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WORKSHOP
GLOBAL GEOPHYSICAL INFORMATICS WITH APPLICATIONS TO RESEARCH IN EARTHQUAKE PREDICTIONS AND REDUCTION OF SEISMIC RISK

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FUNCTIONS ON EARTHQUAKE FLOW

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Functions on Earthquake flow

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EARTHQUAKE CAN BE DESCRIBED BY -

LATITUDE
LONGITUDE
DEPTH
TIME
ENERGY
...
TALES, STORIES, POEMS, ETC.

EARTHQUAKE FLOW - SEQUENCE OF EARTHQUAKES

DUE TO THE ABSENCE OF AN ADEQUATE MODEL
OF A PROCESS WICH GENERATES EARTHQUAKES
WE SIMPLIFY THE PROBLEM CONSIDERING INDEPENDENTLY

SPACE
TIME
ENERGY

CHAOTIC CHARACTER CALLS FOR INTEGRAL DESCRIPTIONS

SPACE -

ONE SHOULD SPECIFY AN AREA (VOLUME)
by REGIONALIZATION OR
REGULAR SCANNING

IT REDUCES THE SPACE COORDINATES

TIME-

HOW TO MEASURE THE TIME ?

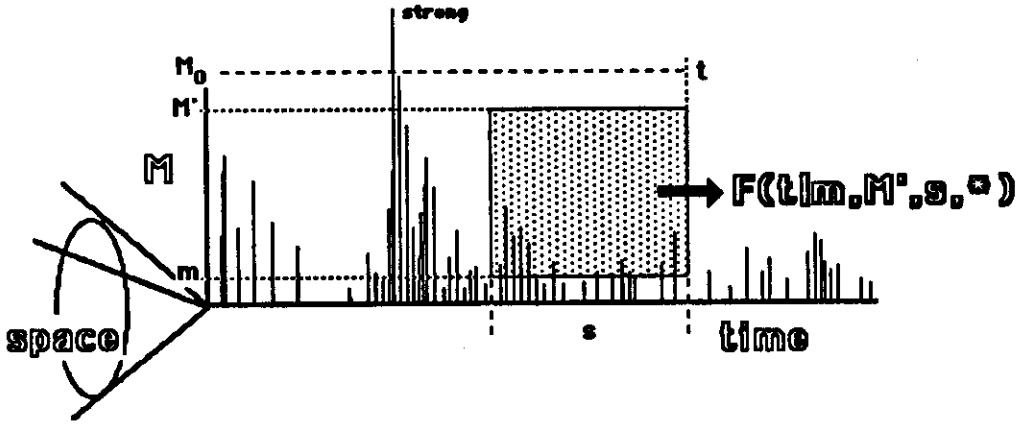
BY UNIFORM TIME INTERVALS
BY THE NUMBER OF CHARACTERISTIC EVENTS
BY UNIFORM ENERGY RELEASE

WE CONSIDER HERE THE SIMPLEST WAY -
UNIFORM TIME INTERVALS

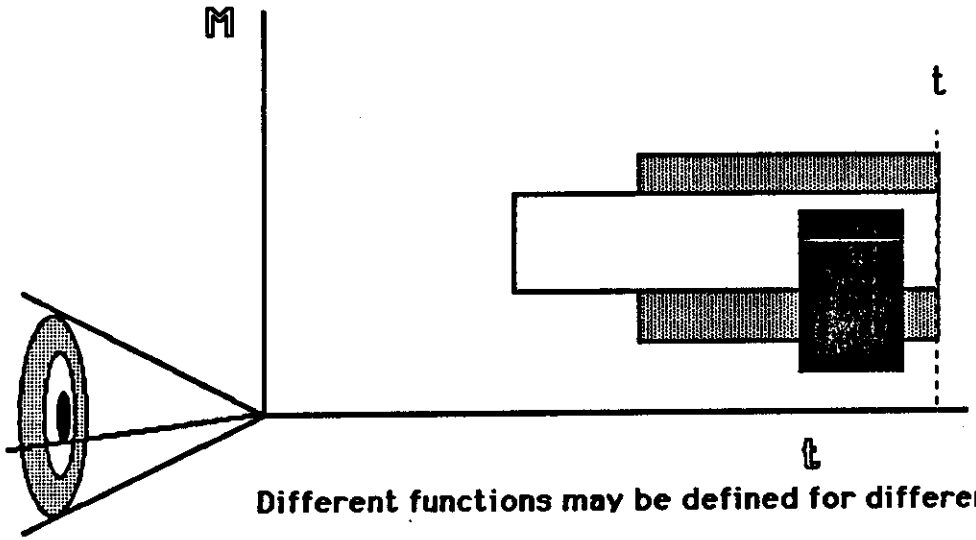
ENERGY -

$\lg E \sim M$

Magnitude is divided into certain ranges
Strong earthquakes are those with $M \geq M_0$



Vector $(F_1, F_2, \ldots, F_L)$



Different functions may be defined for different territoties, time- and magnitude range

How to describe a time sequence?
What values to count ?
And can these values express
the usually considered traits
of an earthquake flow ?

level of seismic activity (quescence, activation, ...)
temporal variation of seismic activity
clustering in time and space
concentration
long range interaction (L-R aftershocks, migration,...)

Basic functions:

Seismic activity -

N(t | m, s) - the number of earthquakes with $M \geq m$ in a time interval.from t-s to t

$\Sigma(t \mid m, M', s, a, \beta) = \sum 10^{\beta(M_i - a)}$ - the weighted number of earthquakes within intervals of time and magnitude, (t-s,t) and (m,M') .

According to the choice of ß this sum can be proportional to **linear size if ß = B/3** , or to **area of sources if ß = 2B/3** , or to **energy release if ß = B :**

Here B is from lg E = A + BM.

Variation of activity -

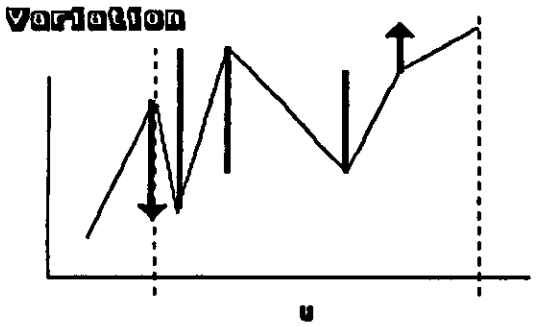
$V(t \mid m, s, u) = \text{Var } N(t \mid m, s)$
$= \sum | N(t_{i+1} \mid m,s) - N(t_i \mid m,s)|$
- variation of N, where t_i are from the time interval from t-u to t.

$L(t \mid m, s) =$
$N(t \mid m, t-t_0) - N(t \mid m,t-s-t_0)\cdot(t-t_0)\cdot(t-s-t_0)^{-1}$

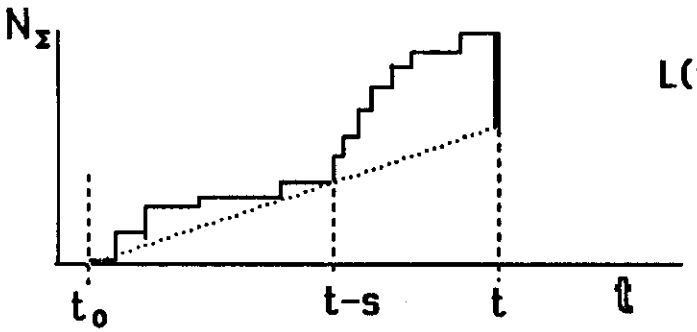
- deviation from long term trend of activity in the period from t_0 to t

$K(t \mid m,s) = N(t \mid m,s) - N(t-s \mid m,s)$

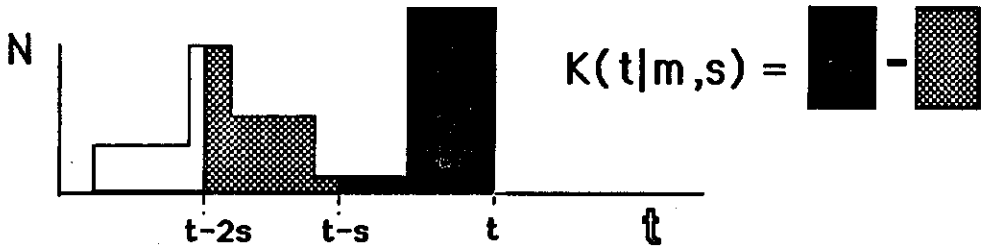
- increment of activity



$$V(t|m,s,u) = \downarrow\Sigma\uparrow$$



$$L(t|m,s,t_0)$$



$$K(t|m,s) =$$

Concentration -

$$Z(t \mid m, M', s, a, \beta) = \frac{\Sigma(t \mid m, M', s, a, \beta)}{(N(t \mid m,s) - N(t \mid M',s))^{2/3}}$$

- ratio of average radius of a fracture to average distance between fractures; here ß = B/3 corresponding to a linear size.

Clustering -

Earthquakes are clustered :
foreshocks - main shock - aftershocks or swarms
For each main shock we count B(e) which is the number of aftershocks .
A measure of clustering - the maximal B(e) for main shocks within intervals (m, M') and (t-s,t) :

$$b(t \mid m, M', s, M_a, e)$$

Aftershocks with $M \geq M_a$ in the first e days after a main shock are counted in B.

Long range interaction -

The territory of higher rank is considered. A main shock that occured within (t, t+u) after a strong earthquake is called long-range aftershock (after Prozorov). A measure of interaction :

$$M_l (t \mid s, M_0, u)$$

- the maximal magnitude of L-R aftershock in preceding (t-s,t) period.

Another measure of interaction can be **N(t | m, s) counted for the territory of higher rank, N_R.**

Contrast in activity -

An area is in a state of **Quescence** if $N(t \mid m, s) \le N_q$, and in a state of **Activation** if $N(t \mid m, s) \ge N_a$ (N_a and N_q are (100 - p)% and p% quantiles of N , correspondingly). Contrast of activity can be measured by **the time since an area and its neighbour were in different states for a year or more** -

$$T_{aq}(t \mid m, s, p).$$

Other functions :

$$G(t \mid M_1, M_2, s) = 1 - \frac{N(t \mid M_2, s)}{N(t \mid M_1, s)} \quad , \quad M_1 < M_2$$

- ratio of the numbers of earthquakes in two magnitude ranges.

$$q(t \mid m, s) = \Sigma_+[a(m) \cdot s - N(t_i \mid m , s)]$$

- deficiency of activity; here a(m) is an average annual number of main shocks with $M \ge m$, and Σ_+ defines summation of the positive terms only in time period (t-s, t).

$$Q(t \mid m, s) = \mathrm{Var}\ N(t \mid m, s)$$

- a "drop-and-increase" in activity; here the variation of N between t and the previous time of local maximum of N is considered.

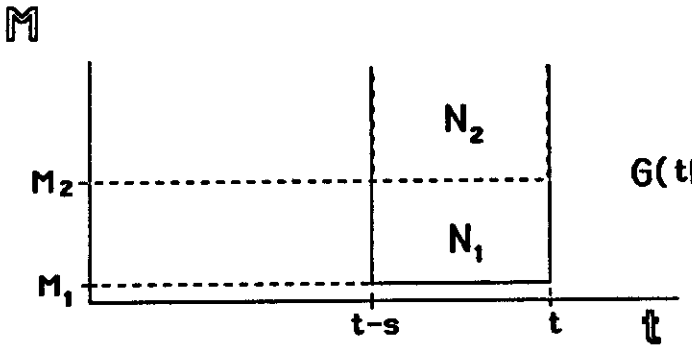
$$S(t \mid m, M', s, a, \beta) = \Sigma (t \mid m , M' , s , a , \beta) / [N(t \mid m , s) - N(t \mid M' , s)]$$

- average area of fractures; $\beta = 2B/3$.

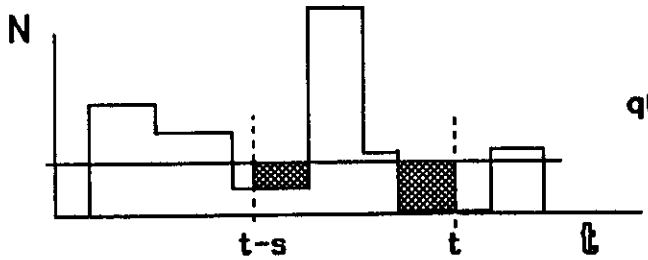
Maximal values of S and Z in a period from t-u to t:

$S_{max}(t \mid m, M', s, u, a, \beta)$ and
$Z_{max}(t \mid m, M', s, u, a, \beta)$

The list of these functions is neither optimal nor complete.
You are encourage to try other functions.



$$G(t \mid M_1, M_2, s) = \frac{N_2}{N_1}$$



$q(t \mid m, s) = \Sigma$ ▩

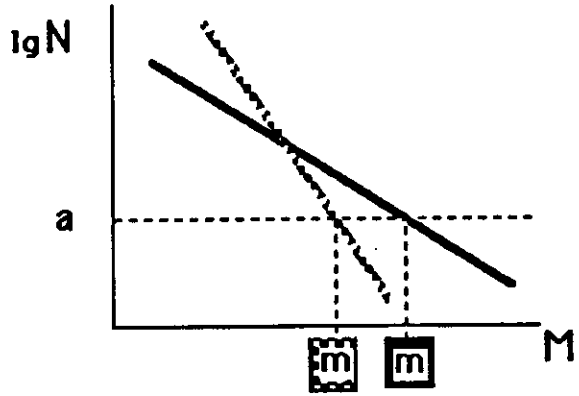
Normalization of Functions

All the areas are different. To compare the values of functions in different areas we need normalization.

Normalization by magnitude thresholds -

a) m is determined from a condition : **a(m) = A ,** where **A** is some fixed constant and **a(m)** is an average annual number of shocks in an area;

b) **$m = M_0 - A$,** where **A** is a given constant, and M_0 is the threshold in definition of strong shocks for an area.



Normalization by quantile presentation -

The values of a function are substituted by corresponding quantiles of its distribution function.