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# QUAKE ALERTS

**Success in Mexico City  
Reaches All the Way  
to Los Angeles**

**The CO<sub>2</sub> Is Coming  
from Your Lawn**

**Tiny Shells Tell Tales  
of Ocean Systems**

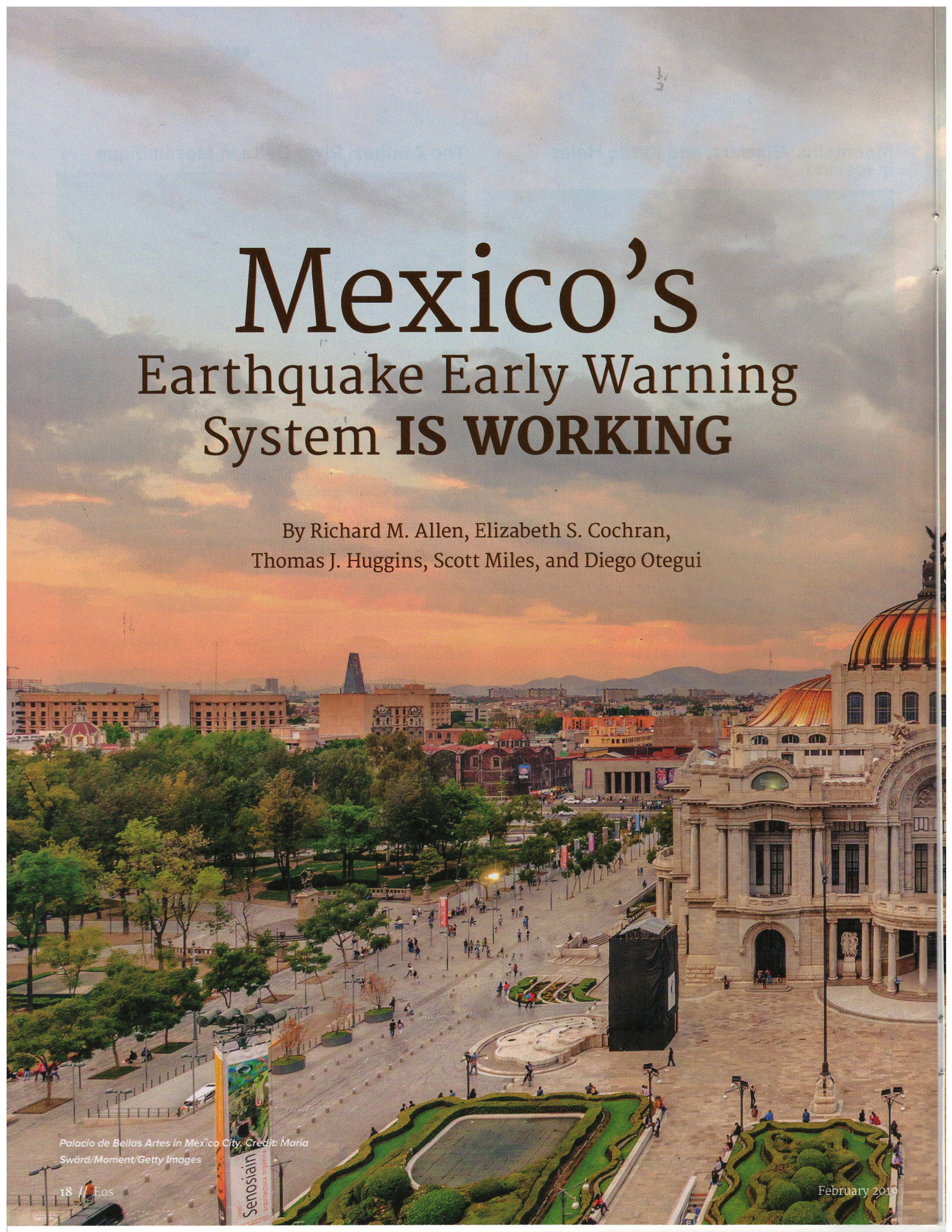
**An Itinerary  
of Ice Giants**

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An aerial photograph of Mexico City at sunset. The sky is filled with soft, orange and pink clouds. In the foreground, the Palacio de Bellas Artes is visible on the right, featuring a large, ornate dome with a colorful, segmented pattern. The city's architecture is a mix of modern and traditional styles. In the middle ground, there are large green spaces with manicured lawns and trees. The overall scene is a vibrant and detailed view of the city's urban landscape.

# Mexico's Earthquake Early Warning System **IS WORKING**

By Richard M. Allen, Elizabeth S. Cochran,  
Thomas J. Huggins, Scott Miles, and Diego Otegui

Palacio de Bellas Artes in Mexico City. Credit: Maria Swärd/Moment/Getty Images

# The devastating 2017 Puebla quake provided an opportunity to assess how citizens react to an alert.

**O**n 19 September 2017, an earthquake shook Mexico City with an intensity not felt since the same day 32 years before, when the 1985 magnitude 8.1 Michoacán earthquake killed more than 9,000 people and left more than 100,000 homeless.

The September 2017 magnitude 7.1 Puebla earthquake was part of a sequence of seismic events that included a magnitude 8.2 earthquake offshore of Chiapas, Mexico, and a magnitude 6.0 aftershock to that event. After the losses resulting from the 1985 Michoacán earthquake [Espinosa-Aranda *et al.*, 2009], the Centro de Instrumentación y Registro Sísmico (CIRES) developed an earthquake early warning system with the hope of providing a

60-second warning for earthquakes initiating along the subduction zone [Espinosa-Aranda *et al.*, 1995].

The system has provided warnings for several small to moderate events since its implementation in 1991. However, the September 2017 sequence is the most significant test of Mexico's early warning system to date. For this reason, the Earthquake Engineering Research Institute (EERI) dispatched a reconnaissance research team of seismologists and social scientists to Mexico City from 1 to 6 October 2017. The team met with people from a wide variety of backgrounds and interests in earthquake early warning, including those responsible for generating alerts and activating sirens, local government organizations, university scientists, and members of the public. The objective of the

reconnaissance research was to understand performance and public perception of the early warning system in the immediate aftermath of a devastating earthquake to draw initial lessons for early warning systems around the world.

The lessons learned from observing Mexico's earthquake early warning system, public attitudes, and responses to earthquake alerts are informing similar efforts in the United States, including implementation of the ShakeAlert early warning system, which began its public rollout in Los Angeles, California last month.

### History of Early Warning Systems in Mexico City

Mexico City started to receive earthquake alerts from the earthquake early warning system in 1991 [Espinosa-Aranda *et al.*, 1995; Goltz and Flores, 1997]. At the time, the system was set up to detect earthquakes occurring along the Guerrero Gap portion of the subduction zone located 300 kilometers from the city. The Guerrero Gap was considered to be the source most likely to generate future events with the potential to affect Mexico City.

The system works like this: Special radio receivers in schools, government offices, and TV and radio stations receive radio broadcast alerts that provide warning of imminent shaking [Suarez *et al.*, 2009]. The system was initially designed to issue an alert that would provide about 1 minute of warning before residents of Mexico City would begin to feel an earthquake (corresponding to about magnitude 5 or larger in the Guerrero Gap portion of the subduction zone [Espinosa-Aranda *et al.*, 1995]).

From its inception through September 2017, the system issued a total of 33 alerts about earthquakes with estimated magnitudes of 6 or larger and 70 alerts for earthquakes with estimated magnitudes between 5 and 6 [Centro de Instrumentación y Registro Sísmico, 2018]. In one case, an alert was issued because of a technical error and was not associated with any known earthquake. A more detailed

evaluation of the system performance is given by Suarez *et al.* [2009].

Since its implementation, CIRES has deployed additional sensors inland and along much of the subduction zone along the western coast of Mexico [Espinosa-Aranda *et al.*, 2009; Cuéllar *et al.*, 2017]. With a larger seismic network, the system—currently called the Mexican Seismic Alert System (SASMEX)—is now able to provide alerts in other cities across Mexico.

SASMEX's alert message indicates only that an earthquake likely to be felt has been detected. The alert does not provide an estimate of the time until shaking starts or shaking intensity, which can vary widely.

At present, several channels provide SASMEX alerts in Mexico City: Specially adapted National Oceanic and Atmospheric Administration weather radios provide alerts in thousands of schools and critical facilities; 12,000 pole-mounted speakers can sound a characteristic siren and verbal notice that is intended to be heard across the city. SASMEX also posts alerts to a dedicated Twitter account (@SASMEX).

### A Busy Month for Earthquakes in Mexico City

September 2017 was a trying month for the population of Mexico City—the city's 12,000 sirens signaled a total of five earthquake alerts. A technician working on the sirens accidentally triggered the first alert on 6 September, but this alert was not associated with an earthquake.

On 7 September, the magnitude 8.2 Chiapas main shock triggered the system. Sirens sounded across Mexico City 2 minutes before the start of the shaking. Although people across the city felt the shaking, it caused relatively little damage because of the large distance (more than 700 kilometers) between the source and the city. On 19 September at 11:00 a.m., the anniversary of the 1985 Michoacán earthquake, the sirens sounded for the annual earthquake drill. About 2 hours

later, the sirens sounded again, triggered by the M7.1 Puebla earthquake. This earthquake was relatively close to Mexico City (120 kilometers away), so the SASMEX alert was issued only about 5 seconds after the primary (P) wave arrival and approximately 20 seconds before the secondary (S) wave arrival.

The P waves caused strong shaking across the city that rendered the alert somewhat redundant: Residents began initiating responses when they felt the P wave arrival. In response to the shaking, some people evacuated structures while others sheltered in place. We visited a school where students and personnel had regularly practiced evacuating to designated safe areas outside of buildings as the planned response to earthquake shaking or an alert. However, during the



This apartment building in Mexico City was damaged during the M7.1 Puebla earthquake on 19 September 2017. One of the 12,000 pole-mounted sirens used to issue SASMEX warnings is visible in front of the building. Credit: Elizabeth Cochran

M7.1 Puebla earthquake, the strength of the early shaking forced students and teachers to shelter in place rather than evacuate the buildings.

On 23 September, the system was triggered again, this time by the magnitude 6.0 aftershock of the 7 September Chiapas earthquake. Most people in Mexico City, however, did not feel shaking from this event.

### Public Perceptions of the Earthquake Early Warning System

Our interviews with people across Mexico City indicated that their attitude toward SASMEX was generally positive following the September 2017 events. People appeared to see value in having an alert system to take protective action, even when they may receive an alert without feeling or otherwise being aware of shaking. In fact, it appeared that Mexico City residents consider an alert to be “false” only if there was no earthquake at all, even if they did not personally feel shaking at their location.

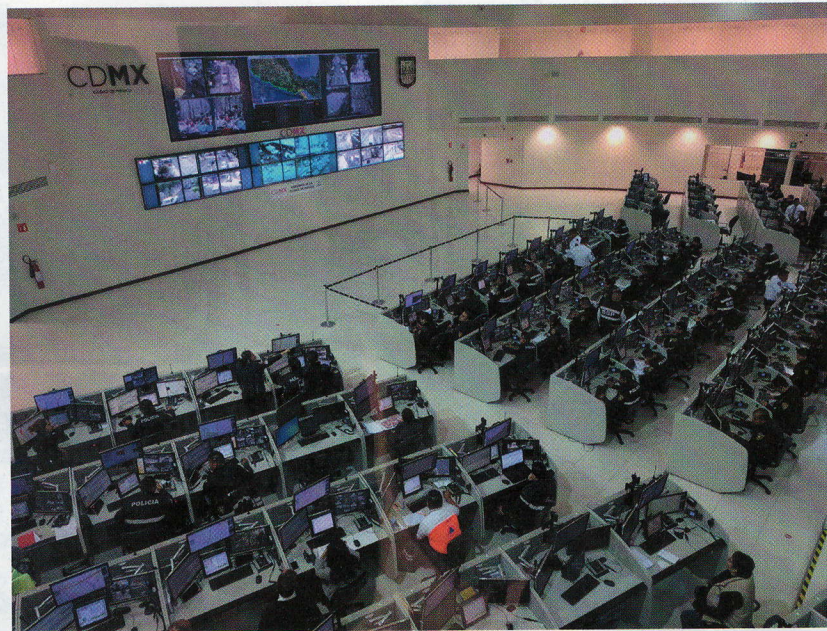
In other words, there seems to be general acceptance of the technical limitations of the early warning system in exchange for some measure of peace of mind, for fostering the general awareness of earthquake hazards, and for promoting protective behaviors such as evacuation from buildings that may be prone to collapse. We noted that people were much more accepting of alerts from smaller events with no perceptible shaking or even no event at all than of not receiving a timely warning (i.e., a missed alert).

We note that it is possible, and perhaps likely, that the perception of the system may change, depending on how recently the alerts and earthquakes have occurred. For example, the perception of the system may be more positive right after a damaging earthquake, but support can wane with increasing time since the last significant earthquake. These questions will require additional follow-up studies to answer.

In Mexico City, we found that having the earthquake early warning can contribute to a certain “culture of prevention” that cultivates hazard awareness and certain response behaviors [Goltz and Flores, 1997]. For example, we spoke with the chief financial officer of a major company who felt that 30 minutes of lost work for a drill or a “false alert” every 2 months would be an acceptable exchange for receiving an alert when strong shaking did occur, and he was considering buying an earthquake early warning receiver for the company’s building.

### Early Warning Messaging and Information

Developers of earthquake early warning systems and seismologists have sometimes proposed that alerts should



Ciudad de Mexico’s (CDMX) emergency operations center broadcasts earthquake early warnings to 12,000 pole-mounted speakers across the city. Credit: Elizabeth Cochran

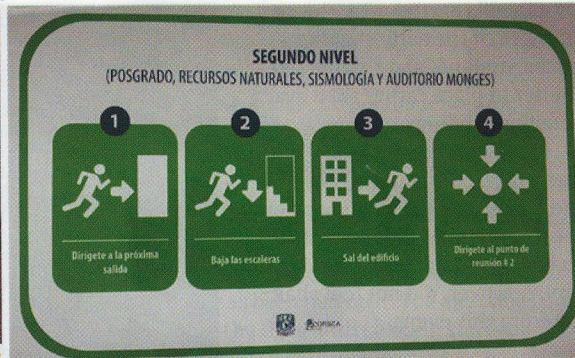
provide an estimate of the expected shaking intensity at the user’s location and the expected time until shaking. We learned in Mexico City that the challenges associated with this approach are unlikely to be overcome.

For example, educating the public about any warning message other than simply warning of imminent shaking poses substantial difficulties. Members of the general public are usually familiar with only earthquake magnitude. They do not appreciate the difference between magnitude (the size of the earthquake source) and shaking intensity (which decreases with distance from the source). Thus, it is unlikely that untrained users of early warning systems would correctly interpret an intensity estimate, especially when the information must be interpreted and implemented within seconds.

In addition, it is technically difficult to accurately determine the time when shaking will start at each alerted location. Typically, earthquake early warning systems, including SASMEX, estimate performance by using the time until the arrival of an S wave, which is usually associated with stronger shaking [Espinosa-Aranda et al., 1995; Allen et al., 2009]. However, in the 19 September M7.1 Puebla earthquake, residents across the city felt the P wave strongly. Communicating an estimate of S wave arrival time to the public would have been meaningless because most people began taking protective action soon after they felt the shaking from the P wave.

### Communication Channels for Earthquake Early Warnings

Mexico City is unusual in having a preexisting public loud-speaker system that could be leveraged to sound earthquake alarms. Even so, many residents want to receive alerts on their smartphones. Indeed, at least two private companies operate their own independent earthquake



Emergency placards from several buildings in Mexico City provide a wide array of suggestions for taking protective actions during an earthquake. Credit: Elizabeth Cochran

detection and warning systems in Mexico, with the goal of pushing alerts to Internet-connected devices.

However, it remains unclear how quickly an alert can be pushed to millions of smartphones running an app. This uncertainty creates a potential mismatch between how people want to receive earthquake warnings and the technical challenges associated with push notifications to smartphone apps.

Cell broadcast is one possible solution for getting alerts to cell phones. This approach has been implemented for distributing earthquake alerts in Japan, but it has yet to be implemented in Mexico.

### Effective Warnings, Prompt Responses

From our reconnaissance, we have drawn several initial conclusions. First, an earthquake early warning system should provide an initial alert that is as simple as possible for technological and protective action purposes. The alert should simply indicate “earthquake” to prompt immediate protective actions. More complex alert information is not necessarily helpful for public warnings.

Second, follow-up information is needed in the seconds and minutes after an alert is issued. The immediate follow-up information can be as simple as indicating that an earthquake did occur and possibly an estimate of its size. This information may help people take further mitigating action, such as safe sheltering, or may avoid frustrating individuals who did not feel shaking. Follow-up information should be delivered through a large range of media channels to ensure that it reaches the

maximum number of people. In Mexico City, social media served as an important source of postwarning information for people.

Third, it is important that the warning information and messaging provided by early warning systems be consistent and distributed as widely as possible.

Last, any warning system is only as good as the action taken by users to reduce harm to themselves and others. In Mexico City, we realized that there is considerable confusion about what action to take when an earthquake alert is issued. The official recommendation from Civil Protection, Mexico’s federal emergency management agency, is to move to a safe space, such as near a structural column, which is often designated to be within a building.

Signage indicating the recommendation is required for many categories of building occupancy, but most people we talked to said they had been told to evacuate and did actually evacuate after receiving an alert. This highlights how messages from an earthquake early warning system can match the capacity for recommended protective actions. Nonetheless, making sure that these protective actions are both feasible and effective means closely pairing earthquake early warning systems with disaster preparedness research, education, planning, and policy.

### ShakeAlert and Early Warning in the United States

The public’s perception of Mexico’s earthquake early warning system may help inform the strategy for the United States’ earthquake early warning system. This system, called ShakeAlert, recently released its first app, in

Apple and Android versions, that will warn users with some notice—at least seconds, perhaps tens of seconds—when an earthquake  $M_{5.0}$  or greater occurs in Los Angeles County.

A significant lesson from Mexico is to simplify this messaging for public alerting. The short time that people have to act prior to the arrival of shaking likely precludes effective interpretation of a large amount of information or updated information as the earthquake (and expected shaking) grows. People are likely to ignore or be confused by detailed or updated information that is not effectively tied to feasible protective action.

In the United States, the current recommended protective action when people feel strong shaking is for them to drop to their hands and knees, cover their head and neck with an arm, seek shelter under a table or near an interior wall if possible, and hold on to their shelter (when shelter is available). This protective action is commonly referred to as “drop, cover, and hold on” and typically takes a few seconds to perform.

“Drop, cover, and hold on” is widely communicated as a part of the popular annual Great ShakeOut earthquake drill, as well as of many U.S. state and local emergency management public education campaigns. Thus, it is hoped that warnings issued on ShakeAlert will result in people taking the protective action recommended in the United States to keep them safe. This pairing of recommended action and early warning, in turn, is likely to be more effective in further reducing future injuries than having no early warning. Aligning the public’s expectations for ShakeAlert’s performance and messaging with the capabilities, design, and track record of the system is the best way to facilitate an effective response to future earthquakes.

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## International Ocean Discovery Program



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