OVER 100 YEARS OF SEISMIC OBSERVATION AT UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

L. Alcántara, D. Almora, C. Pérez, M. Torres, M.A. Macías, L. Ramirez-Guzman
Instituto de Ingeniería, Universidad Nacional Autónoma de México, Ciudad Universitaria, México, e-mail: leonardo@pumas.ii.unam.mx, dam@pumas.ii.unam.mx, cpy@pumas.ii.unam.mx, mtn@pumas.ii.unam.mx, mamc@pumas.ii.unam.mx, LRamirezG@iingen.unam.mx,

C. Valdés, J. Pérez
Instituto de Geofísica, Universidad Nacional Autónoma de México, Ciudad Universitaria, México, e-mail: carlosv@ollin.igeofcu.unam.mx, jesus@ssn.ssn.unam.mx,

SUMMARY:
A brief review associated with the activities that the National Autonomous University of Mexico (UNAM) has made during over 100 years in monitoring the seismic phenomena is presented. Such actions have been under the responsibility of the Institute of Geophysics and the Institute of Engineering; the former is in charge of the Mexican Seismological Service and the latter is responsible for the operation of the Accelerographic Network installed in free field and in some important structures as well. The coordinated work between those entities and the integration of both seismic networks, as a joint project, have undoubtedly converted it in the most important project for monitoring and studying seismic phenomena in Mexico. Given the importance of UNAM´s seismic project, in recent years, the Ministry of the Interior through the National Center for Disaster Prevention has promoted and supported the integration of all existing seismic networks in the country in the so-called Mexican Seismic Network.

Keywords: Mexican Seismic Network, Seismological Network, Accelerographic Network, Seismic Intensity Maps.

1. BACKGROUND

Understanding and monitoring earthquakes, one of the natural phenomena whose occurrence creates major impacts on society, is an essential task in any national seismic hazard program. Therefore, it is necessary to have an adequate infrastructure for measuring and monitoring seismicity, such that the recorded motions provide not only the source description (hypocenter, magnitude and mechanism) but also information regarding the intensities to which population and structures were subjected in an earthquake. These records can provide a rationale for recommendations on land use and building standards safety, as well as plans of action for response to earthquake related emergencies.

The study of earthquakes and its effects on society has always been a subject of interest for the National Autonomous University of Mexico (UNAM), whose researchers have led many of the efforts in Mexico on this matter. Such is the case for seismic monitoring, which began with the founding of the National Seismological Service (SSN) in 1910 and its incorporation into UNAM nine years later. In the sixties, at the height of the construction of large hydroelectric projects in the country, the need to examine the dynamic response of hydroelectric structures when subjected to seismicity bolstered the increase in the use of accelerometers. Thereafter, UNAM maintained a continuous effort to improve the coverage of seismic monitoring in the country to a degree that, without a doubt, today the university provides the most important infrastructure in Mexico for this purpose.

As a part of UNAM's continued efforts to improve seismic monitoring, in the past few years the Ministry of the Interior, SEGOB, and UNAM created an agreement, with an undefined end date, to develop materials for civil protection. The objective of this agreement is to establish a basis for collaboration between SEGOB and UNAM at the end of which both parties can work together using their respective capabilities in order to organize scientific investigations and develop technology for the prevention and protection of the general public, as well as the mitigation of risks in the face of natural and anthropogenic phenomena. Additionally, this collaboration is expected to motivate the development and encourage the completion of projects, studies, and investments necessary to improve and modernize the coverage of early warning systems and evade potential damages from natural phenomena. To this end, as an initial measure UNAM and SEGOB implemented the project known as the Mexican Seismic Network (RSM), whose principal objective is to reinforce and modernize the seismic observation network of the country, and to integrate a system of information and data processing in real time.

UNAM’s Institutes of Geophysics (IGEOF) and Engineering (IINGEN) participated in the first stage of the RSM project. SEGOB’s National Coordination for Civil Protection participated via the National Center for Disaster Prevention (CENAPRED), as well as the Center for Instrumentation and Seismic Registry (CIRES A.C.).

The proposal to integrate the RSM was based on the implementation of the following actions:

- Improve the coverage of the National Seismological Service of IGEOF with 9 broadband stations and satellite communication systems.
- Install a system of seismic information in real time.
- Reinforce and modernize the accelorographic networks of CENAPRED, IINGEN, and CIRES A.C. by installing new stations to improve the actual coverage.
- Reinforce the communications systems of the accelerograph stations to provide information regarding the intensities produced by an earthquake.
- Integrate the information generated by the seismic networks into a national database of earthquakes which occurred in Mexico.

In the article, we present a brief description of the activities which UNAM has completed to improve the seismic observation infrastructure as a part of the RSM project.

2. SEISMIC OBSERVATION AT UNAM

2.1. National Seismological Service

On the first of April, 1904, eighteen countries including Mexico gathered at a meeting in Strasbourg, France to create the International Seismological Association and improve seismic instrumentation worldwide. To meet the commitments made at that meeting, the Mexican government decreed the foundation of the National Seismological Service (SSN) on September 5, 1910 as a part of the National Geological Survey. As a result of this, between 1910 and 1923 the first nine seismic stations were installed in the country. Later, in 1929, the SSN was incorporated into UNAM, and since 1948 has been attached to IGEOF. The responsibilities of the SSN are reflected in the statute of creation and are entrusted by official decree: to provide timely information on the occurrence of earthquakes in the Mexican territory and to determine the main parameters of earthquakes occurring within the territory, such as the magnitude and epicenter. The SSN is also responsible for providing the information needed to improve assessment and prevention of seismic and volcanic risk in Mexico.

The SSN has 58 seismic stations in operation, divided into 4 monitoring sub-networks as described below:

a) National Network of Broadband Seismological Observatories (RNOS). Thirty-eight monitoring stations are incorporated into this network (see Figure 1), of which 9 have recently been installed as a part of the RSM project’s effort to improve the coverage of the SSN. There are 25 stations which transmit their data via satellite; the remaining stations transmit their data via spread spectrum radios, leased lines, and internet connections as illustrated in Figure 2.

Figure 1. National Network of Broadband Seismological Observatories

Figure 2. Broadband Seismological Station

The nine broadband stations considered in the RSM project are: Ahuacatlan, Nayarit (ANIG), Maruata, Michoacan (MMIG), Hermosillo, Sonora (SIG), Hidalgo de Parral, Chihuahua (HPIG), Casas Grandes, Chihuahua (CGIG), Linares, Nuevo Leon (LNIG), Pijijiapan, Chiapas (PCIG), Santa Rosalia, Baja California (SRIG) and Irapuato, Guanajuato (IGIG).

Additionally, UNAM financed the installation of stations in Mexicali and San Pedro Martir in Baja California, and in collaboration with the government of Chiapas, stations in Tapachula and Tuxtla Gutierrez.

b) Conventional Seismic Network (RSC). This network is comprised of 7 short period analog stations which are primarily situated on the central Pacific coast of Mexico. These stations transmit their signals in real time directly to the central station, located in the IGEOF-UNAM, using the microwave network TELECOMM or by use of private telephone lines.

c) Hydro acoustic Network of Socorro Island (RHIS). Composed of 3 stations which transmit their data in real time via SSN's Teleport, which utilizes the satellite *Telstart 5*, property of *Intelsat*.

d) Valley of Mexico Network (RVM). The eight stations which make up the RVM are located in the metropolitan area of Mexico City. Their signals are transmitted using spread spectrum radios, microwaves, and private lines. This network is being renovated and will include six additional stations.

2.2. The IINGEN Acccelerographic Network

From its inception, the implementation of the SSN network has allowed for the localization of the epicenter and the determination of magnitude for seismic events within the national territory. However, the information obtained using this network is not sufficient to determine the damages incurred by structures which experience seismic ground motions. After the earthquake of 1957 (M = 7.5) occurred in the town of San Marcos in the state of Guerrero, Mexican engineers recognized the need to measure and study the seismic waves generated by strong earthquakes from their origin to their arrival in major population centers, and to study the response of soil and, crucially, structures. This marked the beginning. In 1960, a project to record strong earthquakes began by installing the first two accelerographs in Mexico City; one in Alameda Central and the other on the campus of UNAM (Esteva, 1963).

Considering the importance of the seismic potential of the so-called Guerrero gap the IINGEN and the University of San Diego, California, decided to implement a project called the Accelerographic Network of Guerrero. By chance, this resulted in records for the earthquakes of the 19th and 21st of September 1985 (M = 8.1 and 7.6). This was the first major event recorded just a few kilometers from the rupture area. Nevertheless, an excellent opportunity to obtain extensive information about the behavior of soils and structures in regions very close to the epicenter and in Mexico City, which was strongly affected, despite being located 400 km from the seismic source, was missed.

The1985 earthquake established a new trend in instrumentation in Mexico. Several institutions started, and continue today, the deployment of accelerographic stations in sites where damage is likely. For instance, IINGEN keeps expanding its network to improve coverage, especially on the Pacific coast. The latter has been bolstered by the RSM Project, which resulted in the installation and operation of 35 new stations (Alcántara *et al*., 2007). The network improved its coverage from the states of Nayarit to Chiapas on the Pacific coast, the Gulf of Mexico, and Central Mexico, including important population centers such as Tapachula, Oaxaca, Puebla and Acapulco. Today, the network has 110 free-field stations (Figure 3), see Figure 4 for location.

Figure 3. IINGEN network accelerographic station

Figure 4. IINGEN network accelerographic stations

3. SEISMIC INFORMATION SYSTEM AND ITS PRODUCTS

As a part of the RSM project's actions, the IGEOF, IINGEN, and CENAPRED seismic recording networks are integrating via the Information System of the RSM (Valdés *et al.*, 2009). To this effect, it was necessary to reinforce, or in some cases provide, the communication infrastructure required to transmit, in real time, the signals received by the SSN to the central station of IGEOF, and the accelerographic data to the operations center of IINGEN. To do this, as described in the previous section, satellites, radio transmissions, microwaves, private telephone lines and the internet are used. The availability of this communication infrastructure and the transmission of data in real time have afforded the creation of the following products:

3.1. Seismicity Reports

Monitoring is a 24 hours per day, 365 days a year operation. This continuous monitoring allows for the creation of daily seismic reports for Mexico. Additionally, special reports are published for significant earthquakes, *i.e.* those with magnitudes greater than 5, or that were notably perceived by the population of a particular region.

Preliminary reports are published no later than five minutes after the occurrence of an earthquake and can be accessed at the IGEOF website http://www.ssn.unam.mx. These reports include the value of the magnitude, epicentral location, and depth of the earthquake, as well as the date and time of its occurrence. Additional information is provided using a localization map (see Figure 5).

Figure 5. Information system on the SSN website

3.2. Ground motion parameter maps for the Valley of Mexico

In order to provide an estimate of the ground motion parameters, such as peak ground acceleration (pga) and response spectral acceleration (SA), produced by an earthquake in the Valley of Mexico, an automatic seismic ground motion map system was developed (SAPS-II) (Ordaz, 2006). This system is activated automatically upon completion of an earthquake record at the accelerographic station which is located on UNAM's main campus (station CU). Four maps are generated: pga, SA at 0.2, 1 and 2 seconds. The first map represents the severity that an observer would experience at ground level; the next three represent the ground motion that will most likely experienced structures of 2 to 3, 8 to 12, and 15 to 20 stories, respectively.

Once the maps are generated, SAPS-II sends notification to authorized users via the internet, cellular phone systems, and radio-localization. The time the system takes to complete these activities is approximately 10 minutes from the completion of the accelerographic record in CU.

As an example of the SAPS-II process, in Figure 6 we present maps that were generated during the March 20th, 2012 (M=7.4) earthquake. The epicenter of this earthquake was located 29 Km south of Ometepec, Guerrero. This record suggests pga with values on the order of 24 to 48 cm/s^2, which agrees with the information subsequently collected from the different accelerometers throughout the Valley of Mexico. The remaining three maps present the SA at periods (T) .2, 1 and 2 seconds.

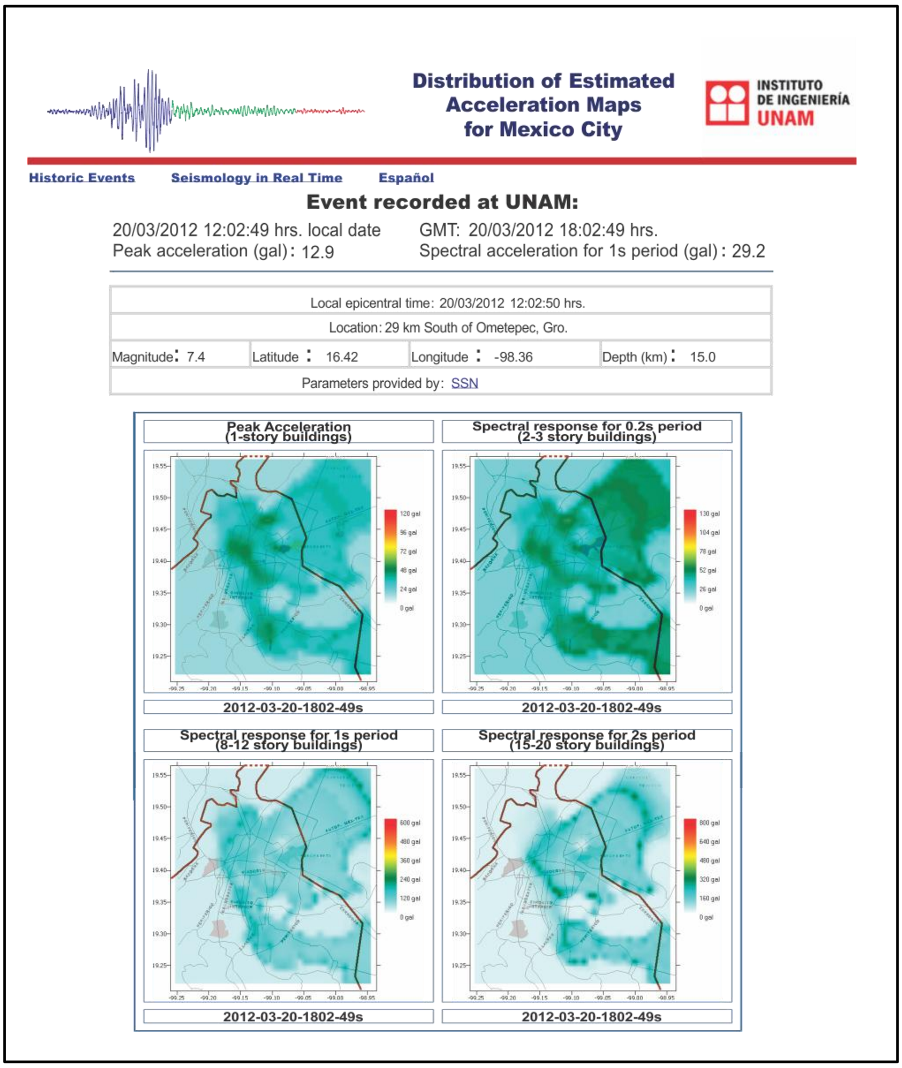

Figure 6. Peak Ground Acceleration and Response Spectral Acceleration maps for the Valley of Mexico from the 20 March 2012 (M=7.4) earthquake

3.3. National ground motion parameter maps

Unlike the maps generated for the valley of Mexico, the creation of national seismic ground motion parameter maps requires the use of accelerometers located in rock. These accelerometers transmit their information in real time, either to the central station in the IGEOF or IINGEN's operations center. For information processing, priority is given to data recorded at stations near the epicenter, as was the case for the March 20, 2012 (M = 7.4) earthquake. Subsequently, an interpolation was performed to estimate the ground motion parameters in sites without an instrument; the result is presented in Figure 7. This figure also illustrates that the maximum pga values near the epicenter were greater than 100 cm/s^2, higher than those experienced in the Valley of Mexico. Finally, the distribution map is created by mechanisms similar to those used for the case of the Valley of Mexico intensity maps. The generation and dissemination of the national map requires more time, due to the varied information arrival times from various stations to their respective processing centers.

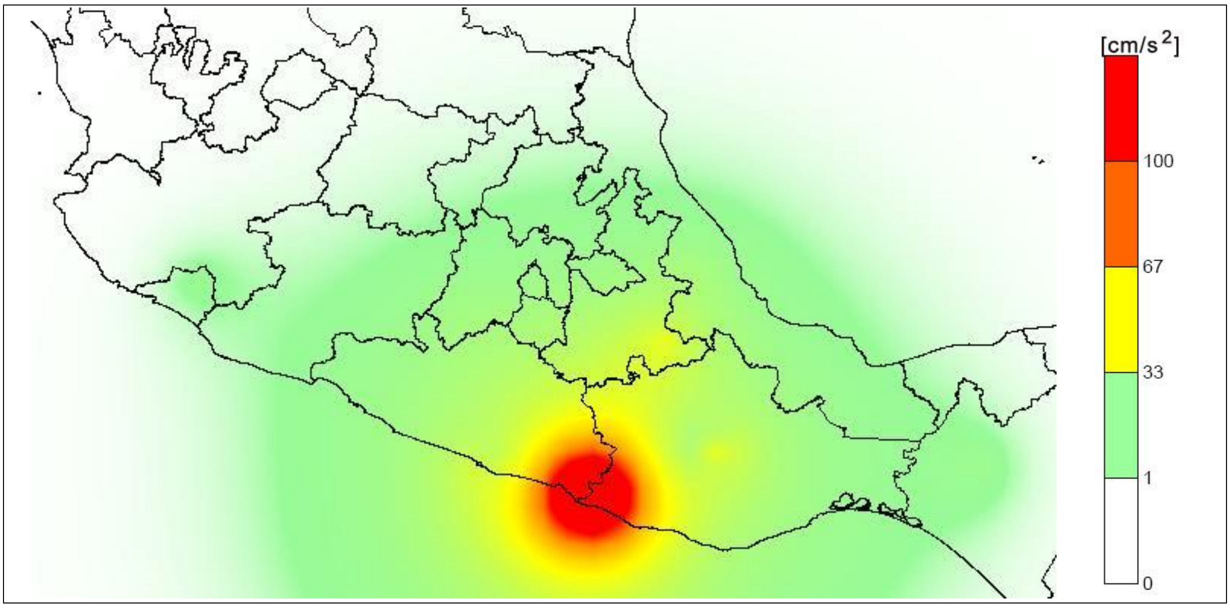

Figure 7. National peak ground acceleration map generated for the 20 March 2012 (M=7.4) earthquake

4. REINFORCEMENT OF THE COMMUNICATION SYSTEM

The reinforcement of the communication and exchange of seismic information between the IGEOF, IINGEN and CENAPRED is included in the objectives of this stage of the RSM project. This requires the development of a bilateral communication system with the capability to transmit and receive in a double-delta configuration. One characteristic of this system is redundancy, for which the delta communication will have a double bond; one using fiber optics by default, the other working with wireless broadband technology.

Figure 8 shows the double-delta bond, immersed in the general communications system operated by IINGEN. Once the RSM's second phase is implemented, the system will be able to send the maps generated in the PCR using the double delta link. The information will be transmitted using the default fiber optic network, and if this fails will automatically switch to transmission via the wireless network. This feature ensures the delivery of information.

The fiber optic link will have a bandwidth of 1 GB, with an availability of 99.99% and will be implemented with a single-mode optical fiber comprised of 12 wires. The wireless broadband link will have a bandwidth of 300MB, with an automatic switching system, and will use nonpublic, exclusive frequencies.

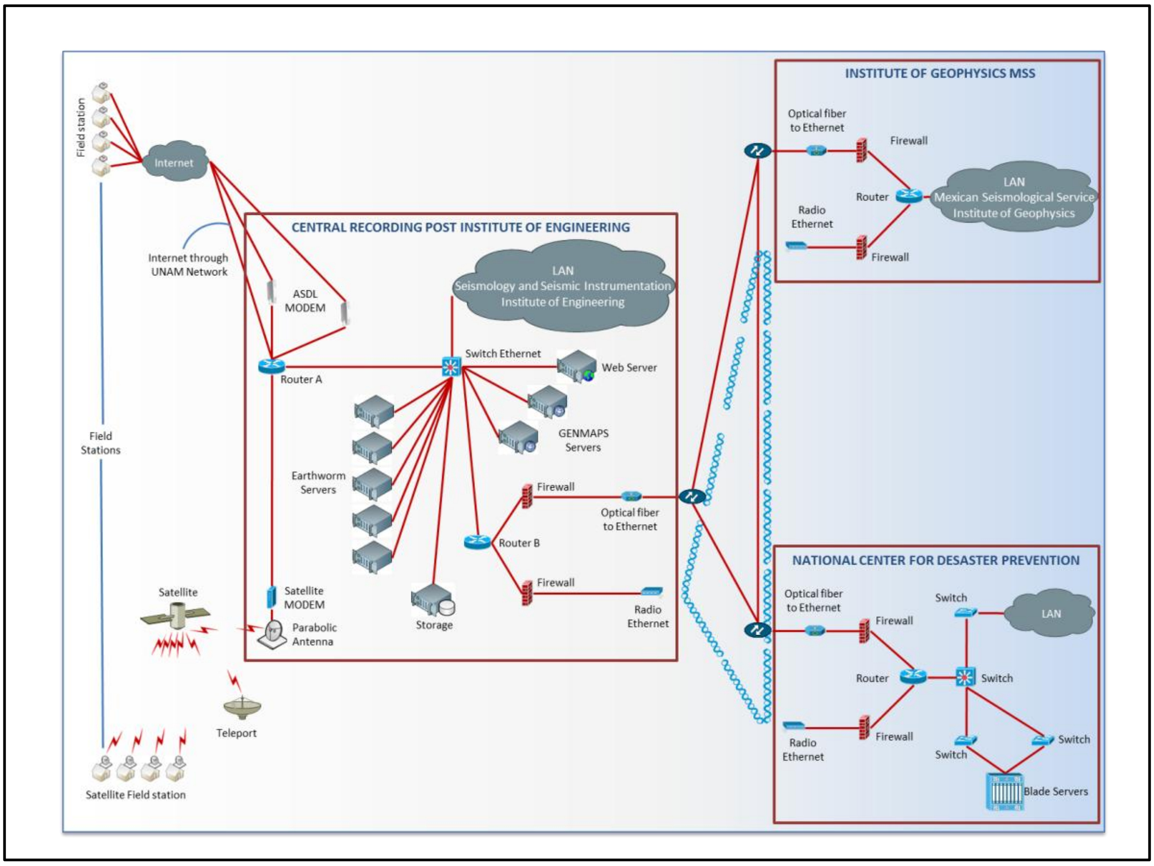

Figure 8. Diagram of the communication delta

5. CONCLUSIONS AND FUTURE WORK

The efforts made by the National Autonomous University of Mexico to observe and study seismic activity in Mexico for over 100 years, and the university's recent collaborative efforts with the Federal Government, have made it possible to consolidate the Mexican Seismic Network (RSM). This infrastructure has made possible the development of tools and systems that the civil protection agencies in Mexico can use to have timely information regarding emergencies caused by earthquakes immediately after they occur. The Institute of Geophysics at UNAM has developed automated systems to determine the magnitude and epicentral location of an earthquake. For its part, the Institute of Engineering at UNAM provides an overview of the severity of ground motion by generating both regional and national maps.

Among the key elements in the development of the RSM, is the communication system's double-delta feature, which will permit the transmission of information if part of the network stops working. This fulfills one part of the Mexican Seismic Network's mission: to guarantee the availability of information, even in the case of large earthquakes.

Repeatedly, history has shown that Mexico is an earthquake prone country. Seismic events in the country have produced substantial loss of life, and have also seriously affected infrastructure. However, it was not until the earthquake of September 19, 1985 that a significant change took place in the study of the phenomenon and how to measure it. Although today the seismic observation infrastructure of the country is much better, it is still insufficient, considering that there are regions with little or no instrumental coverage. Unfortunately the region has the potential to generate strong earthquakes; hence, the collaborative efforts of the National Autonomous University of Mexico and the Federal Government are focused on the creation and maintenance of a Mexican Seismic Network with national coverage in the short and medium term.

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