### Adaptive Reasenberg-Jones approach in progressive time scale

**Approach**

Aftershock process is represented using Reasenberg-Jones model (1989):

\[
N(t, M) = N_t(1 + \beta t)^{-1} \text{modifed Omori-Utsu law (MOL)}
\]

**Estimating Parameters**

- Basic time interval \( \Delta t \)
- Forecast time interval \( t \)
- Effective magnitude \( M \)
- Number of aftershocks \( N(t, M) \)

**Methodology**

The expected aftershock number with \( M \geq M_0 \geq M_t \) is:

\[
\lambda(t, t, M) = N(t, t, M)U(t, t) \frac{dt}{(1 + \beta t)^2} (J. SCHNEIDER, 2012)
\]

- \( N(t, t, M) \) is the number of earthquakes in the \( t \) interval.
- \( b = 4 \) is an effective magnitude.
- \( U(t, t) \) is the duration of the previous step in the \( t \) interval.

We tested intervals for independent estimating \( (b, \, c, \, p) \) for the reasons of awking the optimal intervals.

### Comparing the forecast models calculated the 8 aftershock sequences

We compare the main variant of the forecast to its "priori", "initial" and "posteriori" models:

- **Main variant:** \( c, \, p, \, b \) in (0.03, 0.05, 1.02).
- **Initial model:** \( c, \, p, \, b \) in (0.03, 0.05).
- **"Priori" model:** \( c = 0, \, p = b = 1 \).
- **"Posteriori" model:** \( c, \, p, \, b \) for all data in (0.32).

\[
G_p = \sum (t, t, t, 1, L)_{N(t, M)} \geq 0, \quad G_i = \sum (t, t, t, 1, L)_{N(t, M)} \geq 0, \quad G_p = \sum (t, t, t, 1, L)_{N(t, M)} \geq 0
\]

The main variant gives better forecast than the initial and a priori models. A posteriori model, which should give the best forecast is based on the all data, gives slightly better results.

### Testing the forecast of the areas of aftershocks

To test the optimal forecast of aftershocks we use ANSYS catalog for 1980-2014. Mainshock and aftershocks were chosen by Reasenberg (1989) and Molchan-Dmitrieva (1990) algorithms considering MLS= earthquakes as the mainshock. The magnitude completeness was estimated by the data for 2 years before a mainshock in the circle centered at the mainshock epicenter, radius = 1.25\( \times \)mainshock. We considered series with more than 50 aftershocks occurred during the year.

Reasenberg (1989) algorithm gives 135 and Molchan-Dmitrieva (1992) one - 216 aftershock series. For all of the series we calculate 4 aftershock areas and estimated their quality with the methodology. We calculate center of an area (1) using both common and weighted means. We also estimate the quality for circles with Tuaboi and Gardiner and Knopoff radii centered at the mainshock epicenter.

### Quality of the aftershock areas for the quintile 0.95

We found a simple average rule: the expected number of aftershocks of any magnitude in (12 hours, 1-month) is half as much as the counted number in (0, 12 hours).

\[
N(0.5, 31) = 1.5 \times N(0, 5)
\]

### Example of the Forecast for Earthquake in Kronotski area (MM=7)

- Event number
- Event times
- Forecasted event number
- Forecasted percent:
  - \( c, \, p, \, b \) in (0.03, 0.05).
  - A sprint forecast: \( c = 0, \, p = b = 1 \).

\[
N(t, t, t, 1, L)_{N(t, M)} \geq 0, \quad G_i = \sum (t, t, t, 1, L)_{N(t, M)} \geq 0, \quad G_p = \sum (t, t, t, 1, L)_{N(t, M)} \geq 0
\]

\[
A = \sum (t, t, t, 1, L)_{N(t, M)} \geq 0
\]

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### Next steps:

- do precursors of large aftershocks exist? how to incorporate them into rate estimates?
- what is the impact of the pre-mainshock seismicity?
- what is the impact of the current regional seismicity?