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Using seismology for regional confidence building

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ABSTRACT

Confidence building between regional parties can be facilitated through cooperative seismological research activities. Shared data, facilities, technology, and research results can (1) assure participants that nuclear testing is not taking place, (2) provide information that can be used to characterize the geophysical parameters of a region for earthquake hazard mitigation, and (3) support basic seismic research.

Keywords: regional seismology, confidence building, seismic calibration

2. BACKGROUND

Seismology is a nonintrusive technology whose limitations and capabilities are widely understood by the technical, governmental, and public sectors. Most countries have academic seismic research programs, and those with earthquake hazards also sponsor geophysical hazard research. Seismology is an international science, and with the exception of the smallest events, most earthquakes are observed across international boundaries. Because underground nuclear testing also generates seismic signals, seismology can be used to assure that nuclear testing is not taking place. Basic seismic technologies and facilities have multiple functions, and can be used for test monitoring, hazard mitigation, and geophysical research. Regional cooperation in seismology can address concerns in the above topics, encourage participation in open technical discussions, provide a mechanism for resolving ambitious results from cooperative projects, and increase the security of the region.

3. RECENT DEVELOPMENTS IN REGIONAL SEISMOLOGY

Regional seismic monitoring, using high-quality (digital, broadband, three-component) seismic stations, was a key factor in the success of the Group of Scientific Experts Technical Test (GSETT), which was sponsored by the Conference on Disarmament. The GSETT tested the concept of employing global data exchange for monitoring a comprehensive test ban treaty. Many stations that were installed under GSETT are still operating, and should continue to operate as monitoring stations for the Comprehensive Test Ban Treaty's (CTBT) International Monitoring System. Data recorded by these stations are available (or "open") to all interested parties and will be distributed through the CTBT International Data Center.

In the area of geophysical hazard mitigation, the United Nations has declared an International Decade on Natural Disaster Reduction, which involves a number of elements requiring regional seismological and geophysical cooperation. Participating in this effort requires the parties to exchange seismic data and research results so that they can better characterize the geophysical parameters of their region. With reliable geophysical information, the researchers will be able to more accurately estimate earthquake hazards. Active cooperation by regional parties has been recognized as a necessary condition for addressing earthquake hazard mitigation, and many countries are participating in this program.

In recent years, a number of international seismological organizations, such as the Incorporated Research Institutions in Seismology (IRIS) in the United States and similar consortia in France, Japan, Italy and Germany, have installed high-quality seismic stations around the world to collect the data necessary to accurately characterize the structure and dynamic processes in the earth. Data from these stations are openly available and readily accessible through modern communication links such as the Internet and dial-up modems. The availability of open seismic data through data centers makes timely and advanced analysis possible.

During the past few years, the quantity of high-quality seismic data that is openly available has increased tremendously along with the recognition of the importance of seismology in earthquake hazard research. Because of the public acceptance of the technology and the amount of data, seismic cooperation has become an excellent mechanism for promoting scientific dialogue and cooperation in regions where there are tensions that make other types of collaborative efforts difficult or impossible.

4. CONFIDENCE-BUILDING PROPOSAL

A four-step process toward regional confidence building is proposed here; this process consists of establishing a regional seismology working group, developing analysis capabilities and access to open data centers, conducting calibration experiments with monitoring provisions defined by participating nations, and conducting on-site measurement to resolve ambiguous events. These steps are designed so that each successive step builds on the facilities and mechanism for cooperation that was established in the previous step. With minimal changes and additions, the facilities already in place can provide the basis for regional cooperation. As the level of cooperation increases, measures that are specific to the region can be implemented to further add to the confidence-building effort.

4.1. Establishing a regional seismology working group

A regional seismology working group would consist of seismologists in the region who are interested in collaborations at a professional level and would meet regularly. This group would provide a forum for planning and participating in data exchange and possible joint research projects, and for determining the baseline of regional seismic activity.

Information and data exchange from historical earthquakes, such as a particularly large or damaging earthquake for which there is abundant data, would be the initial topic of discussion in the working group. Source information, such as dates, times, locations, depths, and magnitudes of the earthquake and its large aftershocks could be compared using data from each national network, and then could be analyzed using data from a combined regional network. Supplementary reference data from extra-regional and teleseismic stations would also be available for large earthquakes. A possible product of these collaborations would be a regional earth model, which would help in reducing the uncertainties in the location estimates.

Seismic events of interest, such as large quarrying or mining explosions could be announced and monitored regionally. Such events are particularly important because the origin time and location of the source are known, thus eliminating many of the variables in determining the factors affecting the seismic signal. If the explosion is in a region where there is an absence of natural seismicity, then plans could be discussed for deploying temporary seismic sensors and then recording signals over these different propagation paths.

The working group meetings could also be a forum at which suspicious events are cooperatively processed and analyzed. Each party would be able to contribute its own expertise, experience, and data with which the suspicious event could be compared. Because the number of suspicious events increases as the magnitude threshold is decreased, the group might choose to limit the analysis to events with magnitudes above a predetermined level. Such details as well as the methodologies to be used can be determined by the working group.

The purpose of the working group is to establish communications at a scientific level between the seismologists and to establish a procedure for working on collaborative projects. A commitment for regularly scheduled meetings is important; the venue could be rotated with each party having an opportunity to serve as host.

4.2. Establishing a high-quality data analysis and interpretation capability

Given the availability of the new seismic facilities worldwide and the availability of digital, broadband, three-component data and data from arrays, a regional working group would need a modern data analysis and interpretation capability to take advantage of the data. This capability includes both hardware and software resources; however, with the present capabilities of analysis computers and data acquisition systems, the hardware cost would be reasonable. Such a capability would facilitate acquisition of data from locally owned and operated open stations, using direct connections, telephone links, and satellite downlinks.

More vital to the capability than the hardware is the software and the expertise that would be required to process and analyze the data. Much of the software can be obtained either free or with modest licensing fees. Expertise would be acquired through collaborations with colleagues with greater familiarity and from hands-on experience. Participants would process data from the common pool of open seismic stations, and would use established methodologies for processing, analyzing, and

interpreting the results. Auxiliary data, such as those from local networks, could be used if all parties were given access to the same data.

Although it is not necessary to establish a data analysis and interpretation capability in each country, the cost of such a system would not be prohibitive. As the working group matures, only a few analysis centers would be necessary with participating countries sharing in the resources and cost.

4.3. Conducting joint calibration experiments

Joint experiments provide (1) a means to determine the capabilities of the regional network, (2) opportunities for joint analysis and interpretation, and (3) experience that can be used to increase the efficiency of monitoring methods. Calibration experiments limit the unknown variables because the source, location, depth, size, and time are known quantities; data from such experiments can help researchers determine geophysical properties of the region. Sources can be pre-announced commercial mining or quarrying explosions, or they can be dedicated experiments. Alternatively, earthquake aftershocks may be used as sources if the source parameters are well known as in the case of aftershock sequences that are well instrumented. The method using natural events has the advantage of using sources large enough to be seen at regional distances, and the disadvantages of not being able to choose the site and not knowing the precise time, depth, and epicenter location.

Calibration experiments can also provide baseline data that can be used to discriminate between explosions and earthquakes. In 1992, the US Department of Energy detonated a chemical charge at the Nevada Test Site with an energy release of approximately 1.07 kt in the vicinity of where nuclear explosions of similar size had been previously detonated. Since the geological conditions of the emplacement area for the explosions are similar, this experiment provided an opportunity to compare the differences in chemical and nuclear seismic sources. Seismic data obtained from the chemical explosion showed that large chemical explosions when compared to nuclear explosions of similar size show few differences. Traditional seismic methods for discriminating between source types failed for this case, which implies that a chemical explosion could be used as a surrogate for a nuclear explosion. For example, a series of large chemical explosions could be detonated in an area where there is a question about possible nuclear testing activity. The results of the chemical explosions could be used (1) to calibrate the geophysical model of the earth between the seismic station and the source area, and (2) to provide a signature of the seismic signal expected from an explosion in this area. This calibration would greatly increase the reliability of the monitoring capability.

4.4. Cooperative on-site measurements

In instances for which the analysis of regional and local seismic data yields ambiguous results on the source mechanism of the events, regional participants could use on-site measurements to help resolve these issues through recording and analyzing direct evidence of the event. If there is a question regarding the source mechanism, researchers could deploy local seismic arrays to map the temporal and spatial location of aftershocks and, thereby, help delineate the fault plane and faulting mechanism. If there is a question as to whether the event was a clandestine nuclear explosion, seismologists could use on-site measurements to determine the aftershock pattern. They could also visually examine the area for evidence of test preparations, emplacement of explosives, and presence of radioactive gasses.

Cooperative on-site measurements could also be used to deflect suspicions that industrial operations, such as excavations using chemical explosives, are being used to hide clandestine nuclear testing. Pre-event and real-time event monitoring can confirm the purpose of a declared explosion through visual evidence, detection of low-frequency electromagnetic signals during the explosion, and explosion size inferred from strong ground motion. Post-event evidence would include aftershock patterns, evidence of radioactive gasses, and the presence of an underground cavity after the declared explosion.

On-site measurements from calibration experiments can help establish the methodology and operational procedures used by the regional parties. On-site measurements depend on full cooperation by both the host and the parties doing the measurements.

5. CONCLUSION

Seismic monitoring can form the basis of a regional confidence-building program. This program would consist of four parts, starting with forming a regional working group, which would provide a forum for participating in data exchange, planning possible joint research projects, and determining the baseline of seismic activity. The next step would be establishing a high-quality data analysis and interpretation capability with access to open sources of data; this would provide the basis for

confidence in the results of the experiments. The next step would be conducting joint calibration experiments as a means to determine the capabilities of the regional network, and to provide an opportunity for joint analysis and interpretation. Finally conducting on-site measurement would help resolve ambiguous events through recording and analyzing the direct evidence of explosions or earthquakes.

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