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Development of Strong Motion Network in Georgia

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ABSTRACT

In frame of Shota Rustaveli National Science Foundation project "Accelerometer and Very Low Frequency electromagnetic waves receivers network implementation in Georgia: basis for specifying seismic hazard" project, 6 strong motion recorders were installed on territory of Georgia. This is the beginning of restoration of old accelerometric network, which stopped working in 2006. We are studying soil properties for each station, using active and passive methods and ground resonance frequencies, with HVSR method. Accelerometric database is being created.

Key Words: seismic hazard, accelerometric network.

Introduction

The South Caucasus, particularly Georgia is highly vulnerable to various natural hazards, the most dangerous and devastating of which is seismicity [1]. Observed seismicity in Georgia is characterized as moderate. Maximum observed magnitude of earthquakes is Racha earthquake of 1991, Ms = 7. The moderate and strong earthquake reflect regional tectonics that is largely determined by position of Caucasus between still converging Eurasian and Africa-Arabian tectonic plates. Risk resulting from seismic hazard is closely related to sustainable development of the country. Assessment of seismic hazard is vital for the region. Probabilistic assessment of seismic hazard involves calculation of expected value of ground shaking for a specified probability of exceedance within a specified time period (e.g., peak ground acceleration that has a 10-perecent probability of being exceeded within the next 50 years). So, during the study of seismic hazard, it is important to have accurate earthquake information, which includes: earthquake epicentre location, depth, time and magnitude for seismic sources and good strong motion recordings for building new or selecting existing ground motion prediction equation (GMPE). GMPEs provide means of predicting ground shaking at any location based on earthquake magnitude, fault mechanism, source to site distance, etc. The territory of Georgia includes up to 40 broadband seismometer stations, which can be used for earthquake parameters and source physics study, but using their data by derivative velocity for seismic hazard assessment will introduce additional error. seismometer measures the velocity of the ground during earthquake shaking. Most velocity sensors are high precision, sensitive instruments designed to record motions from distant earthquakes rather than the strong shaking that occurs near earthquakes. Accelerometers are much less sensitive than seismometers, but have a much greater range, detecting ±2g or more of ground acceleration (things start flying off the ground at 1g, when gravity is overcome). By comparison a seismometer will clip at full scale if you tap it too hard with your finger (http://www.src.com.au/strong-motion-accelerographs/).

Strong Motion Network for territory Georgia

Digital accelerograph network in the Caucasus area was operated by National Survey for Seismic Protection of the Republic of Armenia, the Georgian Academy of Sciences and the Swiss Seismological

Service granted by the Swiss Disaster Relief. The initial network, which started operation in 1990 was gradually extending. The network consisted of 12 digital free-field stations, 16 analog strong-motion stations, 6 digital strong-motion instruments for aftershock studies and 2 structural monitoring related arrays. This network operated till 2006, so its data is limited. During EMME (Earthquake Model for Middle East Region) project (2010-2013), strong motion data from this network was analyzed and out of about 450 recording only 88 were used, because most earthquakes were of small magnitude or recording quality was too low [2].

Taking all these into consideration, creating a new strong motion network that covered the whole territory of Georgia was vital. (work presented here was done in the frame of Shota Rustaveli National Science Foundation project "Accelerometer and Very Low Frequency electromagnetic waves receivers network implementation in Georgia: basis for specifying seismic hazard"), 6 strong motion instrumentations have already been installed and more are planned next few years. The locations of stations have been chosen with several priorities. Security of the instrumentation being the first. The network was planned to be evenly distributed in the area. The locations and coordinates of installed and planned stations are shown on Fig 1.

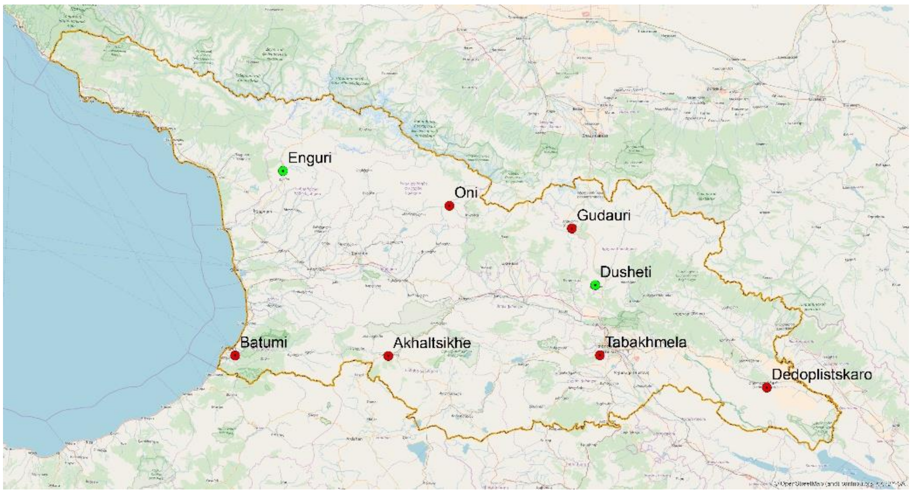


Fig. 1. Network map, red circles – installed, green – planned.

The local sight effects play important role in earthquake recordings. Different sight conditions can give amplification factors in different frequency ranges. Site characterization is necessary for strong motion. For large networks in Japan boreholes of 30 meters are made to study soil properties in detail. But such studies are costly, so for our network we studied shear-wave propagation velocity average for 30 meters (Vs_{30}) using seismic profiles. Horizontal to vertical spectral ratios (HVSR) of ambient seismic noise was used to estimate the thickness of sediment over bedrock, based on empirically-derived, power-curve relationships between sediment thickness and primary resonant frequency of shear-waves [3,4].

For this purpose, Seistronix RAS-24 and Tromino 3G are used. For resonance frequency Horizontal and Vertical Spectral Ratio (HVSR) method was used.

All stations have Kinemetrics Basalt 4X data recorders, with 3+1 channels, 24-bit Delta Sigma converter per channel, selectable sample rates and different supported file formats. An external GPS antenna is used for timing, with accuracy <1 microsecond. Internal Linux system and +1 channel gives user flexibility to use different types of external devices for communication and complex studies.

Tri-axial EpiSensor ES-T is used for ground motion detection. With Dynamic range: 155 dB+; Bandwidth: DC to 200 Hz; selectable full-scale range at: ± 0.25g, ± 0.5g, ± 1g, ± 2g or ± 4g; and extreme operating temperatures: -20° to 70°C.

In order to protect instrumentation from external influences and because of low budget old metal safes were used. To protect instrumentation from abrupt changes in temperature heat insulators were necessary. This provided us with sufficient safety from both weather conditions and theft. Reinforced concrete basement was designed for sensor, the depth of which was chosen considering local weather and soil freezing depths for noise reduction. Fig. 2 shows general block scheme for each station.

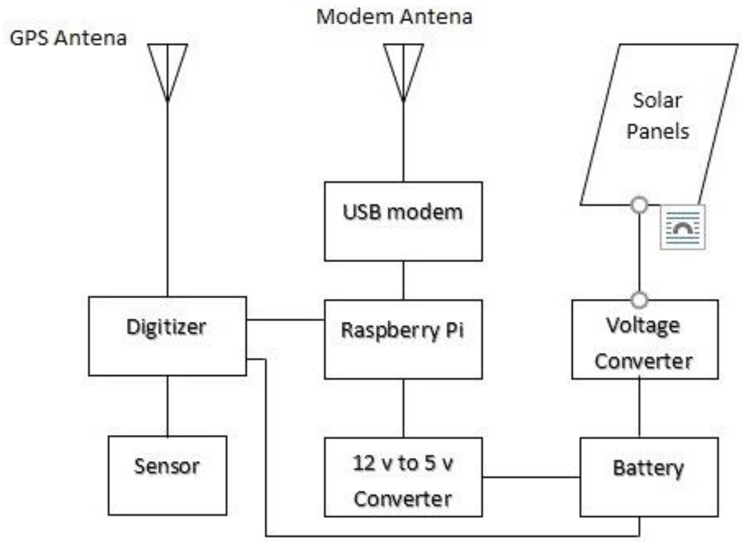


Fig. 2. Block diagram of stations

As none of the station except, Tabakhmela have AC power, solar panels were necessary. Wattage of solar panels were chosen taking weather conditions into consideration. Step down voltage converter with high efficiency can operate up to 80 Volt and give output of Maximum 10 A. 3G/SDMA modem is used for internet connection and Raspberry Pi with VPN technology for data transfer and remote access. Data is collected and stored on server using SSH protocol. Server is located at Tabakhmela, as it is the only location that has AC power and wired internet access.

Data processing of Georgian strong-motion database:

For data analysis different software is used: SMA (Strong Motion Analyst) and USDP (Utility Software for Data Processing). Main steps in data processing for both software are following:

1. Mean removal: Remove the entire mean for accelerograms without a pre-event buffer or Use the pre-event mean for removing it from the accelerogram whenever pre-event buffer is available

2. Baseline correction using the procedure proposed in [5] (procedure that opts to minimize residual displacements) for accelerograms with pre-event segments.

3. Filtering - Acausal

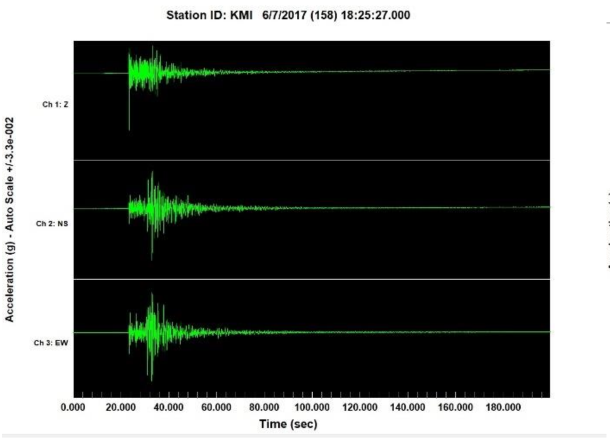
The major difference in causal and acausal filtering are the phase changes in the filtered time series. Causal filters result in phase distortion in the processed data whereas acausal filter does not introduce any phase change (phaseless) to the filtered data. The acausal, phaseless filtering is simply achieved in the time domain by passing the filter response along the record from start to finish and then reversing the order and passing it from the end of the record to the beginning. Acausal filtering requires leading and trailing zeros at the beginning and end of the aceelerogram, respectively to accommodate filter transients; acausal filtering leads to more stable processed data both in terms of time series and spectral calculations [6].

We have chosen Acausal filter. We use the default roll-off slope, that is 8 in USDP. The low and high-cut filter were determined through the guidance of f^2 and $1/f^2$ gradients that can be moved along the FAS plot by clicking on the relevant button. In the figure 38 is represented the pick the limited point in low – frequency.

As we know high frequency decay at rates $1/f^2$, that means spectral amplitudes decrease with increasing frequency. But at some points noise produces an increase in spectral amplitudes. This point is limited point for high frequency

For data analysis different software is used: SMA (Strong Motion Analyst) and USDP (Utility Software for Data Processing) example of the earthquake recording and its processing is given below. data shown below is a recording of earthquake near Dedophlistskaro station, on 07 June, 2017 18:25:41, at coordinates: 41.4056/45.7956, which is about 27 Km from station. The magnitude was M_L=5.

Figs 3 and 4 show raw data from all three channels, and pre-processed data for Z direction, analysis in this case was done using SMA software.



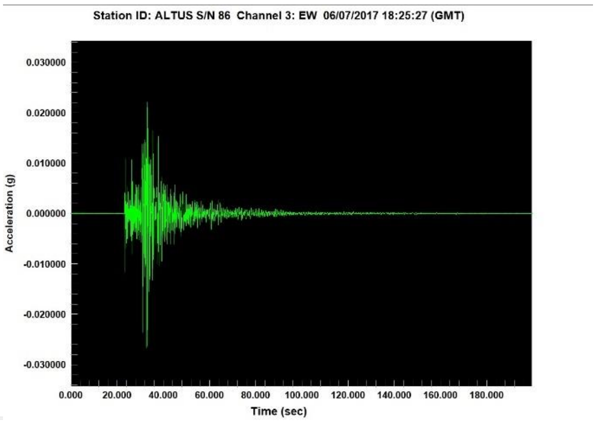


Fig. 3 and 4 – SMA raw data for all three channels and pre-processed data for Z channel.

Data processing by USDP software showing all the steps is shown below on Figs 5- 12.

step 1.

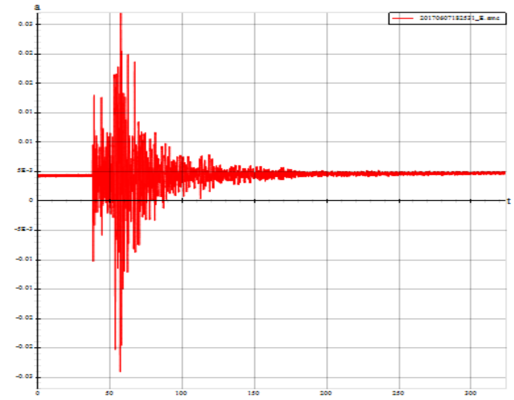


Fig. 5 - Uncorrected records of maximum horizontal components of earthquake (07.06.2017)

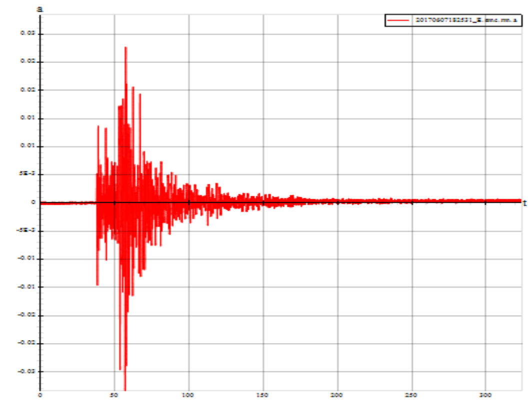


Fig. 6 - The mean of entire pre-events is 36 sec

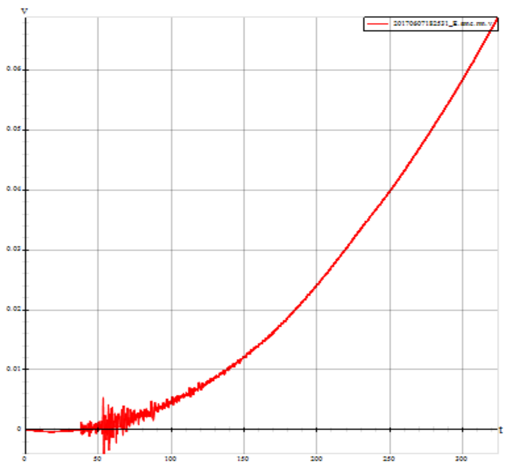


Fig. 7. Velocity time series

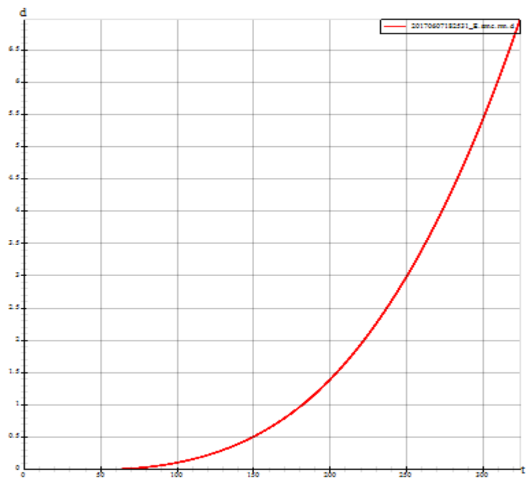


Fig. 8. Displacement time series

In practice the low-cut filtering is used to reduce the long period noise rather than baseline corrections with filtering. Totally there is not significant differences in results obtained by filtering and baseline corrections with filtering. We skipped baseline correction and used only filters.

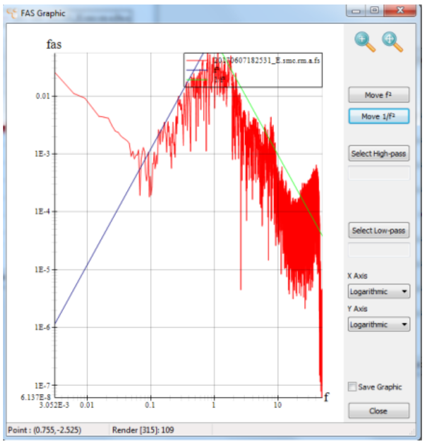


Fig. 9. Example of low and high-cut filter.

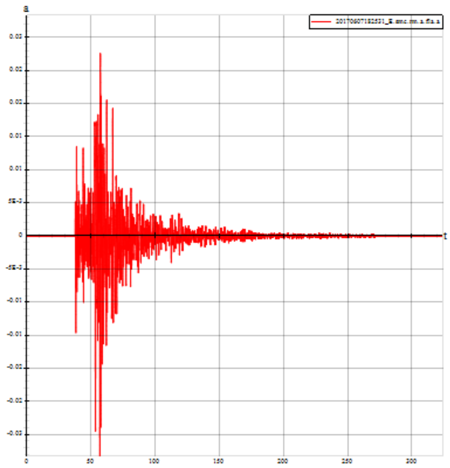


Fig. 10. Corrected records of acceleration time series

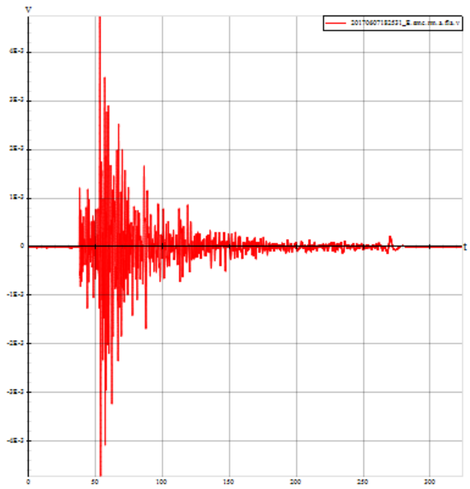


Fig. 11. Corrected records Velocity time series

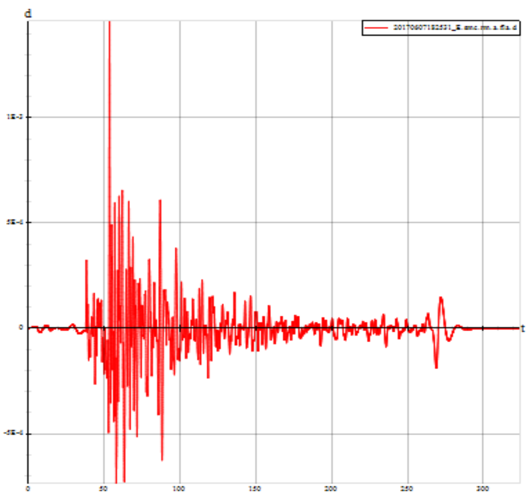


Fig. 12. Corrected records displacement time series

Conclusions

Because Georgia is located in seismically active region, accurate assessment of probabilistic seismic hazard and risk are extremely important. In the past seismic hazard study has shown that for Georgia there is no sufficient strong motion data. Taking this into consideration renewal of old strong motion network has begun. Today 6 stations are installed and operate. Two additional locations have already been chosen for more stations and are planned to be installed next year.

Finally, country-based metadata will be criated. In a reliable metadata, information must be same for same for each event: date and time, magnitude, epicenter coordinates, depth, focal mechanism; and each station must have its data on: initial waveform, processed waveform, description of processing procedure, PGA (Peak Ground Acceleration) and SA (Spectral Acceleration) value, site information, source to site distances.

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ძლიერი მოძრაობის ჩამწერი ქსელის გავნითარება საქართველოში

ნ. ყვავაძე, კ. ყვავაძე, ნ. წერეთელი, ა. გვენცაძე, ზ. გოგოლაძე

რეზიუმე

შოთა რუსთაველის ეროვნული სამეცნიერო ფონდის პროექტი „აქსელერომეტრული და ზედაბალი სიხშირის ელექტრომაგნიტური ტალღების მიმღებები ქსელის განვითარება საქართველოში: საფუძველი სეისმური საშიშროების დაზუსტების “ფარგლებში საქრთველოს ტერიტორიაზე დადგმული იქნა 6 ძლიერი მოძრაობის ჩამწერი,რითაც დაიწყო ძლერი მოძრაობების ჩამწერი ქსელის აღდგენა, რომელმაც შეწყვიტა არსებობა 2006 წელს. შესწავლილი

იქნა თითოეული სადგურის გრუნტის თვისებები აქტიური და პასიური წყაროების მეთოდით, განსაზღვრული იქნა ასევე გრუნტის დომინანტური სიხშირეები HVSR მეთოდით. იქმნება აჩქარებების ნაციონალური მეტამონაცემები.

Развитие сети сильных движений в Грузии

Н.К. Квавадзе, К.Д. Квавадзе, Н.С. Церетели, А.Б. Гвенцадзе, З.Р.Гоголадзе

Резюме

В рамках проекта Национального научного фонда Шота Руставели «Внедрение сети акселерометров и низкочастотных электромагнитных волн в Грузии: основа для определения сейсмической опасности», 6 акселерометров были установлены на территории Грузии. Это начало восстановления старой акселерометрической сети, которая перестала работать в 2006 году. Мы изучаем свойства почвы для каждой станции с использованием активных и пассивных методов и резонансных частот грунта с использованием метода HVSR. Создается акселерометрическая база данных.