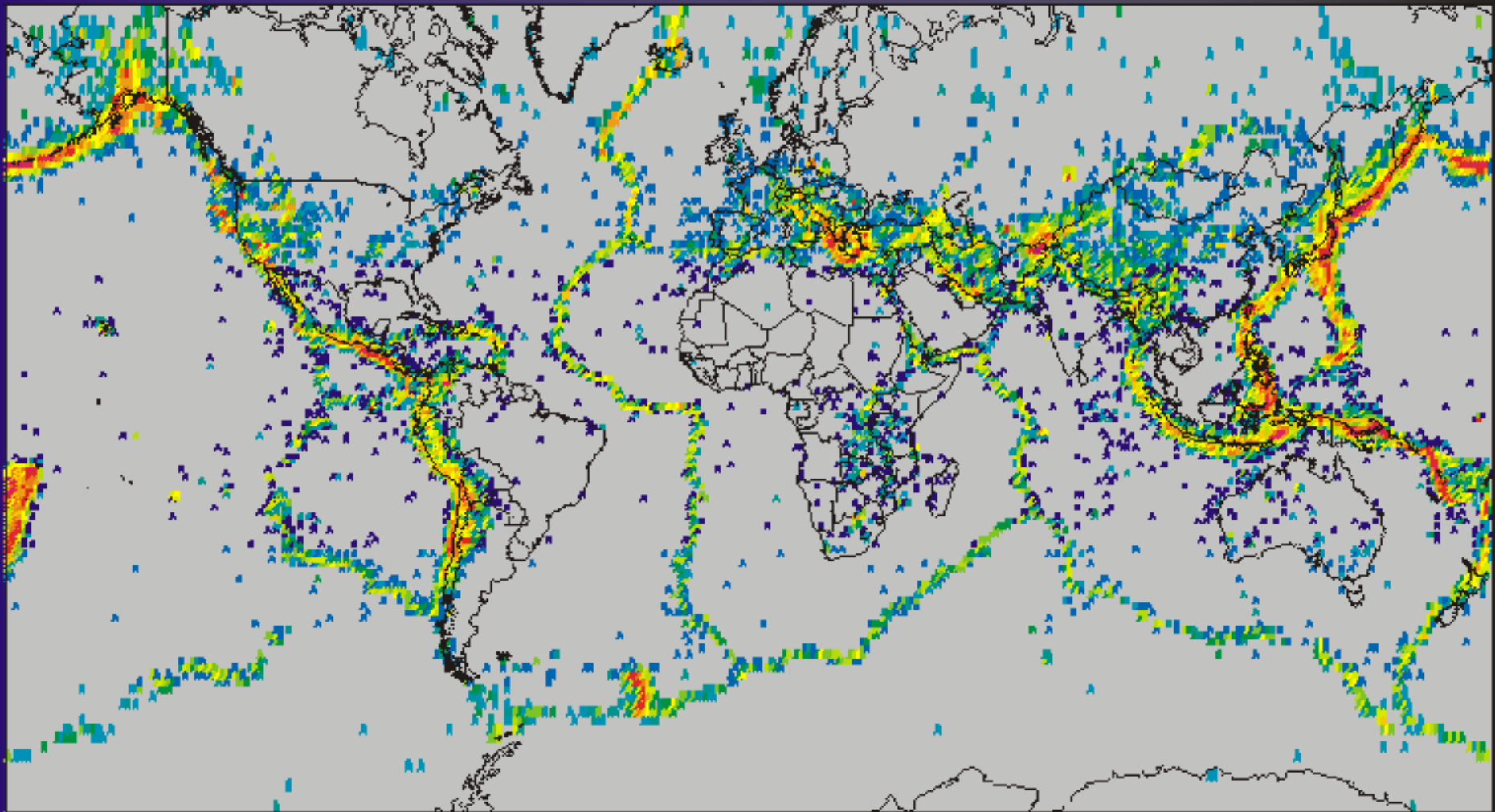
- Moreover, the Gutenberg-Richter law suggests limiting magnitude range of prediction to about one unit. Otherwise, the statistics would be essentially related to dominating smallest earthquakes.



“Undue precision of computations is
the first symptom
of mathematical illiteracy”

A.N. Krylov, (1863-1945)

The accuracy of an earthquake prediction method is essentially predefined by the accuracy of the data available, which is far from ideal. The unavoidable natural difficulties in observing seismic events as well as in correlating them with other geophysical phenomena and fields complicates the design and testing of a new generation of earthquake prediction technique.



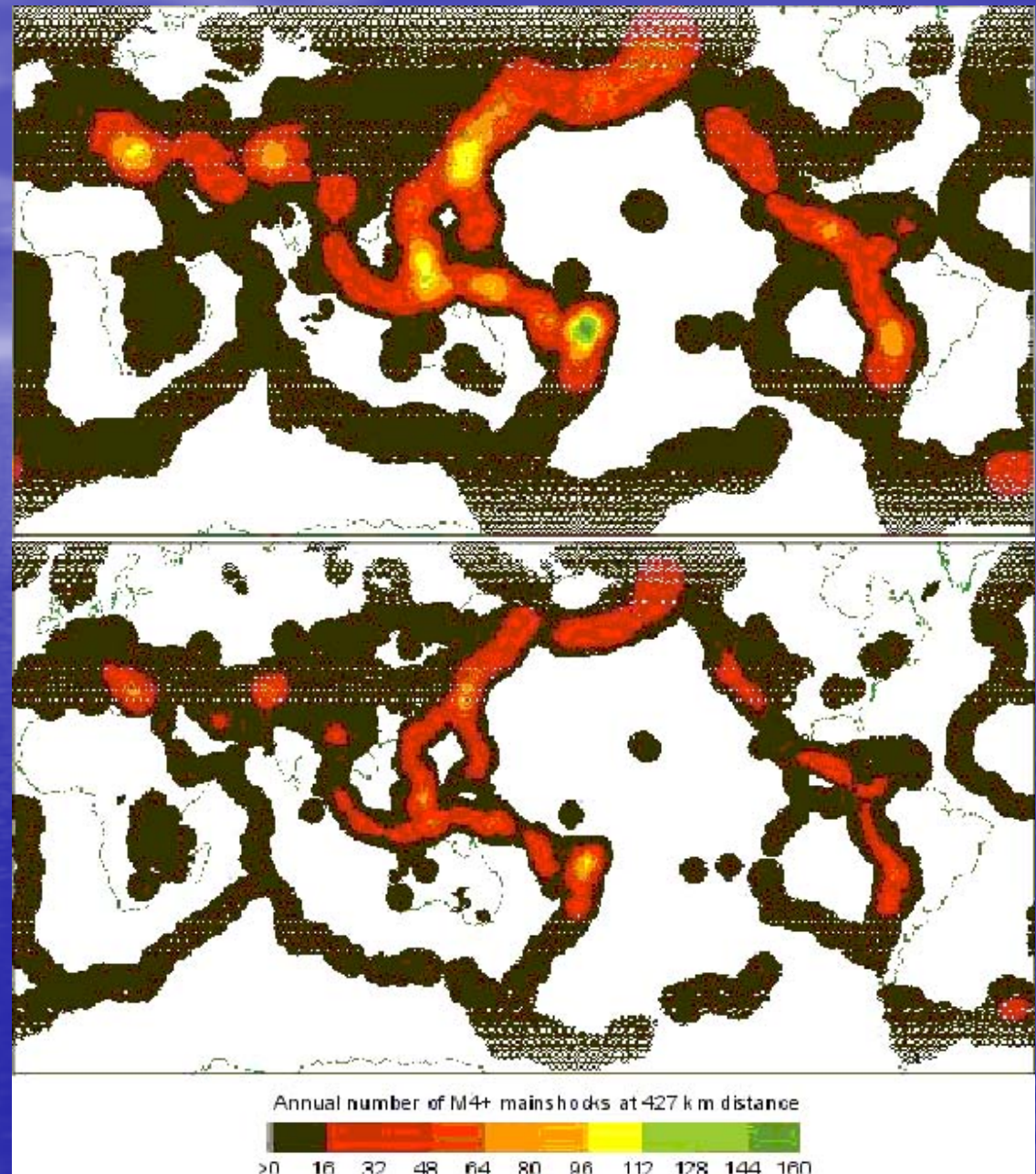
Average annual number of magnitude 4.0 or greater earthquakes at a $1^\circ \times 1^\circ$ cell (*normalized to its area on equator*)

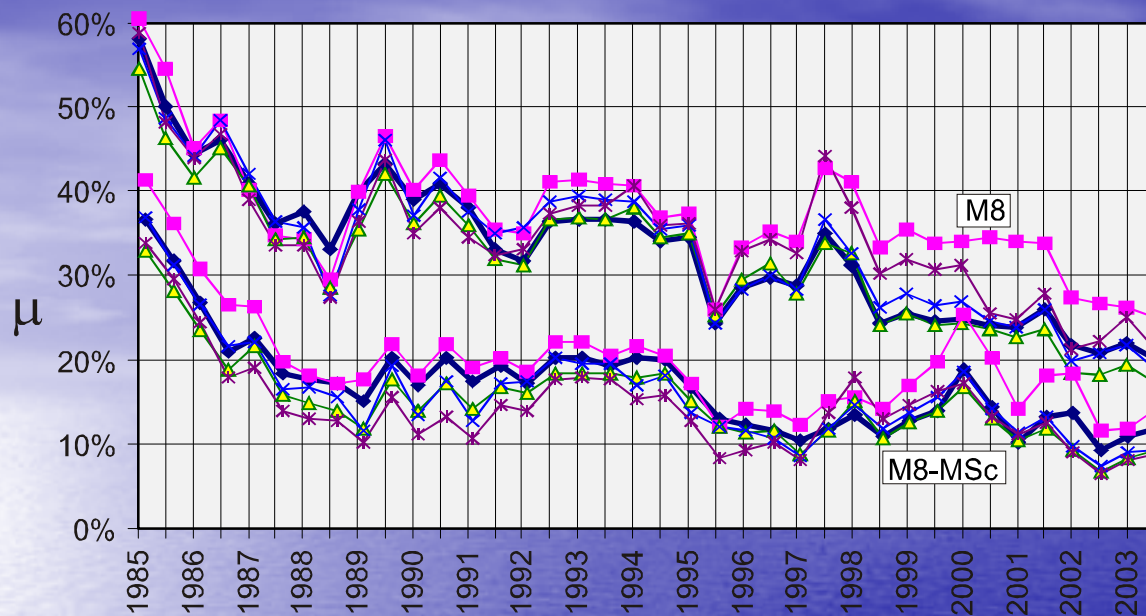
Annual number of earthquakes



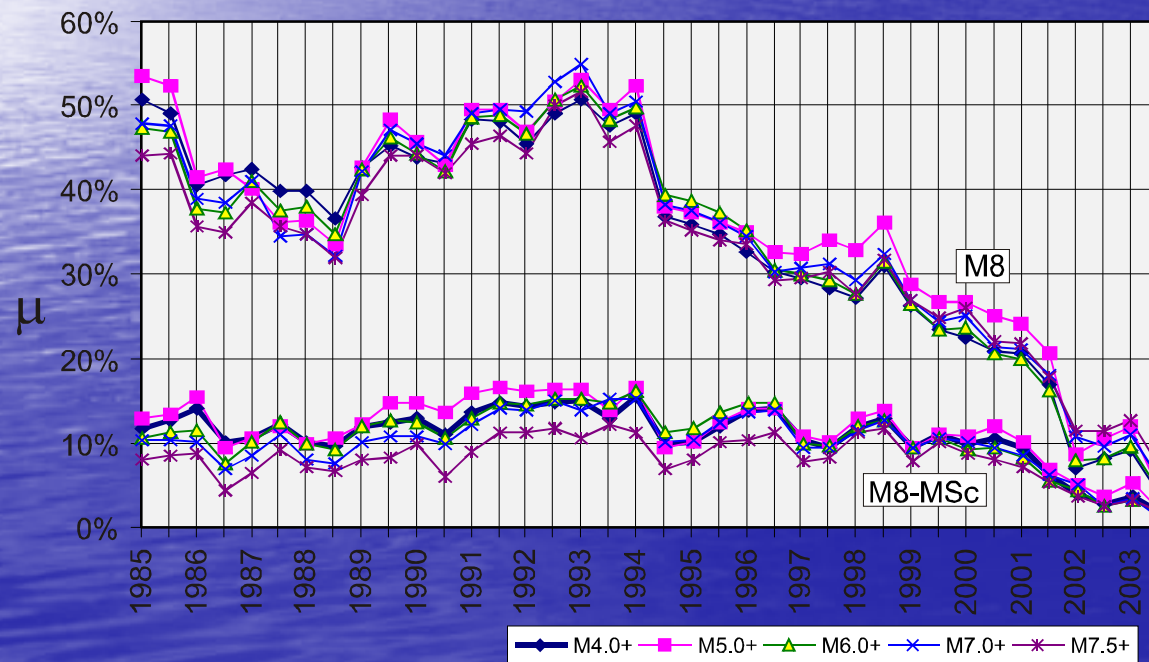
Earthquakes are rare events. Therefore, the application of the M8 algorithm is limited to the areas where reported earthquakes are large enough in number.

The color on the maps signifies the annual average number of earthquakes with magnitude 4 or larger in the 667-km (above) and 427-km (below) circles centered at the point.





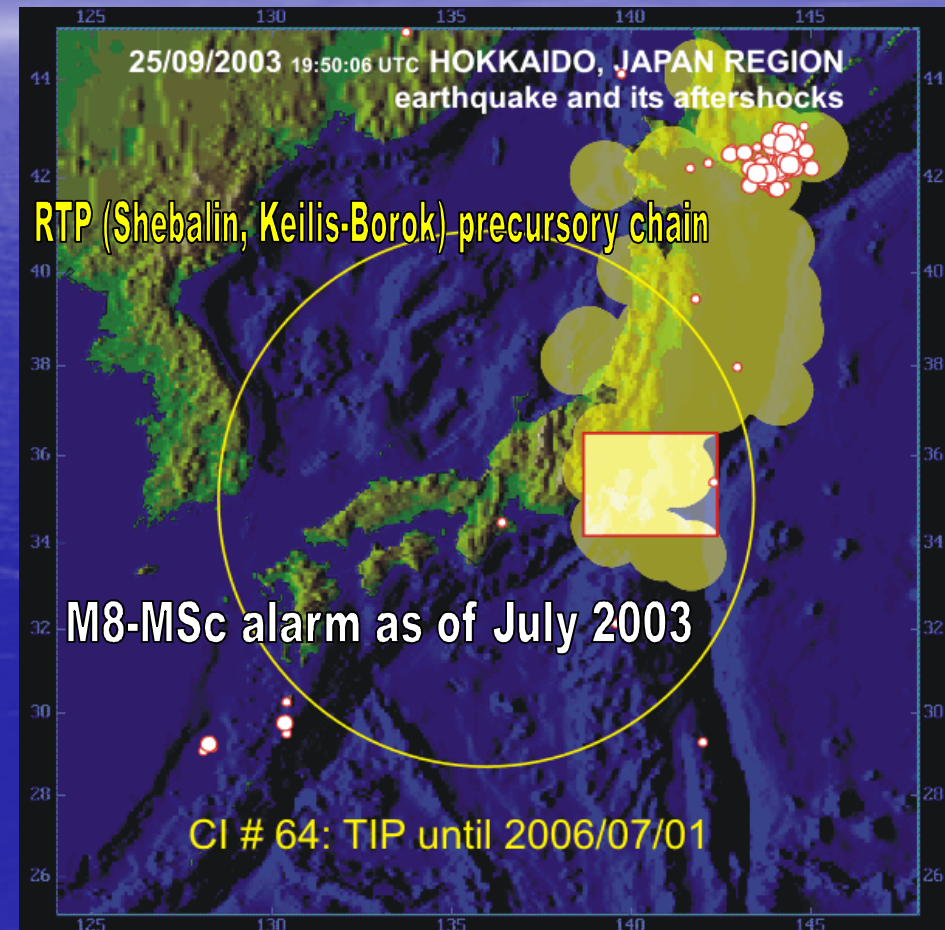
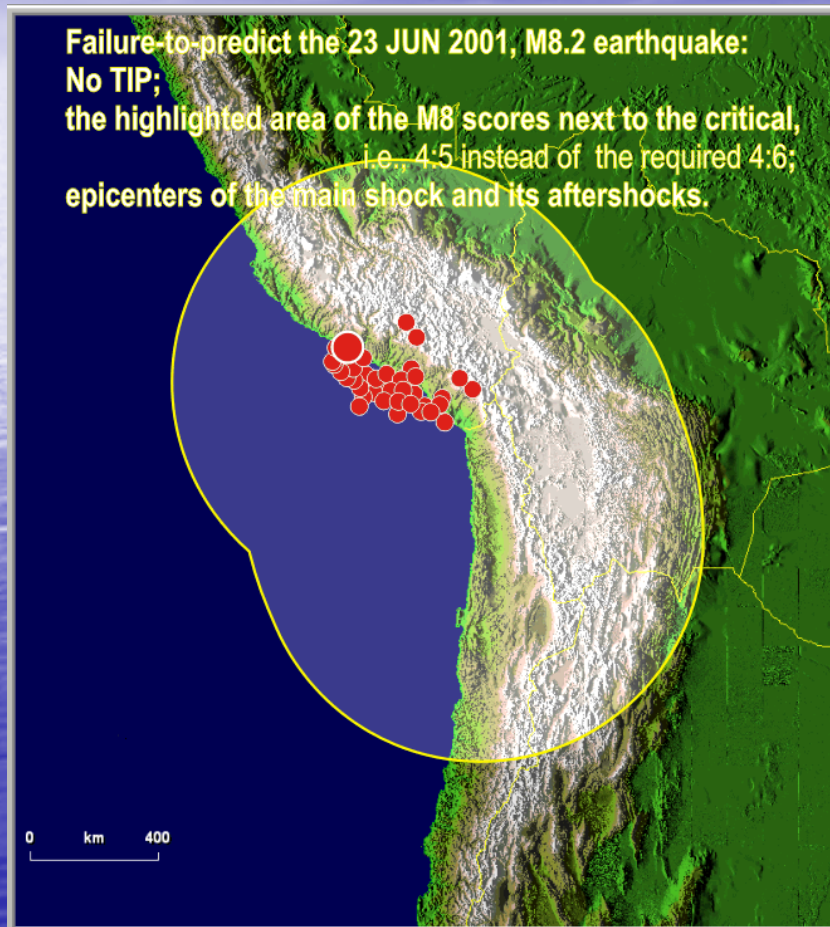
The percentage of alerted area as a function of time for M8.0+ (above) and M7.5+ (below).



The obtained estimates are based on the counts of magnitude 4 or more and 5 or more earthquakes in the period from 1964 through 1984, while the counts of magnitude above 6.0, 7.0, and 7.5 in 1900-1984

The emerging two types of failures-to-predict

All the five M8.0+ earthquakes that were not predicted in course the Global Test are either in the area of the scoring next-to-critical or in the chain of correlated earthquakes connected with M8-MSc prediction.



The area of investigation aimed at the M_0 + magnitude range may be larger than in the original version of the M8 algorithm.

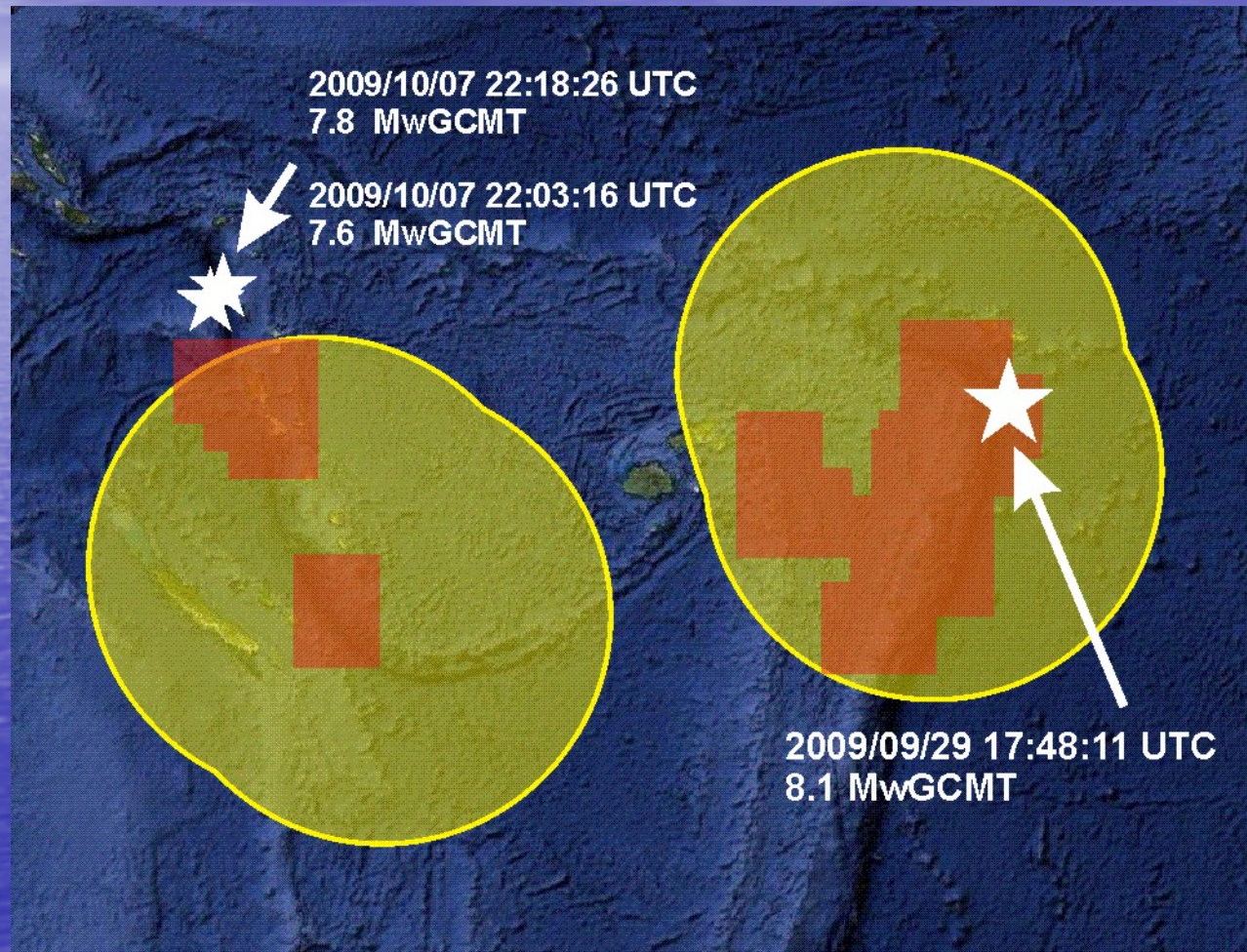
The dimension of the areas of investigation considered by M8 are set proportional to the linear dimensions of the target earthquake preparation zone of $R = 10^{0.43 M}$ km (*Dobrovolsky et al., 1979*) and are independently confirmed by *Bowman et al. (1998)*, who claimed that the size of the critical region of accelerated energy release scales with the magnitude of the impending event according to $\log_{10} R \sim 0.44 M$.

Therefore, the counts of the M8 algorithm are made in the narrow inner part of the potential preparation zone:

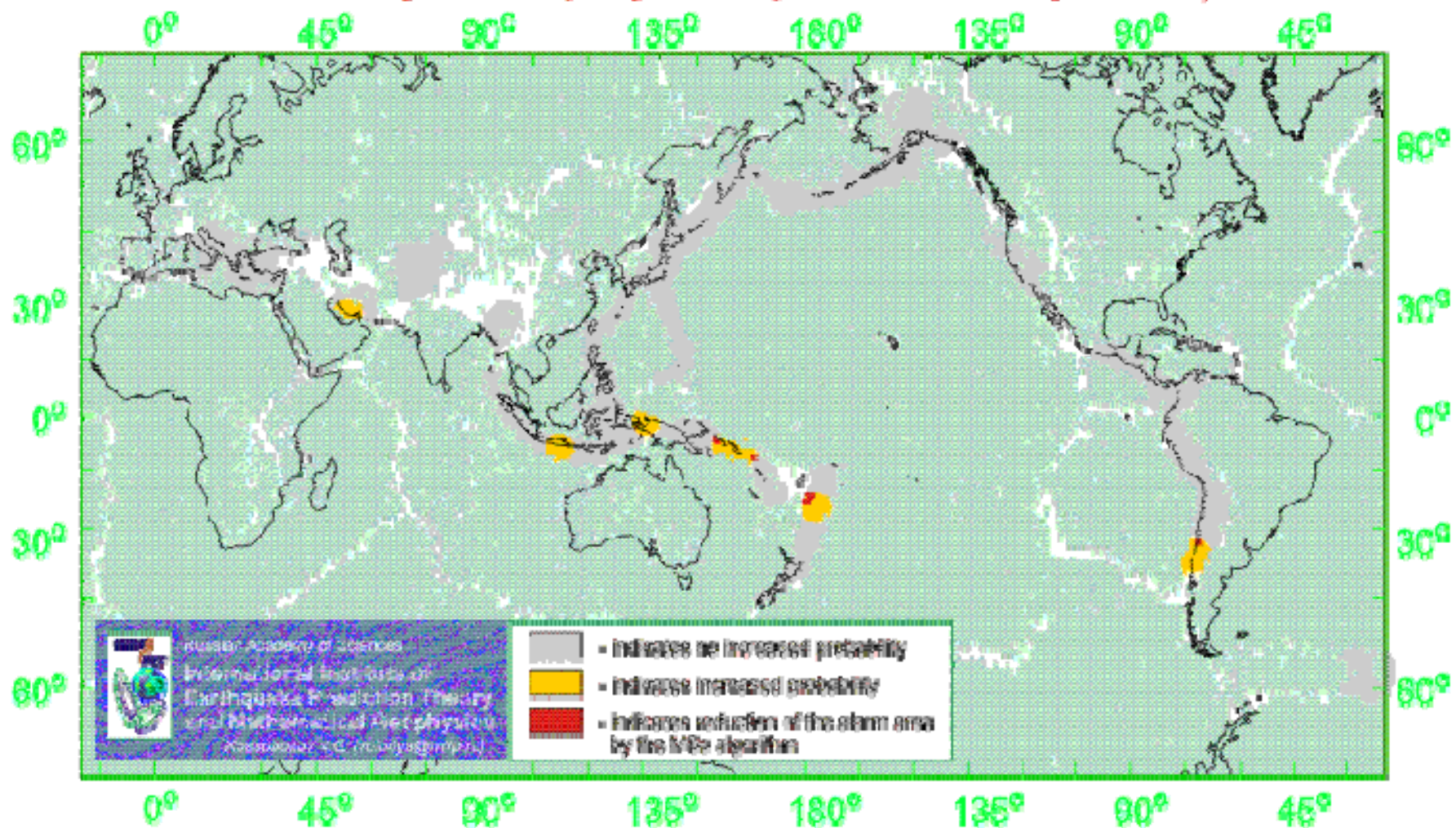
R_{M8} is about one quarter of R .

Real-time prediction of the world largest earthquakes

(<http://www.mitp.ru>)

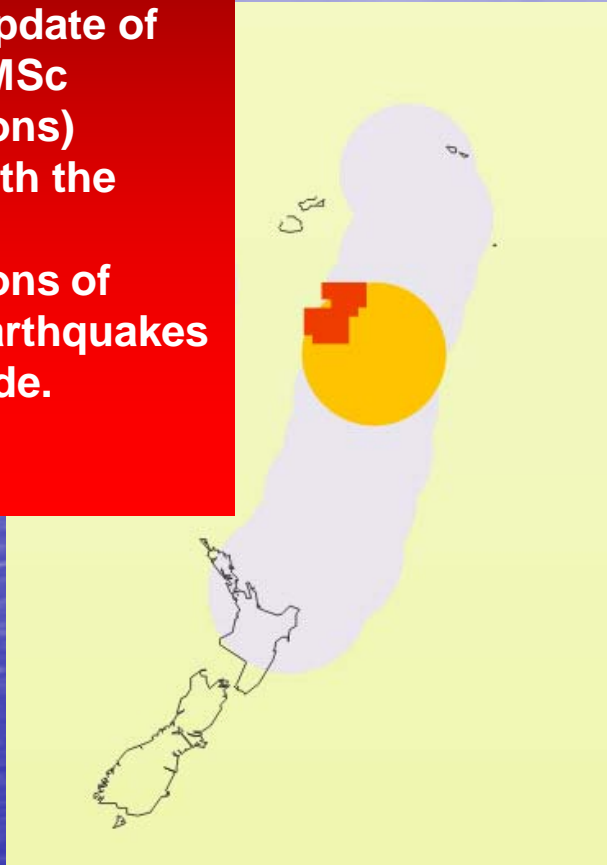


**Regions of Increased Probability of Magnitude 7.5+ Earthquakes
as on July 1, 2002 (subject to update on January 1, 2003)**



What was predicted...

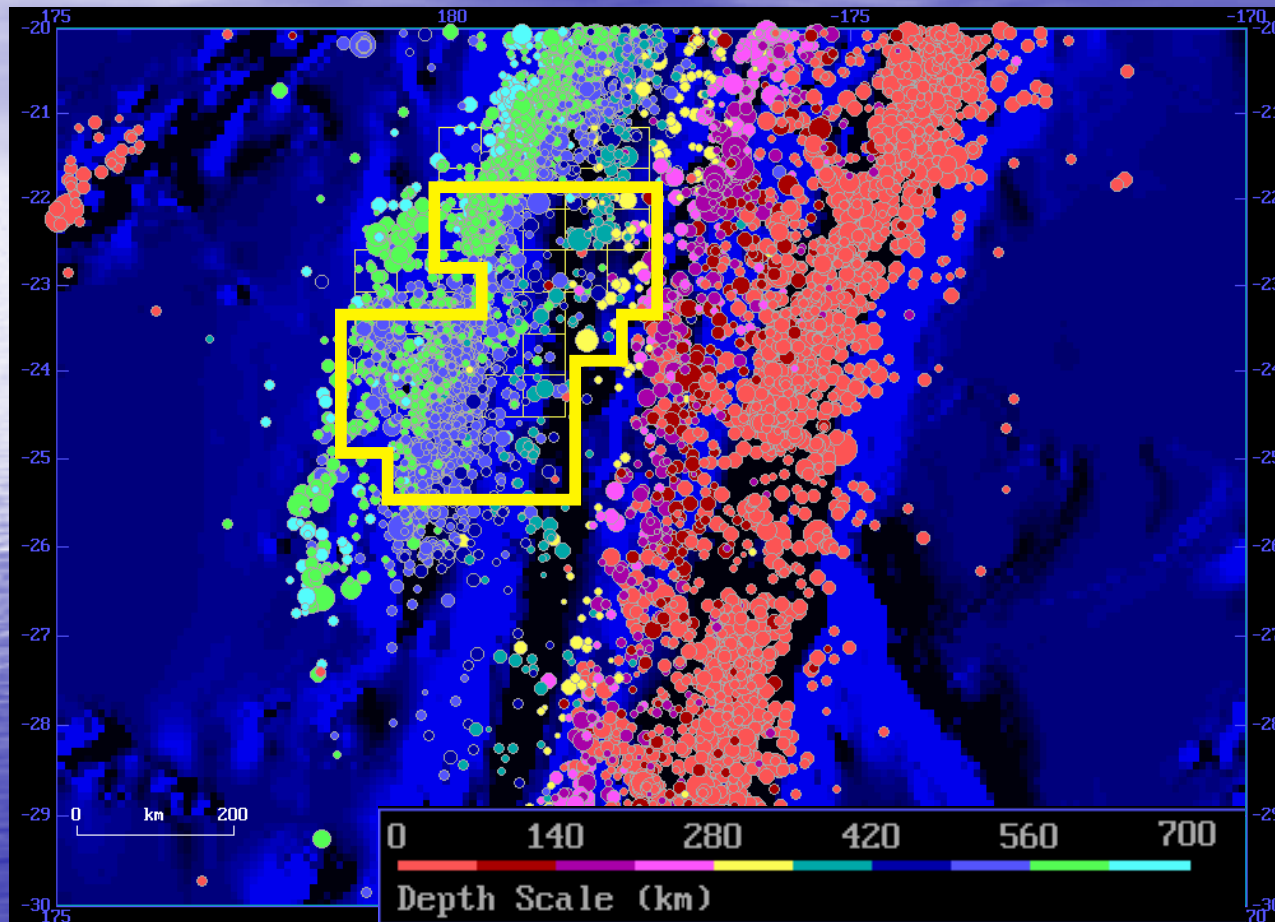
**Sent on Monday,
July 15, 2002
(Subject: The
2002b Update of
the M8-MSc
predictions)
along with the
updated
predictions of
major earthquakes
worldwide.**



- Earthquake(s) with magnitude 7.5 or more will occur in CI #5 (yellow) during the time period from July 2002 through July 2003.
- In the second approximation the MSc algorithm has identified the area (red) that stretch between

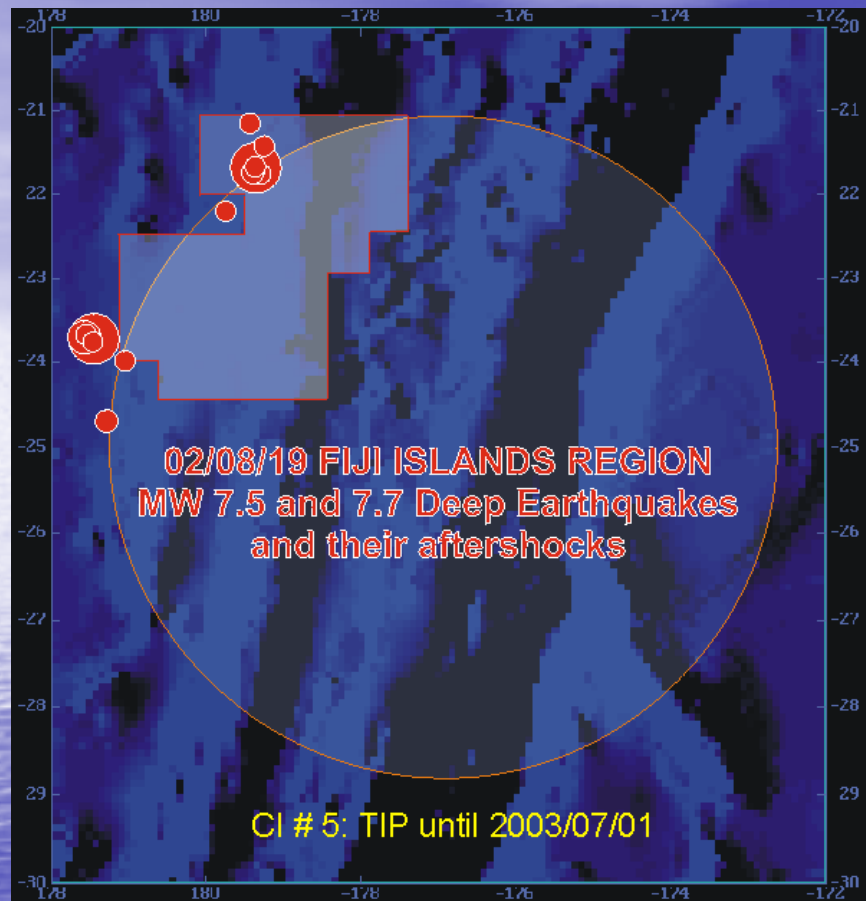
**24.52S - 21.16S and
178.76E - 177.53W.**

What was predicted...



- The position of the M8-MSc alarm that narrow down substantially the prediction area suggested the occurrence of the great deep earthquakes (depth of about 240-700 km).

What happened...



- EARTHQUAKES:
Origin times -
2002/08/19 11:01:01
2002/08/19 11:08:25 ;
Coordinates –
21.80S 179.49W
23.85S 178.41E;
Depths - 586.8 and 693.7 km;
Magnitudes –
MwGS (MeGS)
7.5 and 7.7 (7.7 and 7.4);
F-E Regions –
FIJI ISLANDS REGION and
SOUTH OF FIJI ISLANDS.

The two August 19 main shocks mark both northern and southern edges of the prediction area.

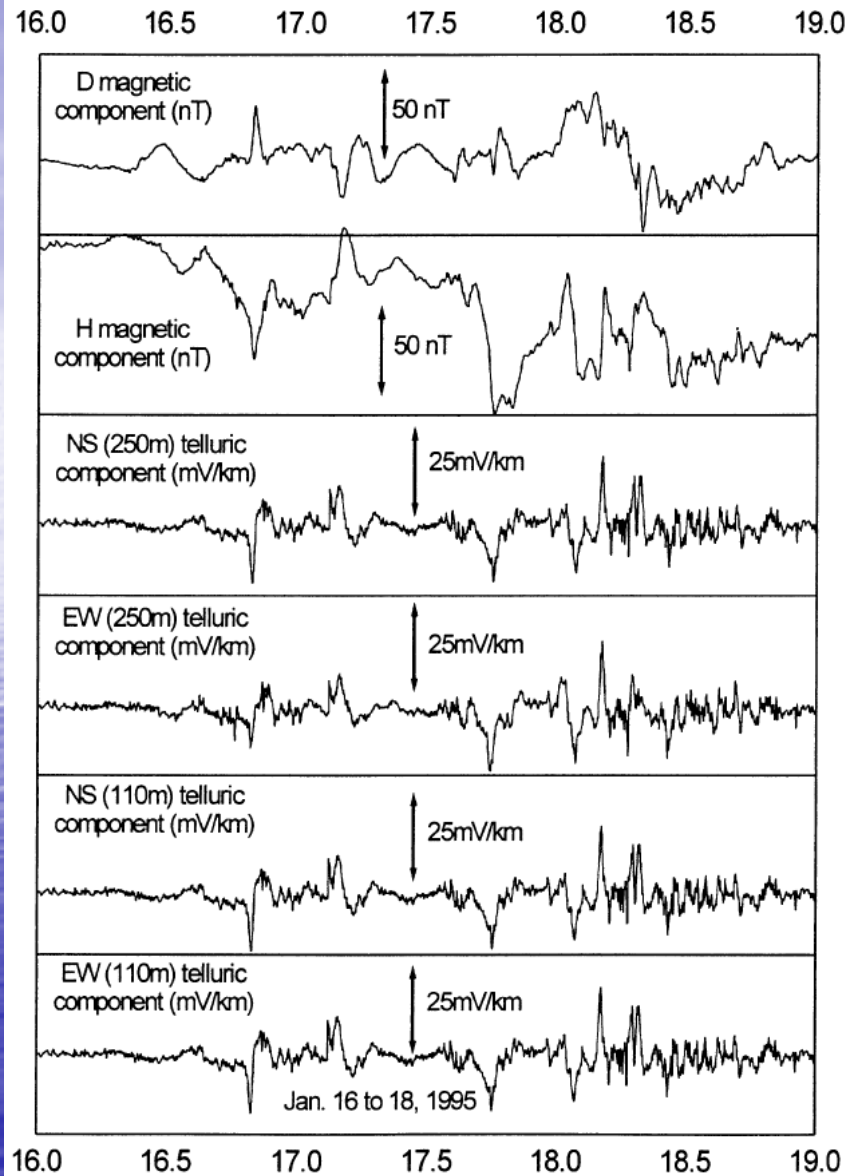
**Does it mean that sometimes exact prediction is not possible?
This reduction of the uncertainty provides probability gain of more than 25.**

Thus, the accuracy achieved by M8 and MSc algorithms in the on-going Global testing is intermediate in time domain and varies from middle to exact in space domain.

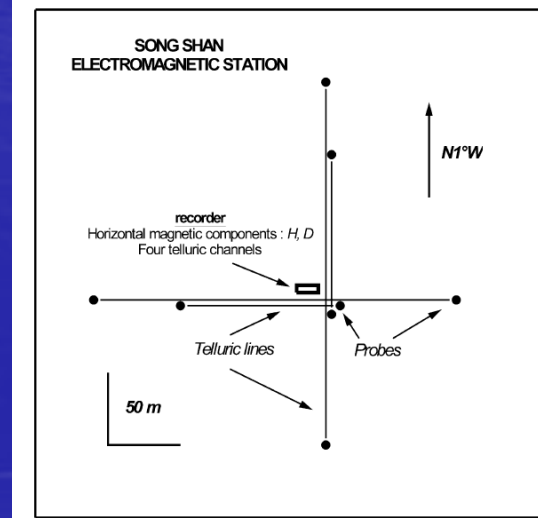
In some cases, the accuracy could be improved by making use of additional short-term monitoring of seismic activity and, perhaps, other geophysical fields in the alerted area of investigation.

One case-study of electromagnetic record about
the site of 21 July 1995, M5.7 Yong Deng,
China, earthquake in Tibet

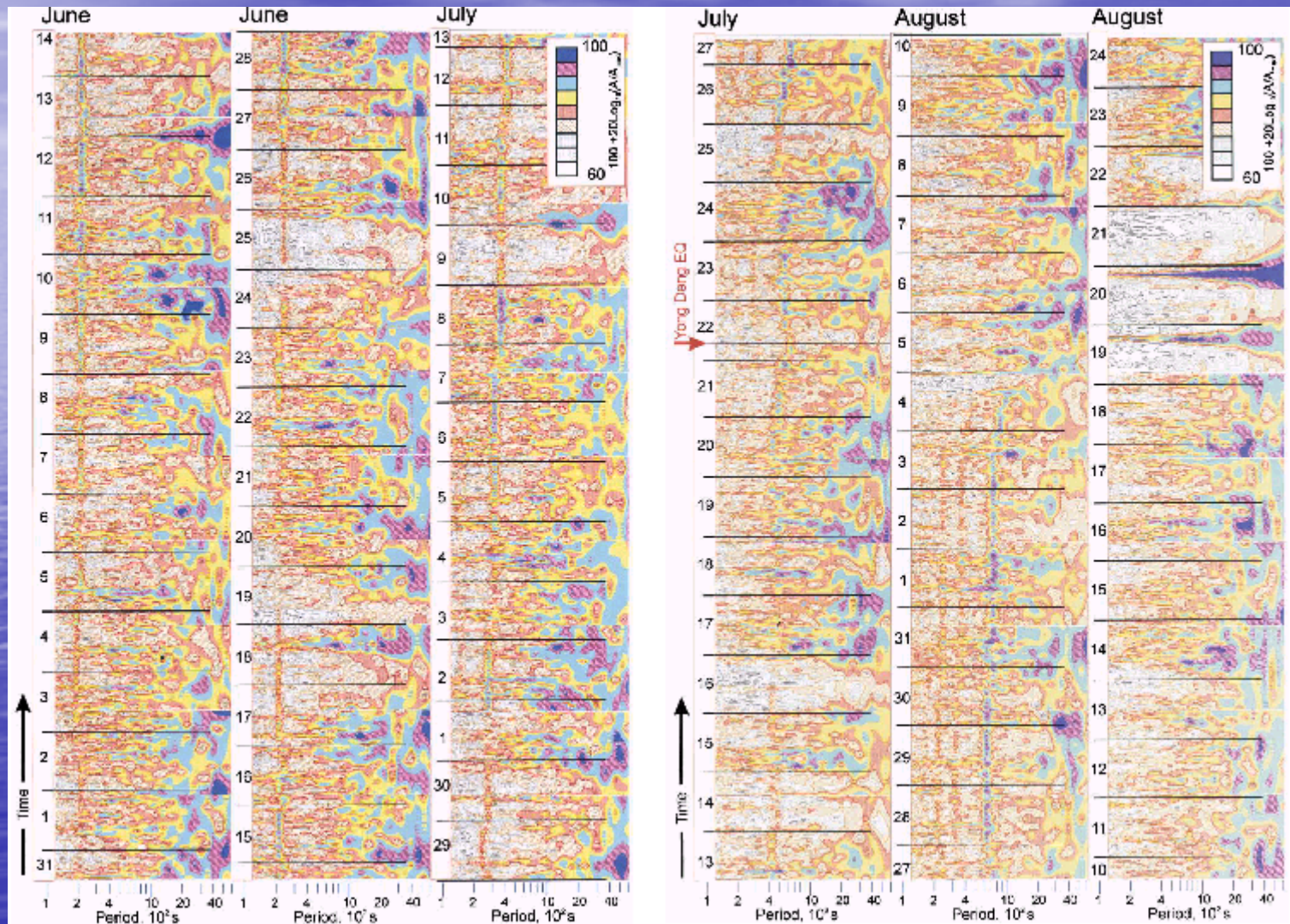


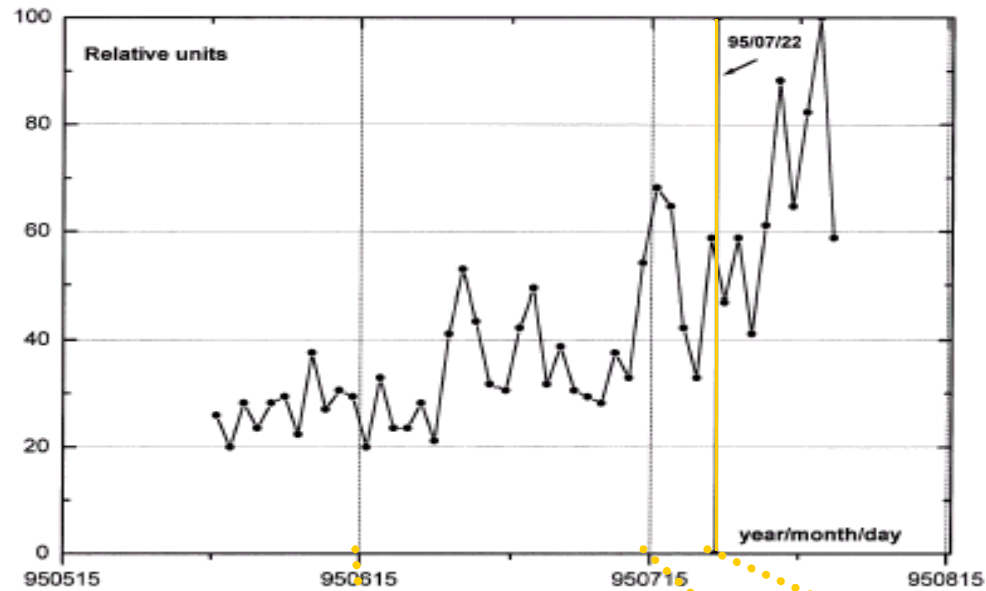


An example of raw data recordings on the six channels in 1995



FTAN diagram of the resistance observed on NS 250-m line

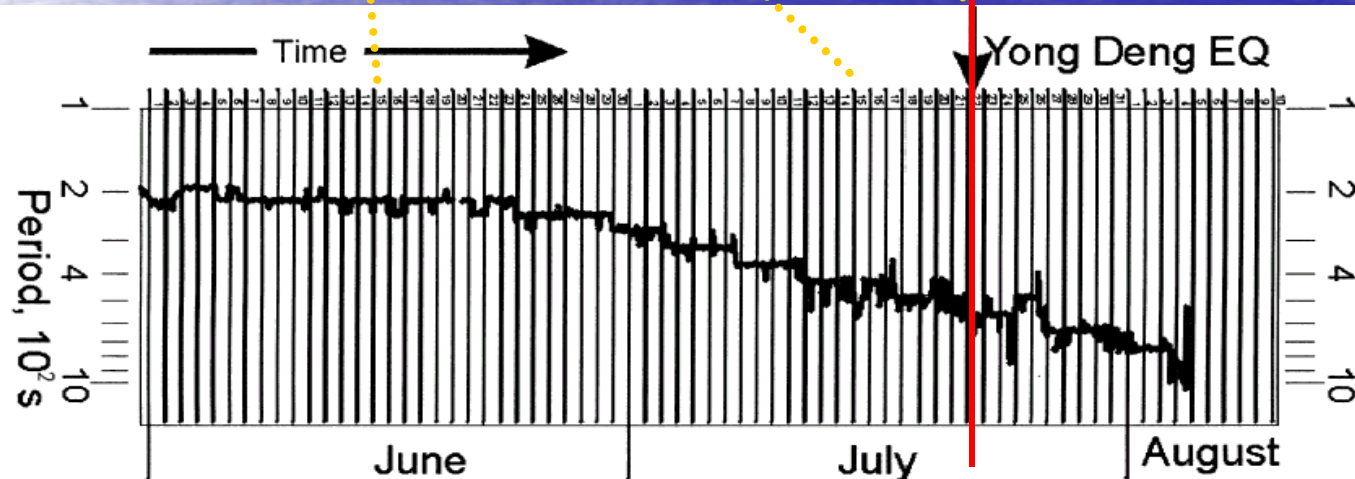




Evolution of the ULF signal

- Intensity and
- Period

GROW

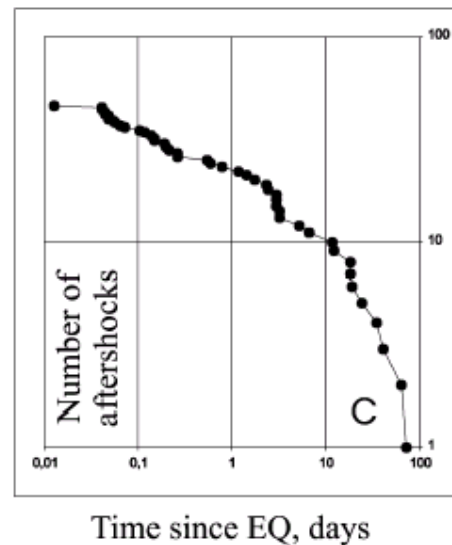
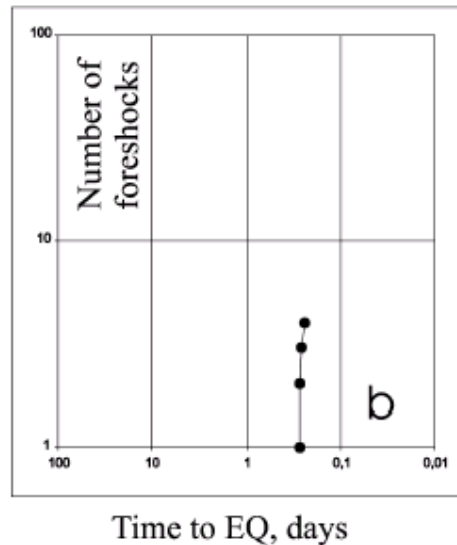
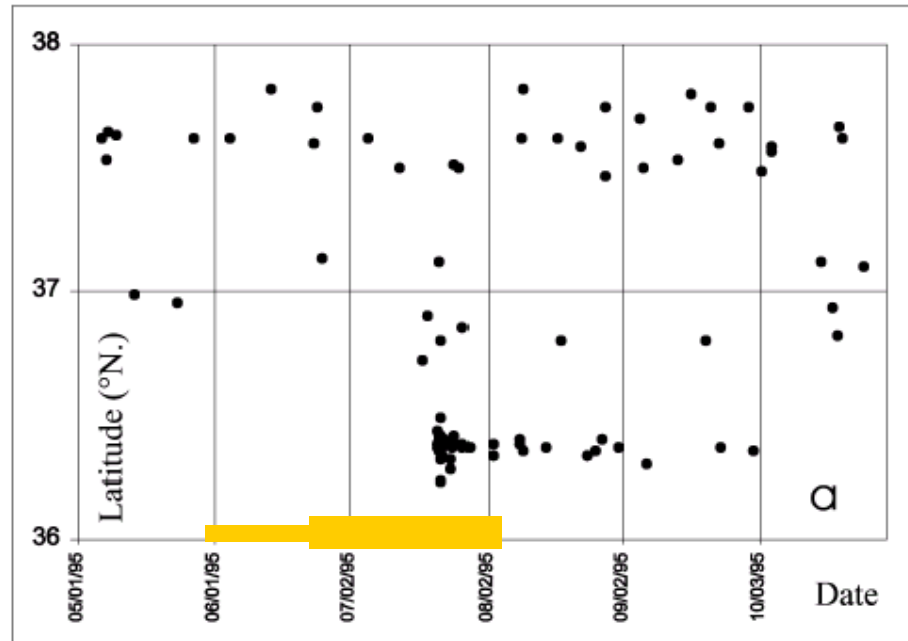


Evolution of the ULF signal

The 1995 Yong Deng earthquake occurred in less than 100 km from the instrument at the time of characteristic ULF and/or its power decay on component directed at the epicenter.

The appearance of the ULF signal accompanied with a rise of seismic activity on adjusting segment of Haiyuan fault system.

The characteristic ULF collapsed just before aftershocks fast disappeared (exponentially).



Thus, the accumulated case-histories of predicted and not predicted earthquakes provide us unique and so far rather limited information that may help understanding the ultimate limits of seismic predictability.

- Nevertheless, the accuracy of the M8-MSc predictions is already enough for undertaking earthquake preparedness measures, which would prevent a considerable part of damage and human loss, although far from the total.
- The methodology linking prediction with disaster management strategies does exist.
- These achievements encourage Geoscientists to initiate shifting the minds of community from pessimistic disbelief to optimistic challenging issues of

Seismic Hazard Predictability



Thank you!

"When sorrows come, they come not single spies, but in battalions"
(William Shakespeare, 1564-1616)