

# **Predictability of extreme events with applications to surges of mass violence and terrorism**

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## **Collaboration of scientists and technical experts from:**

- ❖ IIEPT, Moscow
- ❖ Moscow State University
- ❖ Institute of Mathematics & Mechanics, Russian Ac. Sci. (Ekaterinburg)
- ❖ Vernadsky State Geological Museum, Russian Ac. Sci.
- ❖ UCLA
- ❖ MIT
- ❖ UC Davis
- ❖ Purdue University
- ❖ USGS
- ❖ LA Dept of Water and Power
- ❖ Los Alamos Natl. Laboratory
- ❖ LA Police Department
- ❖ The Abdus Salam International Centre for Theoretical Physics, Trieste
- ❖ University of Trieste
- ❖ University of Rome (La Sapienza)
- ❖ EU Int. School for Public Policy Studies, Luxembourg
- ❖ Institut de Physique du Globe de Paris
- ❖ Ecole Normale Supérieure (Paris)
- ❖ Observatoire de la Côte d'Azur
- ❖ Geophysical Institute of Israel
- ❖ University of Tel Aviv
- ❖ Council for Disaster Preparedness, Govt. of Israel
- ❖ Natl. Center for Physics, Islamabad
- ❖ Natl. Institute of Geophysics, Hyderabad

**Intermittent collaboration with disaster management organizations in Russia, Italy, US, and reinsurance companies in Russia, Switzerland, and Spain.**

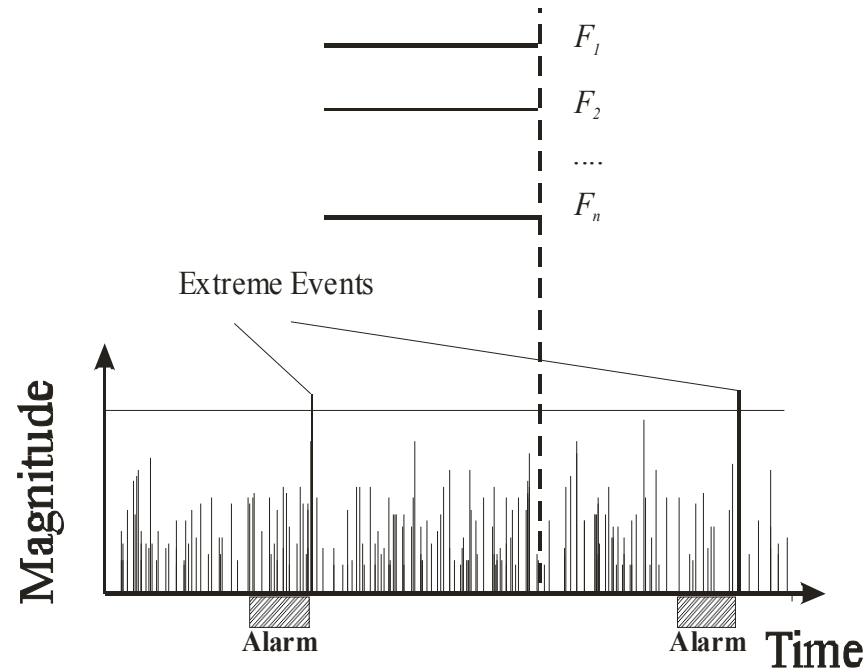
## **Coping with the lack of fundamental equations**

*“It became clear for me that it is unrealistic to have a hope for the creation of a pure theory [of the turbulent flows of fluids and gases] closed in itself.*

*Due to the absence of such a theory we have to rely upon the hypotheses obtained by processing of the experimental data.”*

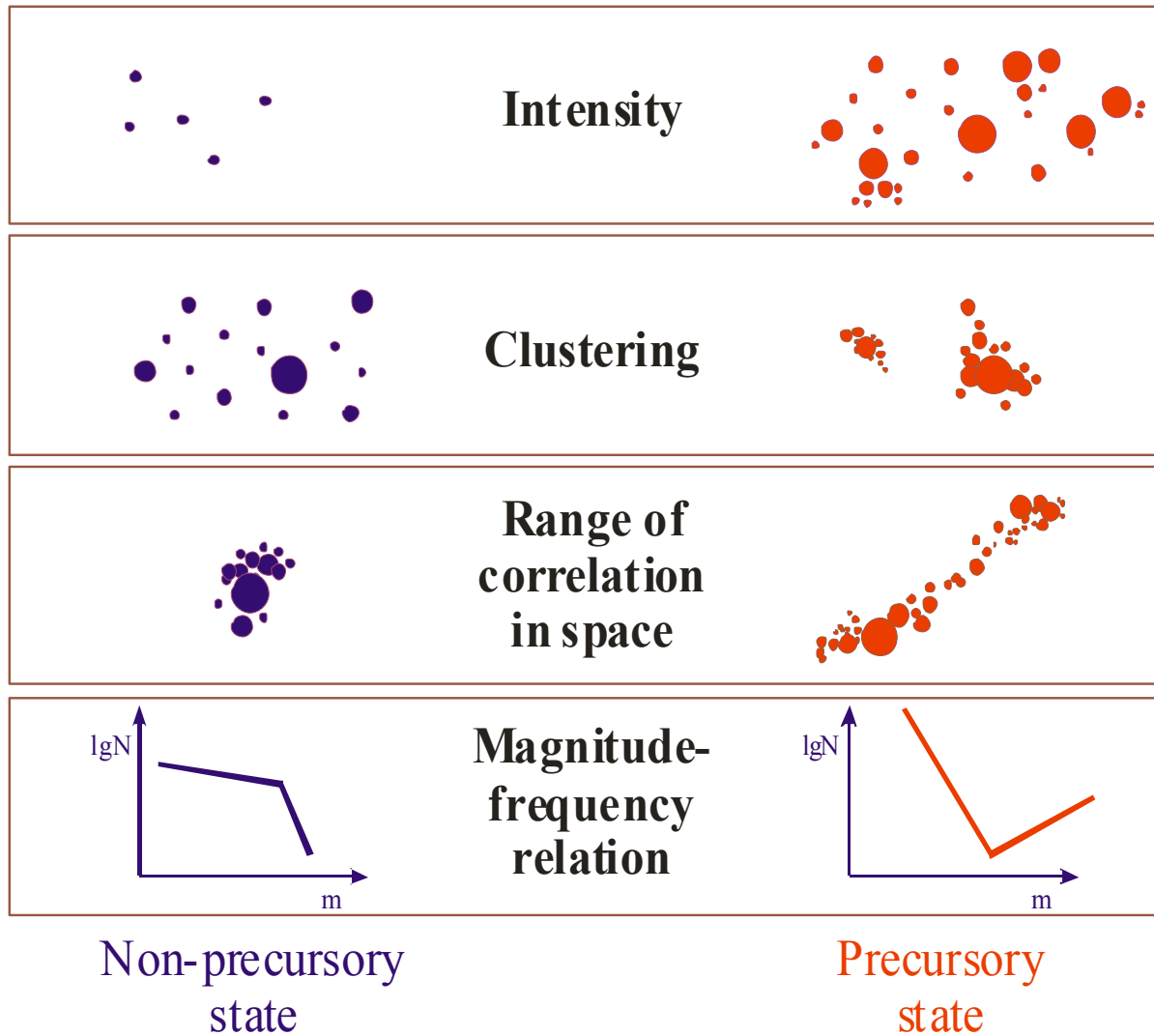
**A. Kolmogorov.**

# SCHEME OF DATA ANALYSIS

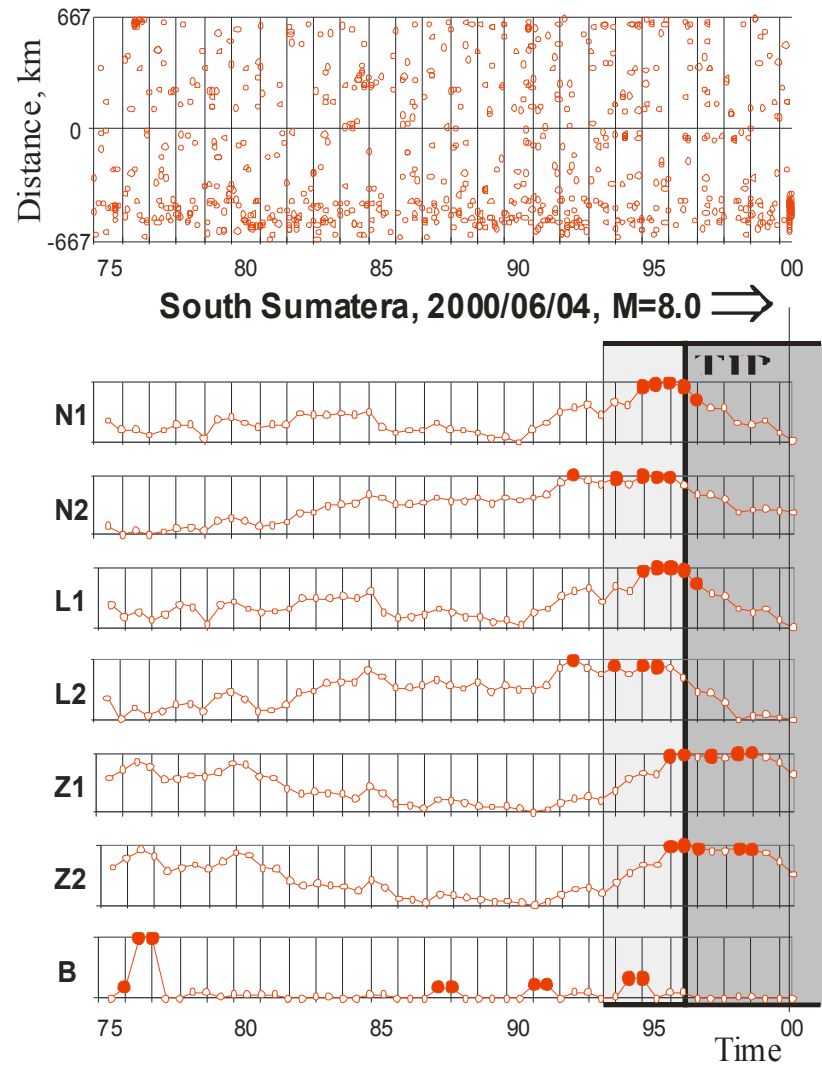
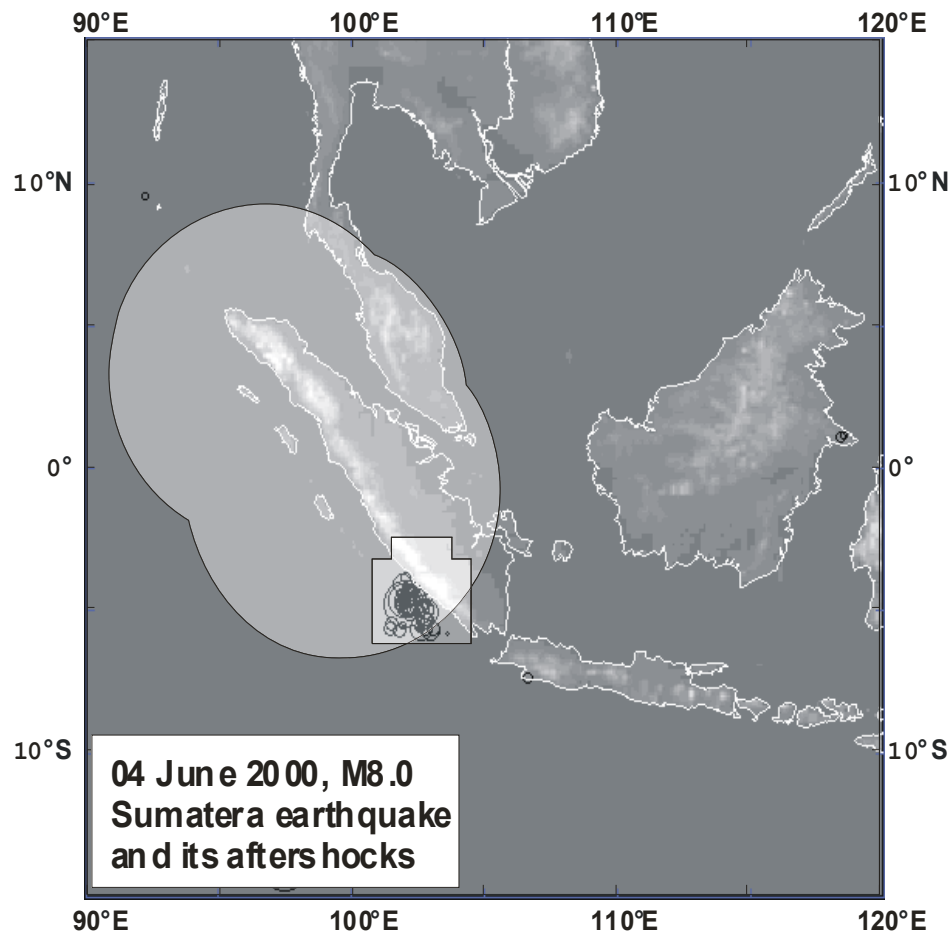


Prediction is targeted at **extreme events**.

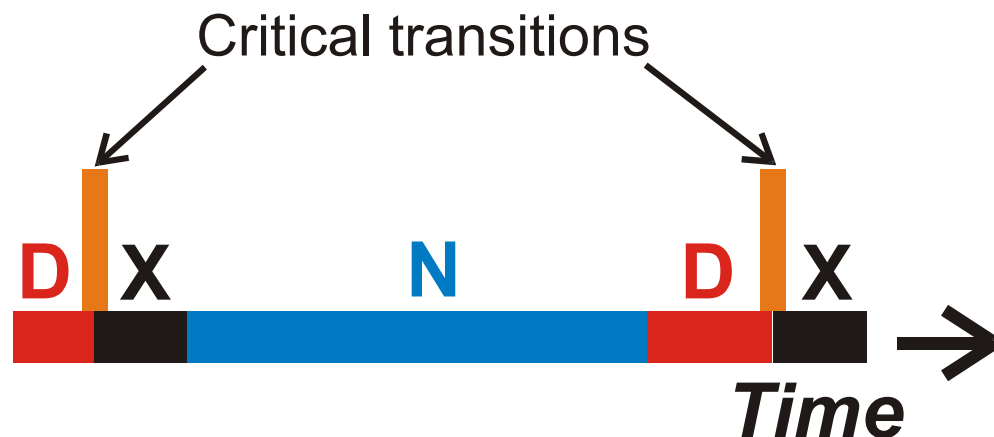
Vertical lines show the point process, where precursors are looked for; continuous processes might be considered as well.  $F_k$  are the its integral characteristics, capturing hypothetical precursors. The set of precursors is used for pattern recognition of alarms.



**Premonitory transformation of complex processes (found in modeling and data analysis).**



# COMPARING SCALING CLOSE TO AND FAR FROM EXTREME EVENTS



- Time is divided into periods of three kinds:  
**D** - preceding a critical transition; **X** - following it; **N** – other time intervals
- Scaling relation is function  $N(m)$  - the number of events of the size  $\geq M$ ; its useful normalization is  $N(M) = \check{N} P(M)$  where  $\check{N}$  is the total number of events.
- We determine  $N(M)$  separately for periods **D** and **N**. Their difference demonstrates premonitory pattern considered. Its predictive power requires further analysis.

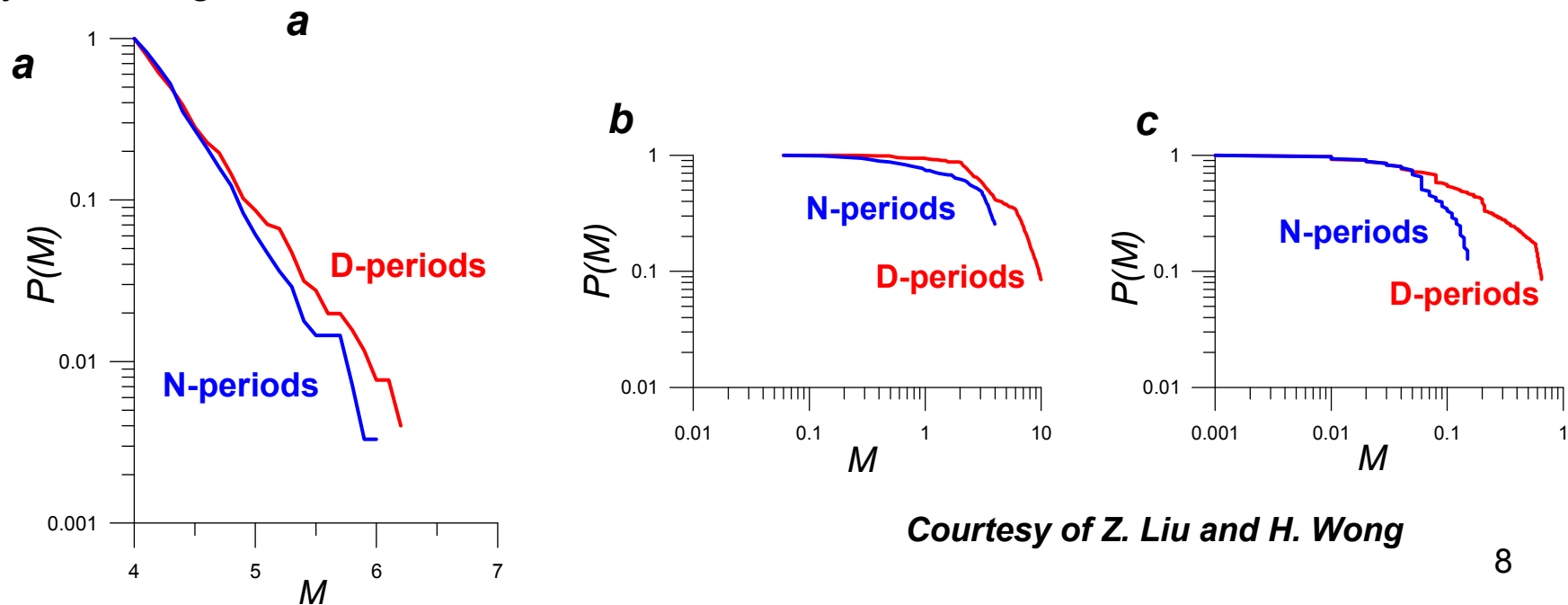
# A POINT OF DEPARTURE – EARTHQUAKES

SOUTHERN CALIFORNIA, 1954 – 2006 (a), CALIFORNIA, 1968 – 2005(b, c).

**Critical transitions (prediction targets)** are the earthquakes with  $M \geq 6.4$  (a) and the main shocks with  $M \geq 6.4$  (b, c).

**Probabilities  $P(M)$**  are estimated for magnitudes of individual earthquakes (a),  $M$  is the logarithmic measure of energy released by an earthquake, and for clusters of aftershocks formed around individual earthquakes.  $P(M)$  is estimate of probability that the magnitude of an earthquake  $\geq M$  (a) or that cluster's size  $\geq M$  (b, c).

Cluster's size is measured in number of aftershocks not weighted (b) or weighted (c) by their magnitudes.



Courtesy of Z. Liu and H. Wong

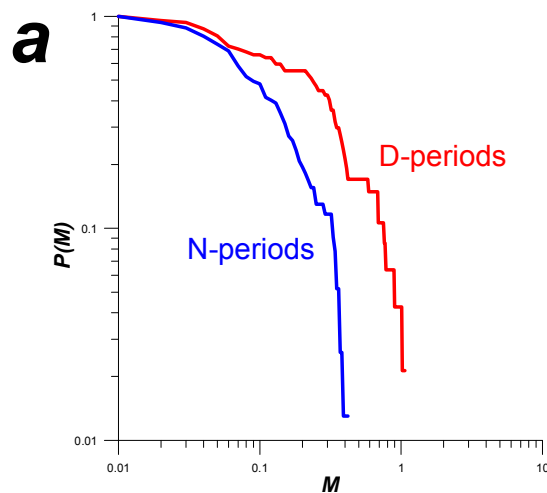
# Socio-economic crises

## US ECONOMIC RECESSIONS (a), SURGES OF UNEMPLOYMENT, US, 1961 - 2005 (b), SURGE OF HOMICIDES, LOS ANGELES, 1975 – 1993 (c).

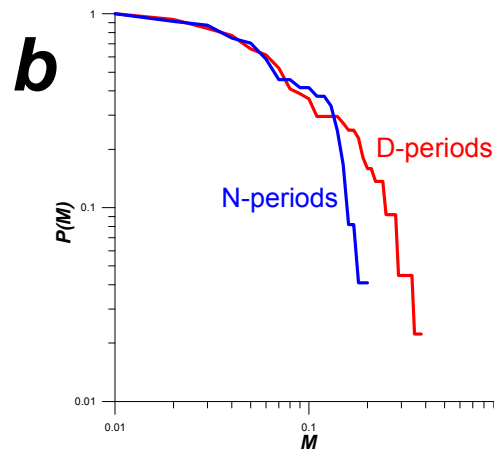
**Critical transitions (prediction targets)** are the start of a recession (a), the starting point of a fast and lasting acceleration of unemployment rate (b), and the starting point of a lasting surge of homicide rate (c).

**Probabilities  $P(M)$**  are estimated for the drop  $M$  of industrial production's trend (a and b) and for the monthly rates of lesser crimes – assaults with firearms (c).  $P(M)$  is estimate of probability that the drop of industrial production's trend (a and b) or of the monthly rate of lesser crime (c) has the absolute size  $\geq M$ .

**Refs:** links given in the figures.



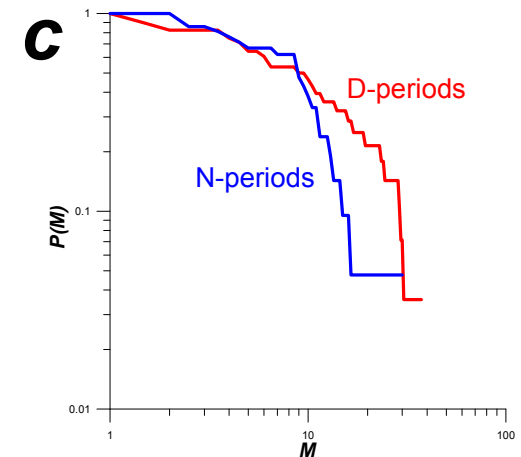
<http://www.igpp.ucla.edu/prediction/ref/Pre-recession.pdf>



<http://www.igpp.ucla.edu/prediction/ref/Homicide.pdf>

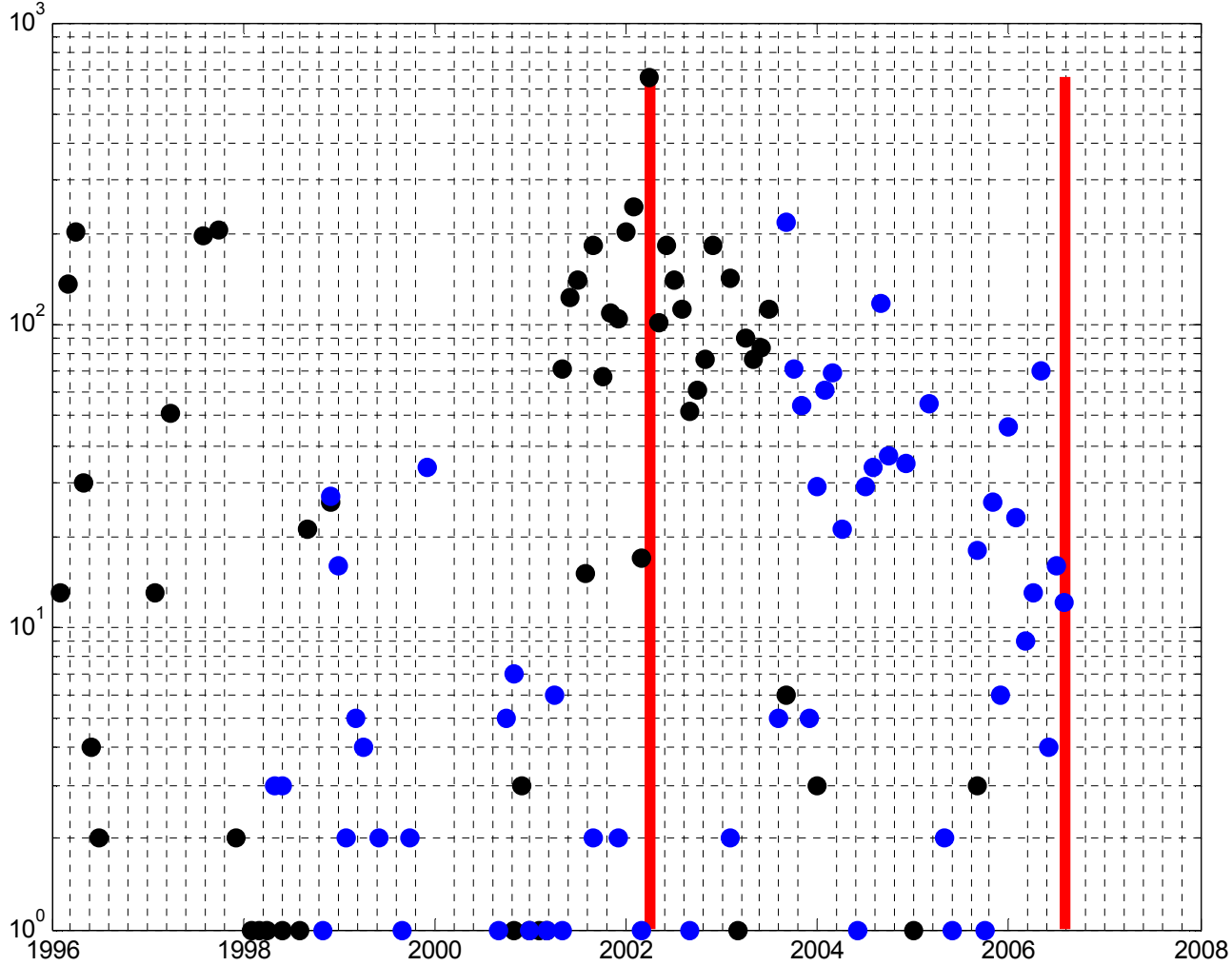
**Current alarm** is placed on prediction website of the Anderson's school of management, UCLA.

<http://www.uclaforecast.com>



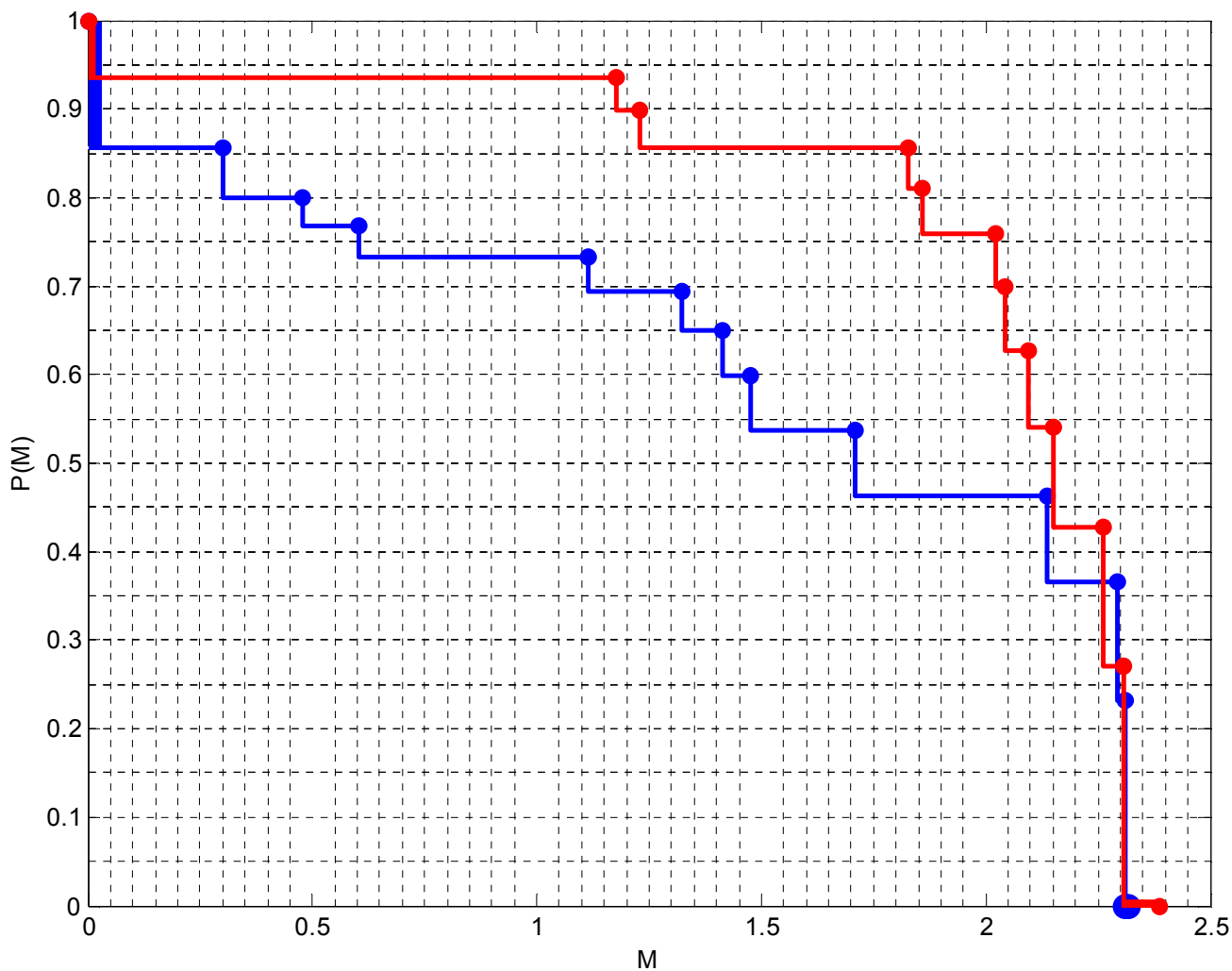
<http://www.igpp.ucla.edu/prediction/ref/Unemployment.pdf>

**Israel, deaths & injuries per year**, monthly indicators,  
international (black dots) & domestic (blue dots), 1996.01-2006.07.  
Extreme events: 2002.03 (Gaza) and 2006.07 (Lebanon)

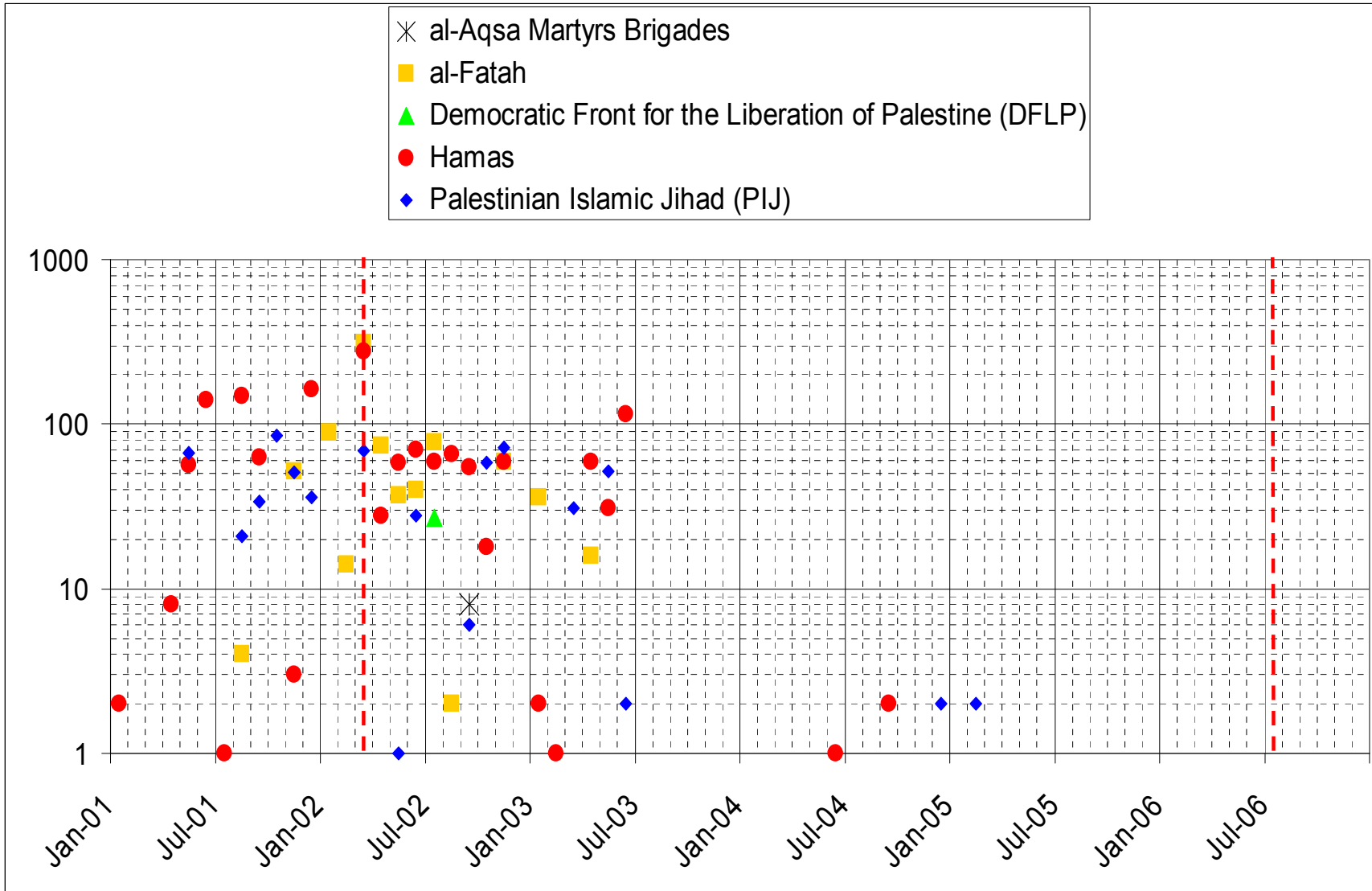


**Israel, deaths & injuries per year, international,  
1996.01-2002.03 (first extreme event).**

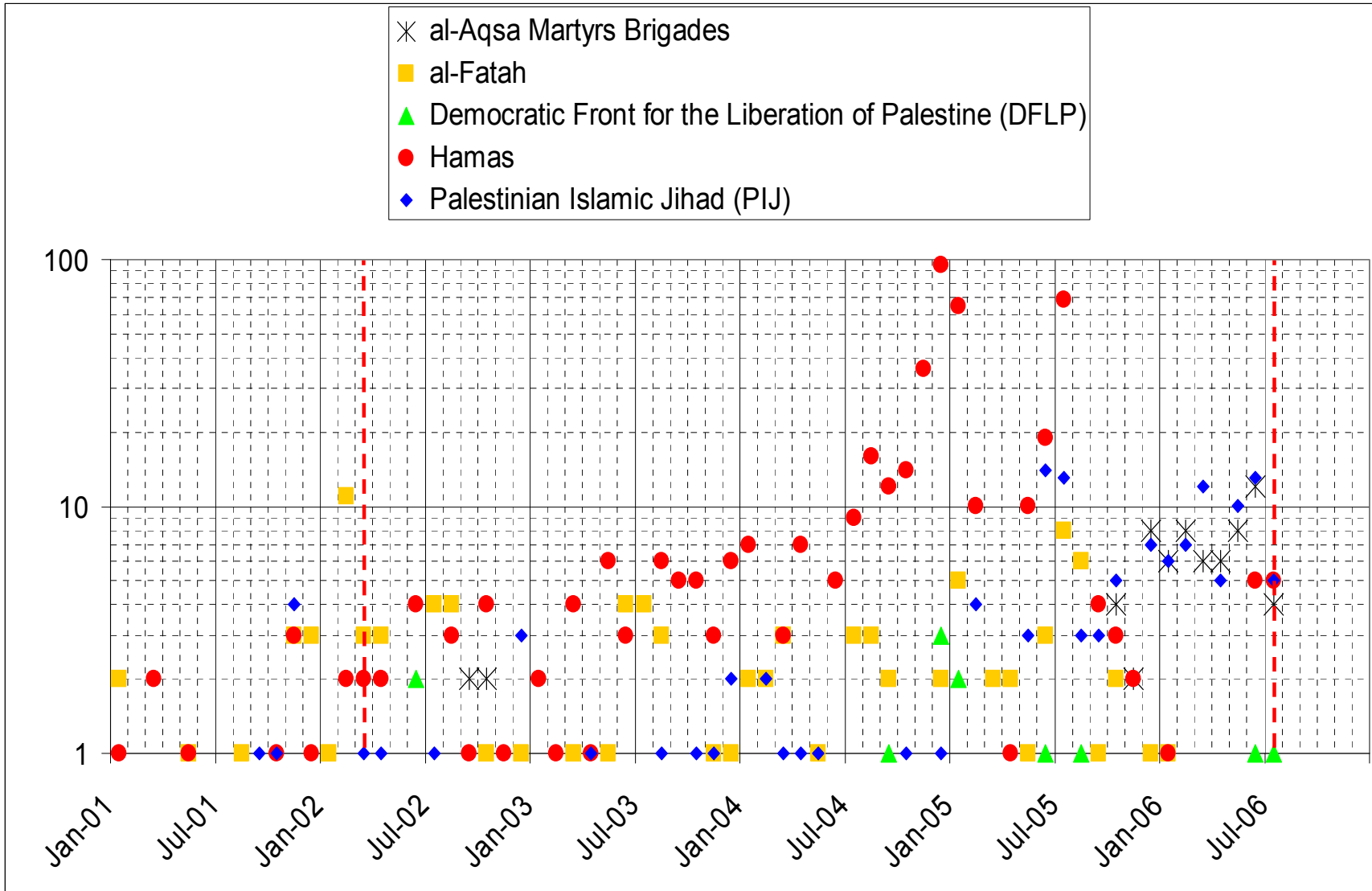
$D = 14.8$  months,  $N = 59.2$  months ,  $N_{tot}^D = 13$ ,  $N_{tot}^N = 20$ .  
Magnitude distributions for interval D (red) and N (blue).



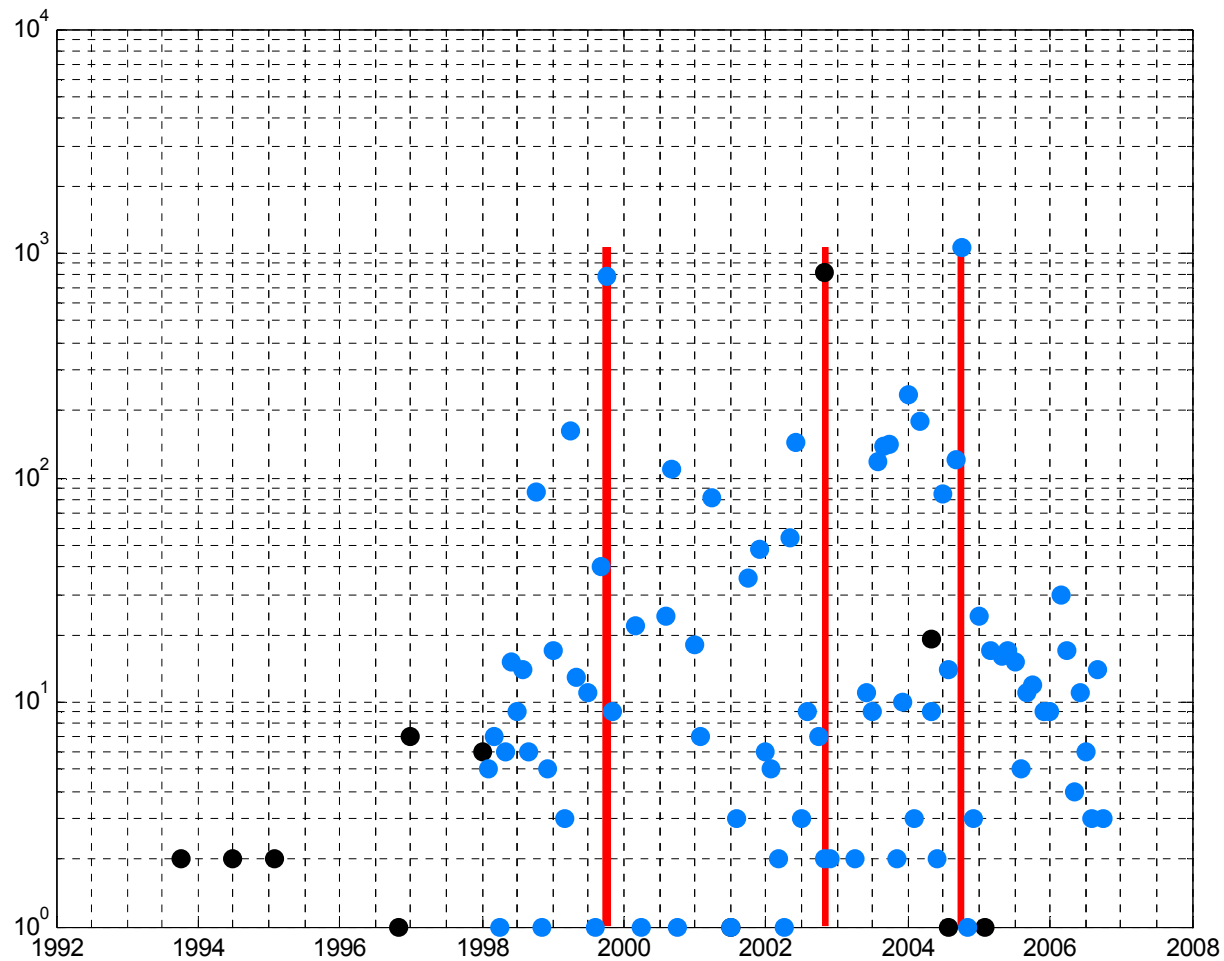
**Israel, deaths & injuries by groups, international, 2001.01-2006.07.**  
 Extreme events: 2002.03 (Gaza) and 2006.07 (Lebanon).



1.3d Israel, incidents by groups, domestic, 2001.01-2006.07.  
 Extreme events: 2002.03 (Gaza) and 2006.07 (Lebanon).

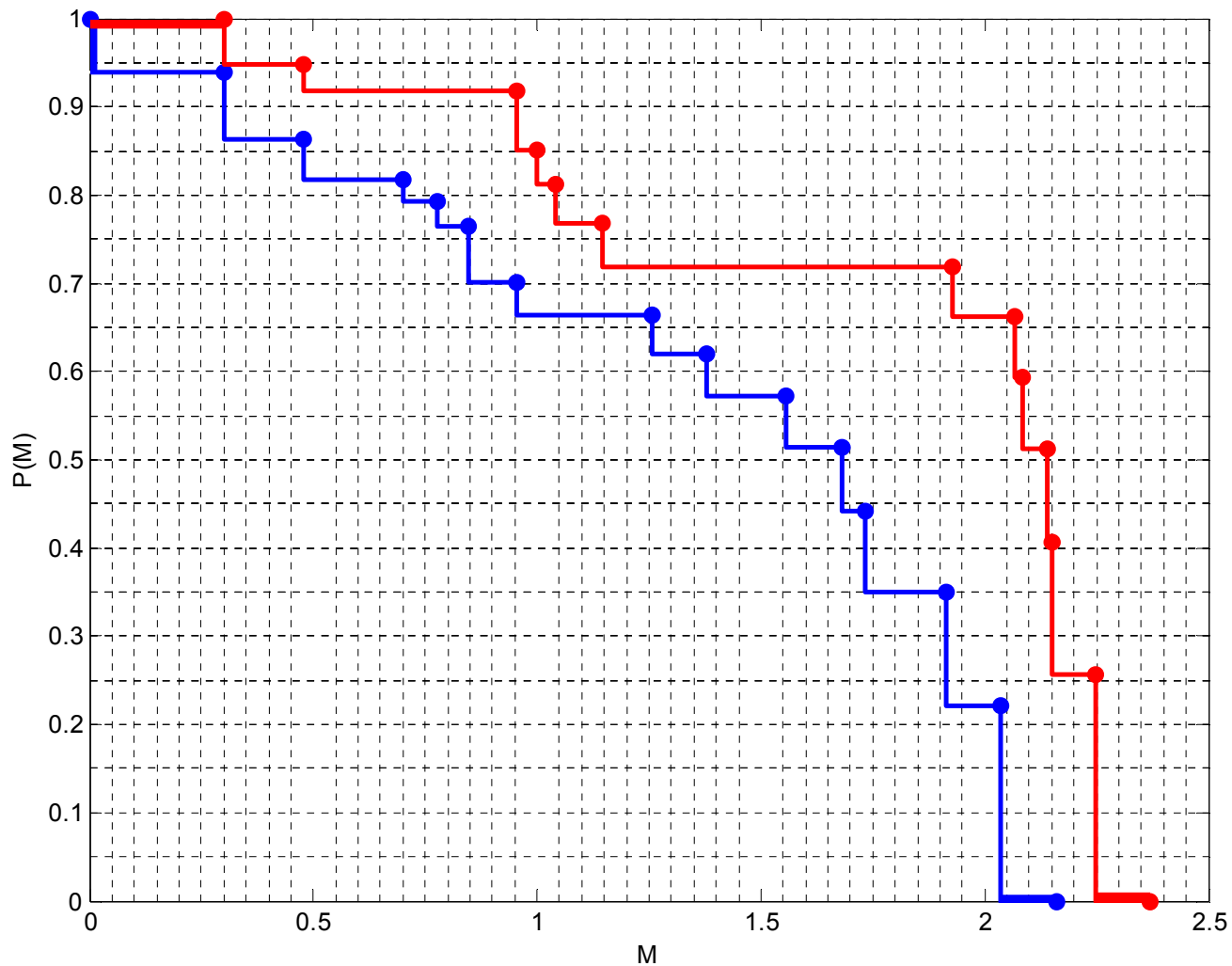


**2. Russia, deaths & injuries per year, monthly indicators, international (black dots) & domestic (blue dots), 1993.01-2006.07.**  
Extreme events: 1999.09 (Moscow), 2002.10 (Moscow) and 2004.09 (Beslan)

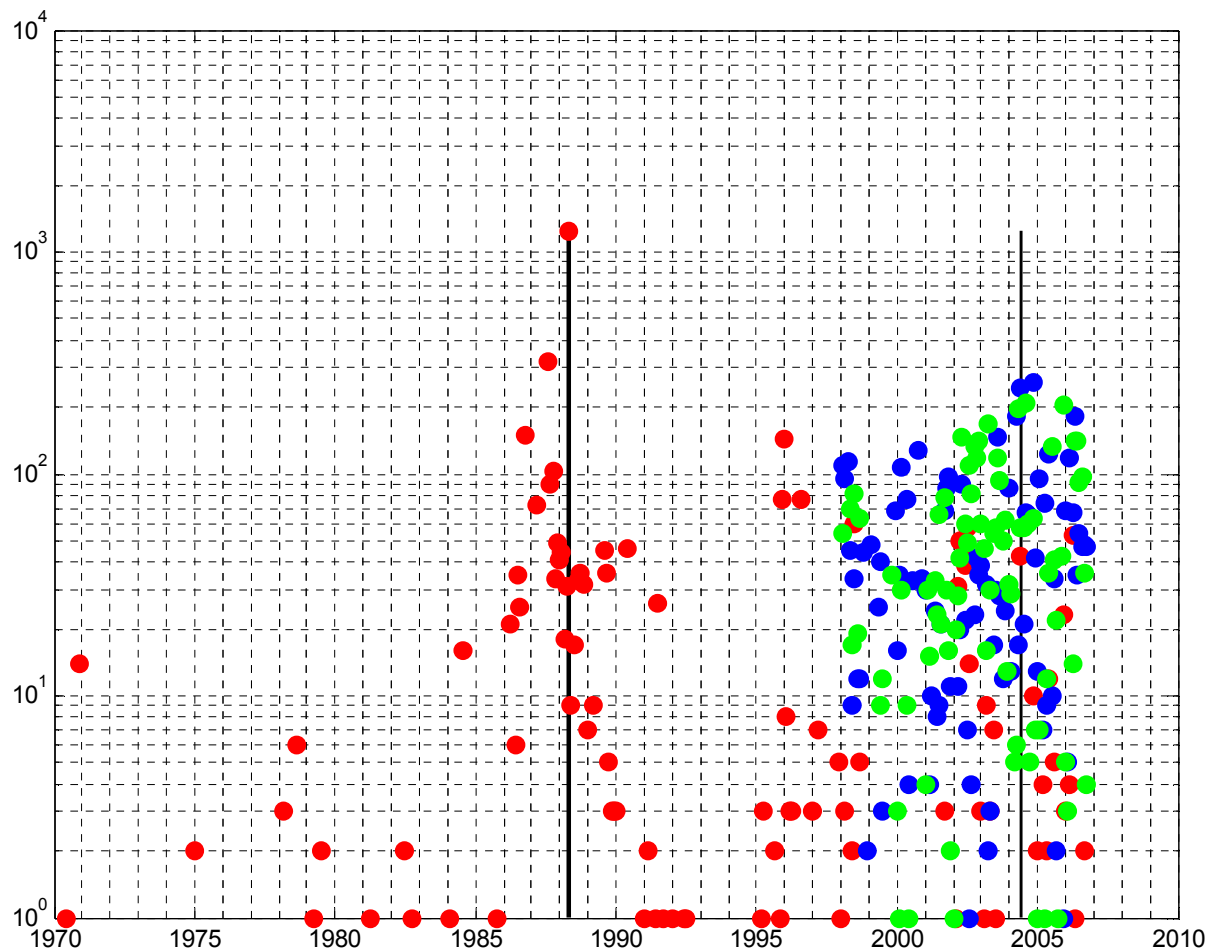


**Russia, deaths & injuries per year, domestic,  
2000.01-2004.09 (second extreme event).**

$D = 17.1$  months,  $N = 39.9$  months,  $N_{\text{tot}}^D = 15$ ,  $N_{\text{tot}}^N = 23$ .  
Magnitude distributions for interval D (red) and N (blue).

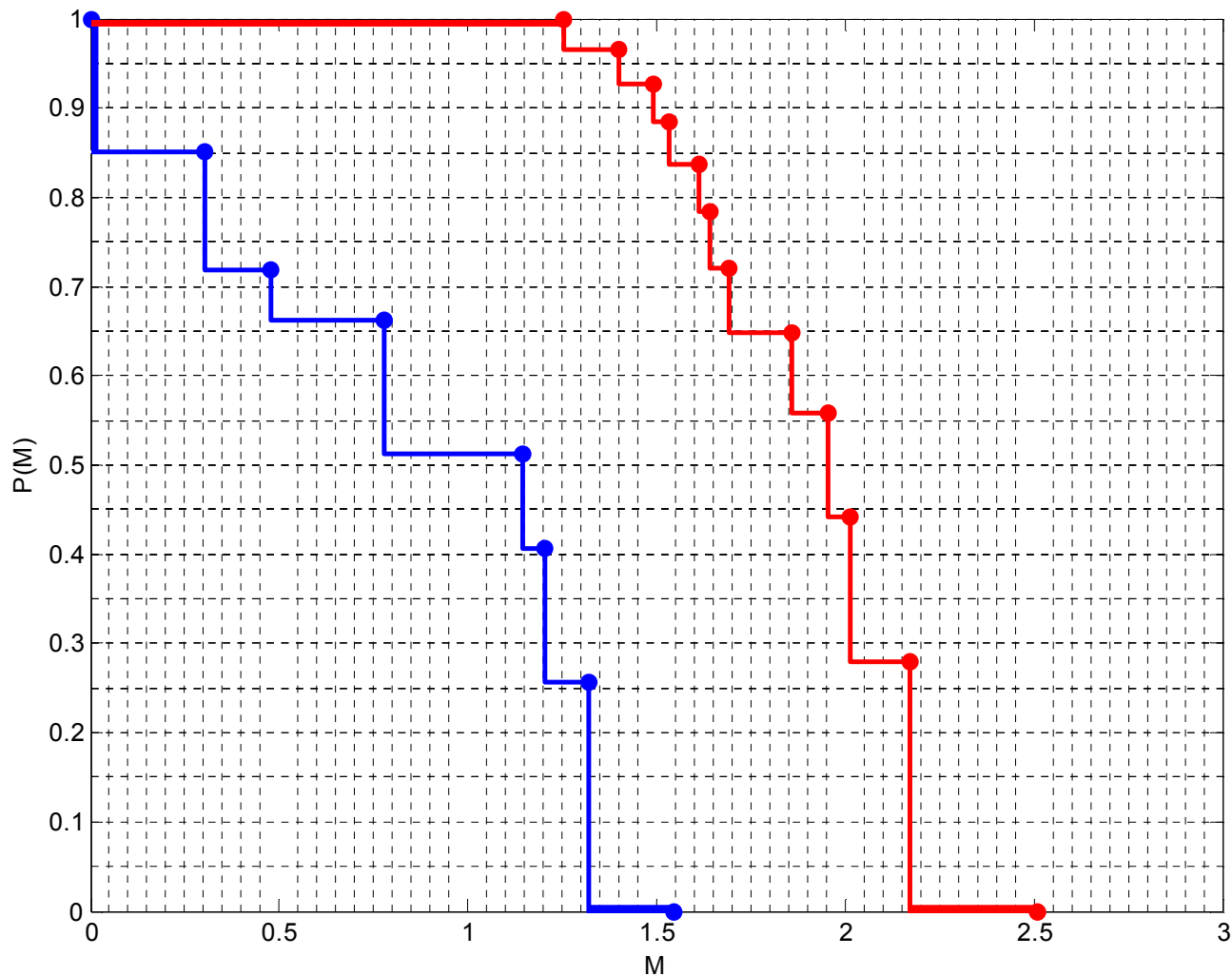


**3. Pakistan, deaths & injuries per year**, monthly indicators,  
international (red dots) & domestic (blue dots), 1970.01-2006.07.  
[ Kashmir, domestic (green dots) ]  
Extreme events: 1988.04 (Islamabad) and 2004.03(Quetta)

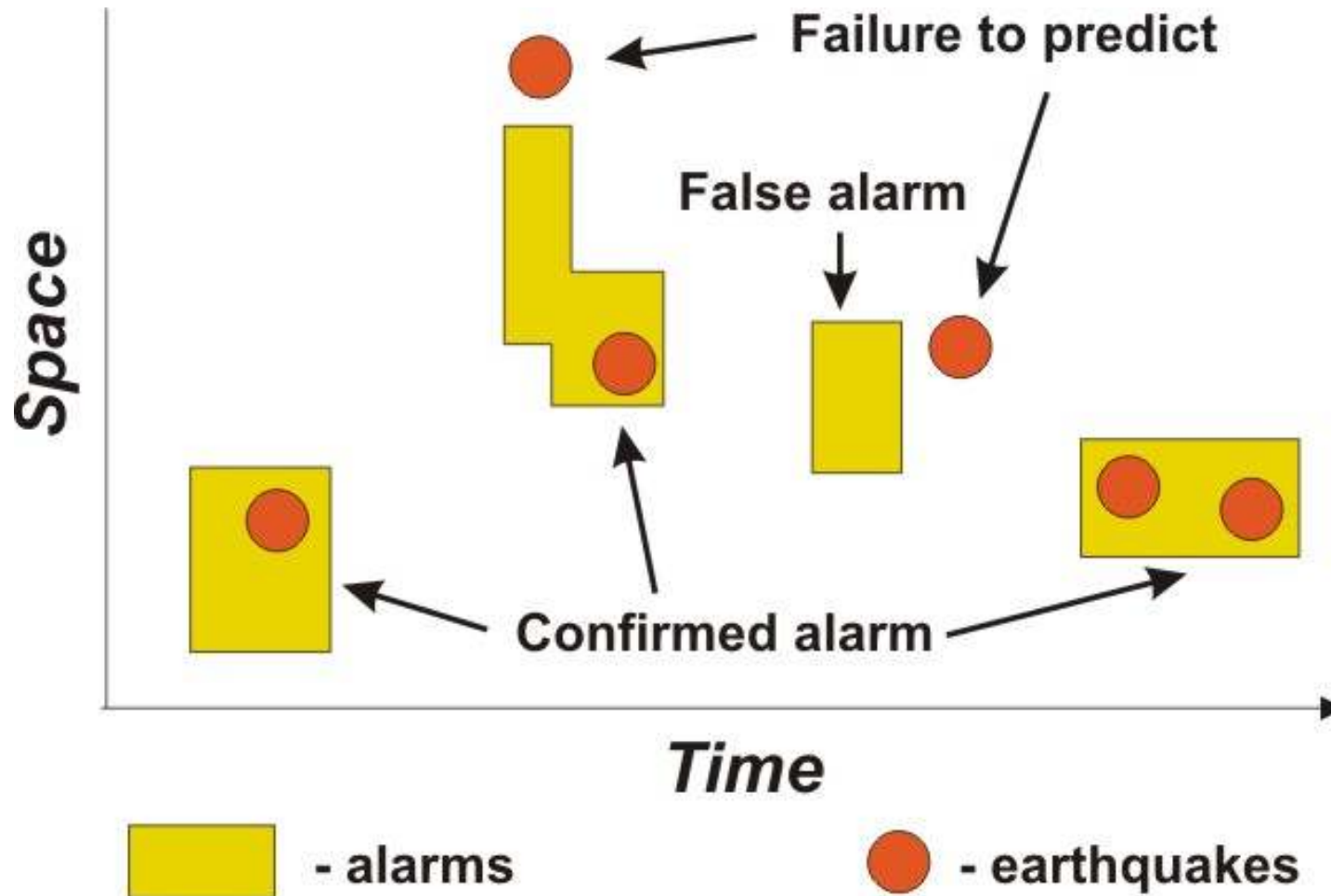


**Pakistan, deaths & injuries per year, international,  
1970.01-1988.04 (first extreme event).**

D = 21.6 months, N = 197.4 months ,  $N_{tot}^D = 12$ ,  $N_{tot}^N = 15$ .  
Magnitude distributions for interval D (red) and N (blue).

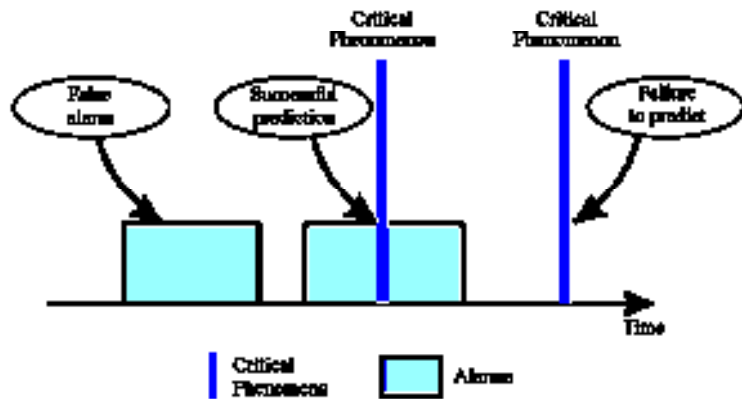


# Possible outcomes of prediction



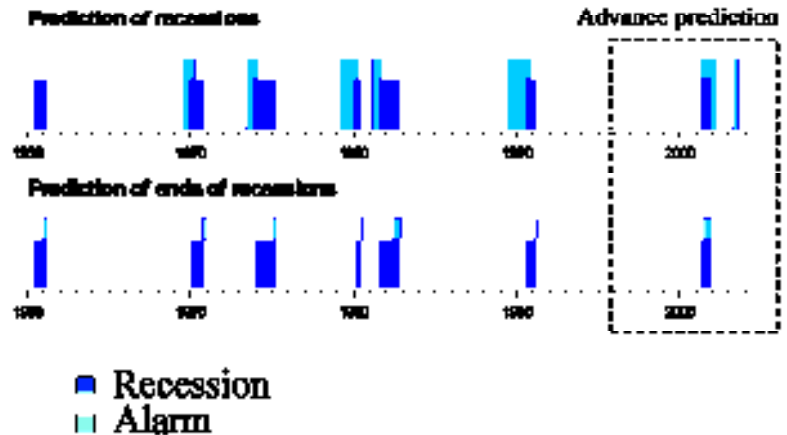
# SOCIO-ECONOMIC PREDICTIONS

## Outcomes of prediction

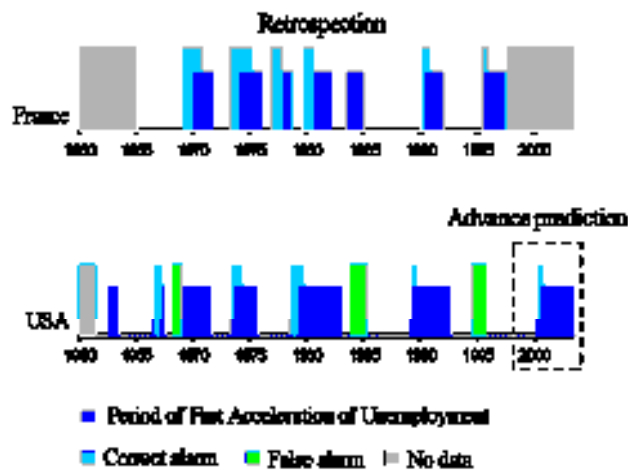


*Probabilistic nature of prediction is represented by probability gain and probabilities of false alarms and failures to predict.*

## Prediction of US recessions



## Prediction of surges of unemployment



## Prediction of homicide surges



*C.B. Allegre, D.J. Garcon, M.D. Intrigator, Y.I. Kritis-Barok, P. Mikhalov, R. Pichardo, A.N. Sobolevskii, A.A. Solovtsev, J. Stock, F.E. Witsberg*

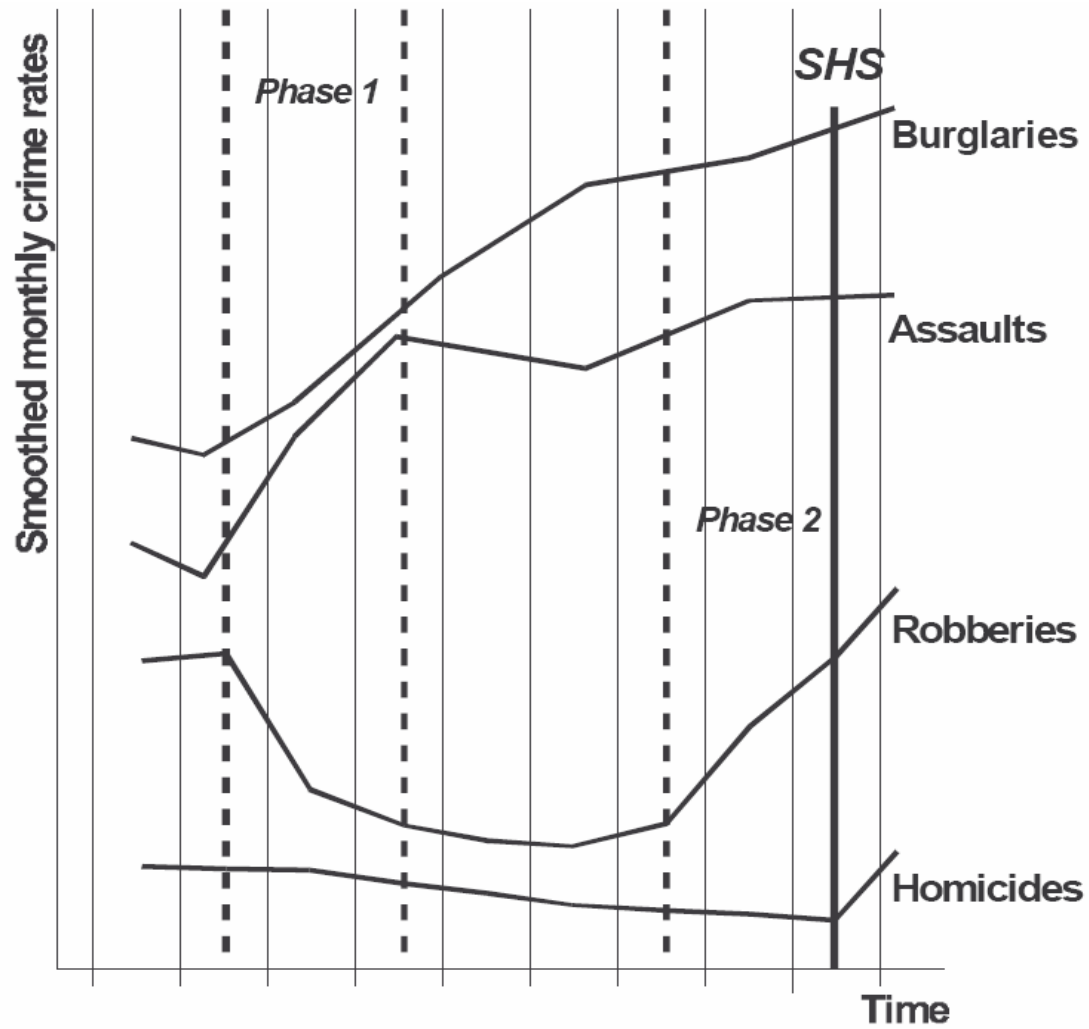
## TYPES OF CRIMES (TIME SERIES) CONSIDERED

Note that other potentially relevant data might also be used for prediction.

Homicide	Robberies	Assaults	Burglaries
<ul style="list-style-type: none"> <li>❖ All</li> </ul>	<ul style="list-style-type: none"> <li>❖ All</li> <li>❖ With firearms</li> <li>❖ With knife or cutting instrument</li> <li>❖ With other dangerous weapon</li> <li>❖ Strong-arm robberies*</li> </ul>	<ul style="list-style-type: none"> <li>❖ All*</li> <li>❖ With firearms</li> <li>❖ With knife or cutting instrument</li> <li>❖ With other dangerous weapon*</li> <li>❖ Aggravated injury assaults*</li> </ul>	<ul style="list-style-type: none"> <li>❖ Unlawful not forcible entry</li> <li>❖ Attempted forcible entry*</li> </ul>

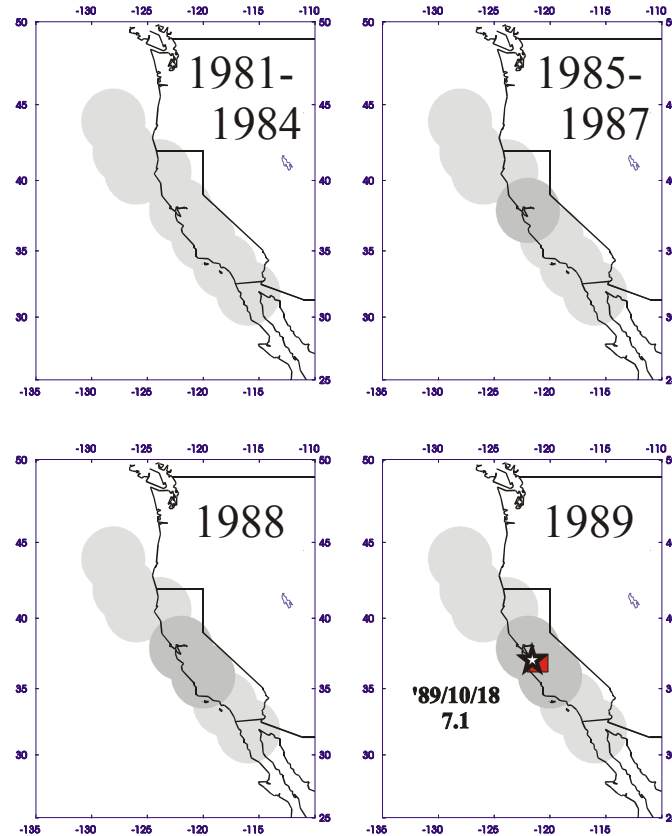
\* Analysed in error diagrams only

## SCHEME OF PREMONITORY CHANGES IN CRIME STATISTICS



# Algorithm M8. Prediction of Loma Prieta

ea-ke, 1989,  $M = 7.1$



Subject of correspondence between M.Gorbachev and R. Reagan  
in 1988

# SCORING

Several algorithms are tested by prediction in advance placed at the web site.

**Ea-s with  $M \geq 8$**  Since 1885; Algorithm “**M8**” captured 8 out of 10 earthquakes with occurred alarms altogether occupy 1/3 of time-space.

**Second strong ea-ke in a pair.** Since 1989 Algorithm “**SSE**” was applied since 1989. Out of 29 predictions 24 were correct and 5 wrong (2 failures-to-predict a and 3 false alarms).

# WHAT IS THE PLACE OF SUCH PREDICTION IN THE BROAD FIELD OF PREDICTION RESEARCH?

This prediction is targeted at the **rare extreme point events**; predictor is a discrete sequence of alarms.

**Gelfand's pattern recognition of rare events** - natural framework for Intergation modelling, theory, and data analysis

That approach is complementary to:

- classical Kolmogoroff-Wiener prediction, - extrapolation of a whole process
- cause-and-effect analysis
- multi regression

The premonitory phenomena might be not perpetrators but witnesses; and they might predict not an extreme event per se but destabilization of the system, which makes is ripe for an extreme event.