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Geophysics

Echo of 2011 Great Japan Earthquake in Georgia: Dynamic Triggering of Local Earthquakes

Tamaz Chelidze*, Teimuraz Matcharashvili, Natalya Zhukova****

* *Academy Member, M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, Tbilisi*
** *M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, Tbilisi*

ABSTRACT. Introduction of new sensitive broadband seismographs, new dense seismic networks and new methods of signal processing lead to the breakthrough in triggering and synchronization studies and formation of a new important domain of earthquake seismology, related to dynamic triggering of local seismicity by wave trains from remote strong earthquakes. Considered in the paper are the peculiarities of triggered seismicity in Georgia on the example of 11.03.2011 great Tohoku earthquake in Japan (M=9) and moderate earthquake in East Greece (09. 03. 2011). *© 2011 Bull. Georg. Natl. Acad. Sci.*

Key words: *dynamical triggering of earthquakes, Tohoku earthquake, local seismicity.*

The study of seismic response of the lithosphere to a weak forcing is a fundamental problem for seismic source theory as it reveals an important detail of the tectonic system, namely, how close is it to the critical state. In recent years introduction of new sensitive broadband seismographs, new dense seismic networks and new methods of signal processing lead to the breakthrough in triggering and synchronization studies and formation of a new important domain of earthquake seismology, related to dynamic triggering (DT) of local seismicity by wave trains from remote strong earthquakes [1-3]. The trivial aftershocks' area is delineated mainly by static stress generated by earthquake and decay rapidly with distance d as d^{-3}, whereas the dynamically triggered stresses decay much slower (as $d^{-1.5}$ for surface waves). This means that dynamic stresses generated by seismic wave trains can induce local seismicity quite far from the epicenter; they can be defined as remote aftershocks.

In most cases triggering is observed during surface waves, especially during Rayleigh wave arrivals, i.e. long periods and large intensity of shaking are favorable for exciting remote triggered events. Periods in the range 20-30 sec are considered as most effective in producing triggered events for the same wave amplitude. In principle the optimal period of DT should depend on the earthquake preparation characteristic time and can change from dozens of seconds for microearthquakes to hours and days for moderate events. For tidal stresses with periods 12-24 h the threshold can be as low as 0.001 MPa.

The triggered events belong to one of two classes: regular earthquakes with sudden onset and so-called non-volcanic tremors or tectonic tremors (TT) with emergent onset.

Tectonic tremors are considered as a new class of seismic events related to recently discovered phenomena of low frequency earthquakes and very low frequency earthquakes. As a rule individual tremor has dominant frequencies in the range 1-10 Hz, lasts for tens of minutes and propagates with shear wave velocity, which means that they are composed by S body waves. Spatially triggering is most frequently encountered in hydrothermal areas.

At present a lot of instances of triggering and synchronization are documented using statistical approach,

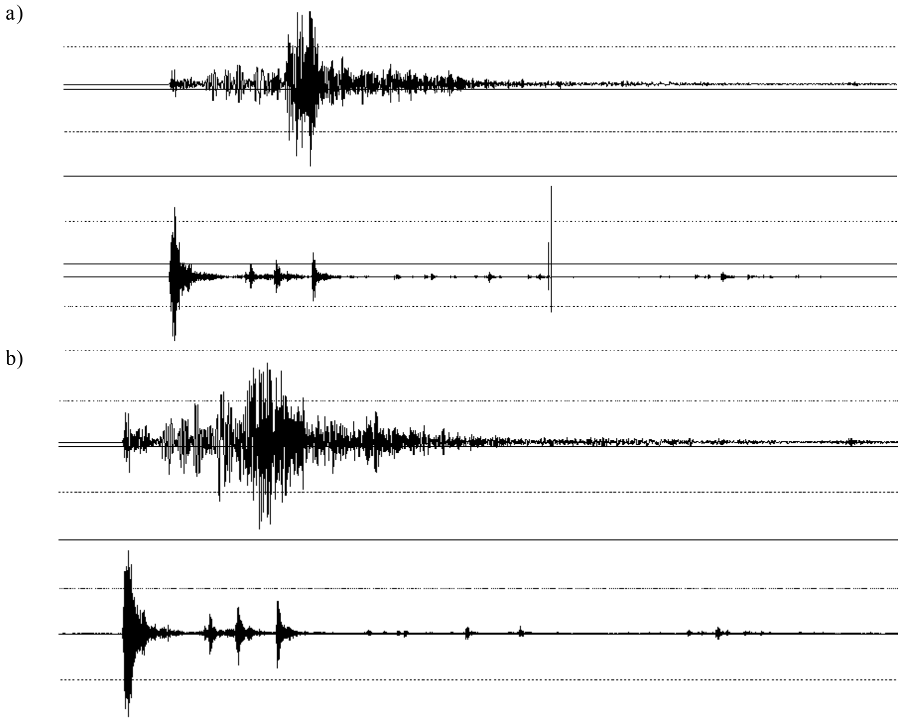
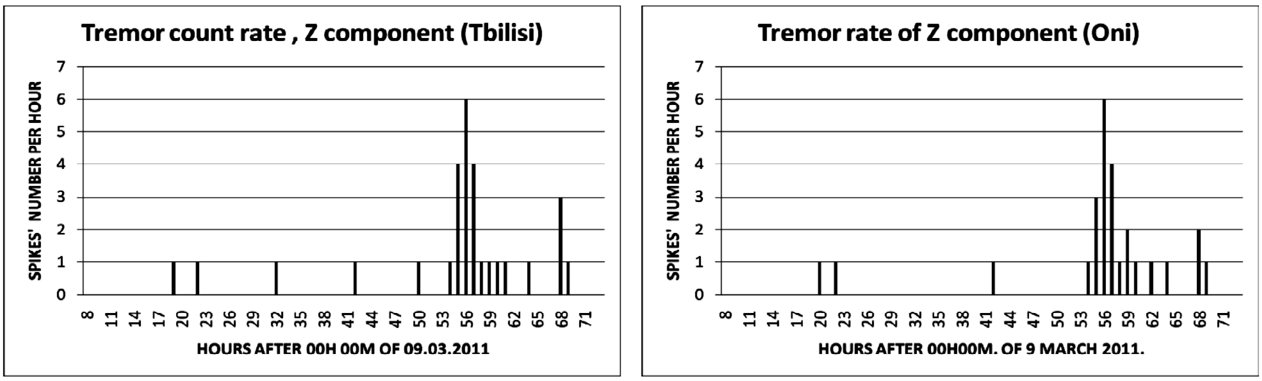


Fig. 1 a,b. Broadband records of M= 9 Tohoku EQ, Japan (11.03.2011) wave train z-component (upper channel) and the same high-pass band (0.5-20 Hz) filtered record (lower channel). The lower channel shows local triggered events; the strongest event corresponds to arrival of p-wave. a. Oni and b. Tbilisi seismic station.

but the most informative technique is the double-filtering method. As a rule, triggered events belong to the class of triggered tremors. Tremor's signatures are: emergent onset, lack of energy at frequencies higher than 10 Hz, long duration from dozens of seconds to several days, irregular time history of oscillations' amplitude, close correlation with large-amplitude surface waves.

Of course, different patterns can be observed also. For example, the great Tohoku M= 9 earthquake, Japan triggered local seismic events in Georgia (Caucasus), which is continental collision area, separated from Japan by 7800 km (Figs. a, b). As the Caucasus is dominated by compression tectonics and the triggering examples from such areas are rare, the presented data are significant for understanding trigger mechanisms. High pass (0.5-20 Hz) filtered records at two broadband seismic stations located in Oni (south slope of Greater Caucasus) and Tbilisi (valley of the river Kura), separated by the distance of 130 km show that in this case the strongest triggered event at both sites corresponds to arrival of p-wave instead of surface waves. The sequence of triggered events is quite similar at both stations. Tbilisi is a hydrothermal area and so it falls into the general class of triggering-prone regions, but Oni is not a hydrothermal area. Here the fracture can be promoted just by pore fluid pressure.

Recorded seismic waves were converted to WAV format with the corresponing sampling rate using tools provided in MATLAB application.



a) b)

Fig. 2. Tremor rate (number of local events per hour) before, during and after Tohoku event. Tohoku earthquake arrival time is marked by arrow.

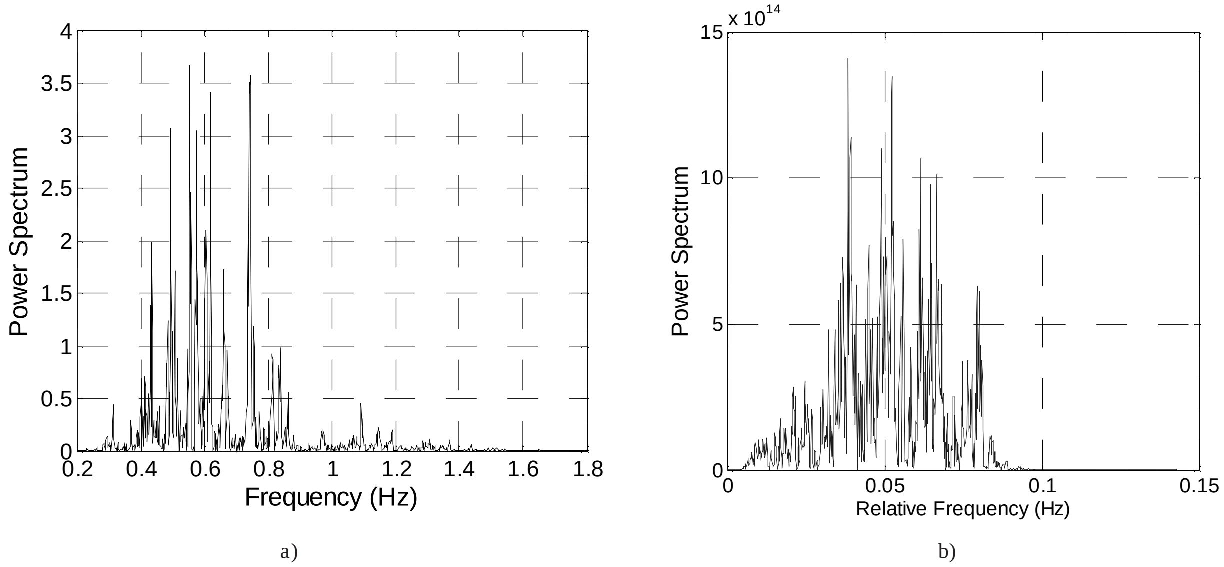


Fig. 3. a. Spectrum of the largest (first) triggered tremor in Tbilisi. Bandpass Butterworth filter was used to filter data in the range of 0.5-20 Hz; b. spectrum of the broadband recording of Tohoku earthquake in Oni.

The counting of tremors' rate (number of local events per hour) before, during and after the Tohoku event both in Oni and Tbilisi reveals a clear maximum during the passage of wave trains of the strong earthquake, including coda (Fig. a, b). The duration of anomalously high tremor rate is of order of 6 hours.

The power spectrum of the triggered tremors shows that the maximal energy is released in the frequency range 0.4-0.8 Hz, i.e., these events are deficient at relatively high frequencies (Fig. 3 a, b). Tremor spectrum differs very much from the power spectrum of the broadband recording of Tohoku earthquake, which indicates that maximal power in Georgia was relieved at much lower frequencies, in the range 0.01-0.1 Hz. This means that very low-frequency forcing is necessary for triggering tremors. In other words, forcing of a period 100-10 sec is the time necessary for tremor area activation.

It is interesting that not only strong earthquakes, but also middle size remote events also can trigger local earthquakes. For example, M=4.6 earthquake in East Greece (09. 03.2003) also triggered local seismicity in Georgia, separated from the epicenter by 1700 km, here again the strongest triggered event coincides with p-wave arrival (Fig. 4 a, b).

The above results are in accordance with our laboratory modeling of triggering the stick-slip events (approved models of earthquakes mechanism on the laboratory scale) by weak electromagnetic or mechanical forcing [4-6].

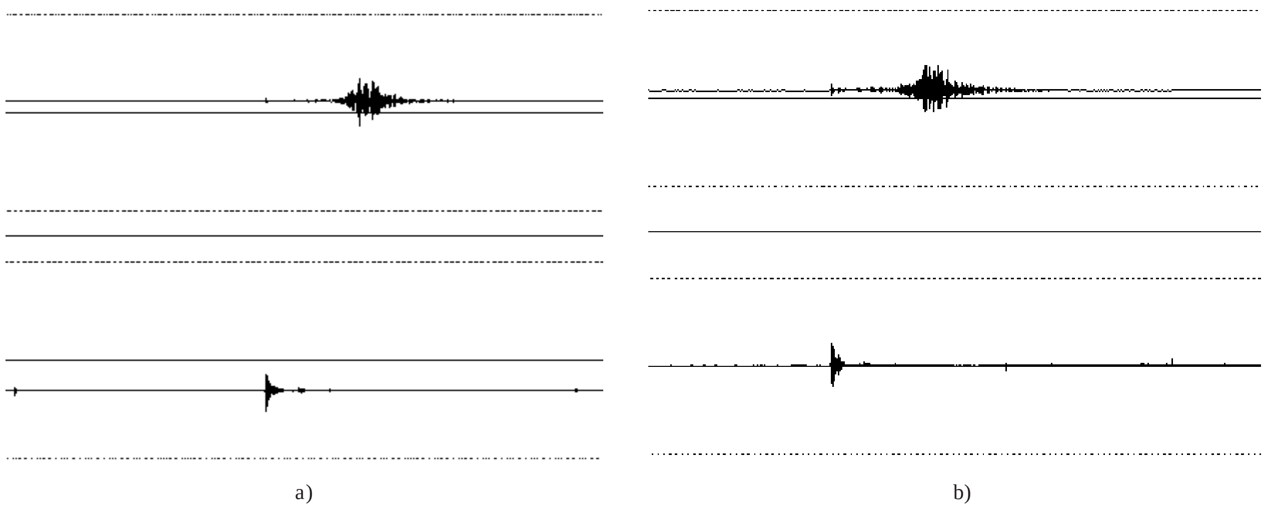


Fig. 4. a. Broadband record of M=4.6 earthquake in East Greece (09. 03.2011) wave train z-component (upper channel) and the same high-pass band (0.5-20 Hz) filtered record (lower channel). The lower channel shows local triggered events; the strongest event corresponds to arrival of p-wave. a. Oni and b. Tbilisi seismic station

It seems that further development of sensitive devices, dense networks and processing methods will develop a new avenue in seismology, which can be defined as microseismology and which will study systematically small earthquakes and tremors, especially triggered and synchronized events. These events at present are ignored by routine seismological processing and are not included in traditional catalogues. At the same time, microseismic events contain very important information on the geodynamics of processes and can give clues to understanding the fine mechanism of nonlinear seismic processes and may be, even contribute to the problem of earthquake prediction. Microseismicity can be compared by its importance to studies of elementary particles in physics.

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გეოფიზიკა

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თ. ჭელიძე*, თ. მაჭარაშვილი, ნ. ჟუკოვა****

** აკადემიის წევრი, ი. ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტის მ.ნოდიას გეოფიზიკის ინსტიტუტი, თბილისი*

*** ი. ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტის მ.ნოდიას გეოფიზიკის ინსტიტუტი, თბილისი*

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